Feeding Behavior and Diet of Free-ranging Black-crowned Night Herons on a Catfish Aquaculture Facility in Mississippi

Jimmy D. Taylor II,[1] *USDA, APHIS, Wildlife Services, National Wildlife Research Center, Box 6099, Mississippi State, MS 39762*

Andrea L. Cooper,[2] *Department of Wildlife and Fisheries, Mississippi State University, Box 9690 Mississippi State, MS 39762*

Scott C. Barras,[3] *USDA, APHIS, Wildlife Services, National Wildlife Research Center, Box 6099, Mississippi State, MS 39762*

Nagaraj Chatakondi, *USDA, ARS, Catfish Genetics Research Unit, P.O. Box 38, Stoneville, MS 38776*

James R. Jackson, *Department of Natural Resources, Cornell University Biological Field Station, 900 Shackelton Point Road, Bridgeport, NY 13030*

Samuel K. Riffell, *Department of Wildlife and Fisheries, Mississippi State University, Box 9690 Mississippi State, MS 39762*

Ben C. West, *University of Tennessee Extension, 605 Airways Boulevard, Jackson, TN 38301*

Abstract: The impacts of many species of piscivorous birds on aquaculture are well documented in the southeastern United States; however, specific studies of black-crowned night heron (*Nycticorax nycticorax*) in these areas are lacking. Because black-crowned night herons opportunistically exploit abundant food resources and inhabit an important catfish production area, we initiated a study to assess their use of and potential impacts on a catfish aquaculture facility. We conducted a biweekly survey October 2004–September 2006 on Harvest Select Farms near Inverness, Mississippi, to quantify year-round patterns of free-ranging night heron presence and collected 75 night herons for stomach content analysis. We also documented nocturnal behavior by night herons twice weekly June–September 2004–2006 on these ponds During the summer and early fall each year, we observed approximately 85 night herons per biweekly survey. The most common behavior observed on ponds each year was standing and waiting. Night herons numbers declined at Harvest Select Farms beginning in November and use of ponds ended by January of each year. Night heron use resumed in late spring (April 2005) or summer (June 2006) with peak abundance occurring in September of each year. Stomach content analysis ($n = 75$) revealed 72% of stomachs contained catfish fingerlings, ranging from 0–26 fingerlings/stomach. Mean number of catfish/stomach ($n = 63$) was 3.95 (SE = 0.58). Mean length of fingerlings was 9.8 cm ($n = 159$, SE = 0.19), and mean weight was 11.0 g ($n = 159$, SE = 0.59). A review of pond health records revealed that 53% of birds collected were on diseased ponds. Mean number of fingerlings found in stomachs of night herons collected on diseased ponds (4.36; SE = 0.99) was greater than healthy ponds (2.14; SE = 0.37; $t_{40} = 2.09$, $P = 0.043$). Night herons' ability to rapidly exploit distressed catfish fingerlings during disease outbreaks may prevent fisheries managers from capturing the true loss to disease in their inventories. Although we documented consumption of catfish and use of the farm as a foraging area, their actual economic impact is unknown without additional studies to assess the issue of compensatory mortality.

Key words: aquaculture, behavior, black-crowned night heron, channel catfish, waterbirds

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Fish-eating birds are attracted to aquaculture facilities because the ponds and open raceways provide easy and reliable foraging opportunities (Parkhurst et al. 1992). Loss of fish to piscivorous birds at aquaculture ponds in the southeastern United States is well documented (King 2005, Dorr 2006). An average flock of 250 American white pelicans (*Pelecanus erythrorhynchos*) can cost a producer US $2,900 from a single day of foraging (Glahn and King 2004) while losses of catfish to double-crested cormorants (*Phalacrocorax auritus*) in the Mississippi Alluvial Valley has been estimated to exceed $10 million annually (Dorr 2006). While cormorants and pelicans have been seen foraging at night on catfish ponds, they are primarily diurnal foragers. Consequently, most methods to haze these birds from ponds occur between dusk and dawn.

Black-crowned night herons (*Nycticorax nycticorax*, hereafter night heron) are opportunistic foragers that may consume a variety of abundant or easily available prey items (Beckett 1964, Collins 1970, Wolford and Boag 1971, Davis 1993), although they

1. Present address: National Wildlife Research Center, 321 Richardson Hall, Corvallis, OR 97331
2. Present address: 2399 Hwy 43 N, Canton, MS 39046
3. Present address: USDA, Wildlife Services, P.O. Box 130, 21425 Hull Street Road, Moseley, VA 23120

have nocturnal and crepuscular feeding habits and are often overlooked by human observers (Davis 1993). Night heron foraging techniques also are diverse. Prey are generally grasped with the bill rather than stabbed, but foraging posture varies from crouched to upright. Of 38 feeding behaviors described for herons, night herons are known to use 8: standing, bill vibrating, standing fly-catching, walking slowly, hovering, plunging, feet-first diving, and swimming feeding (Kushlan 1976).

Black-crowned night herons migrate along coastal areas and Mississippi River systems to wintering grounds in the coastal southeastern United States, the Caribbean, and Mexico (Davis 1993). Migration routes send birds through the greatest density of catfish farming in the United States. Of the 76,000 ha of ponds in catfish production in the United States, the Delta region of Mississippi boasts 45,000 ha (NASS 2003). Because night herons concentrate opportunistically on abundant food resources and because they use a core catfish production area, we initiated a study to observe their behavior and assess potential impacts on a catfish aquaculture facility.

Study Area

Harvest Select Farms (HSF) in Inverness, Mississippi, is a production unit that raises catfish from hatchling or fry (1–1.5cm) to brood-fish stage (35–50 cm; 5–8 lbs.). Unlike a more traditional catfish farm that produces only food fish (25–40 cm; 1–3 lbs.) or fingerlings (10–20 cm), HSF has all size classes of catfish on site. Fry are raised in covered indoor facilities, while fingerlings, food fish, and brood fish are reared in earthen, excavated outdoor ponds. Located in Sunflower County (331665N, 903554W), this facility had 323 land ha and 267–278 water ha. From 2004 to 2006, farm managers combined many impoundments to create fewer yet larger production ponds. During this period, size class and density of catfish stocked within the ponds also changed. In 2004, brood fish were stocked in 29 ponds, food fish in 8 ponds, and fingerlings in 67 ponds. As of December 2005, brood fish were stocked in 16 ponds, food fish in 6, and fingerlings in 70. As of October 2006, 30 ponds had brood fish, 2 had food fish, and 65 had fingerlings.

Methods

Behavior of Night Herons on Catfish Ponds

We conducted observations at Harvest Select Farms from June to September 2004–2006 to determine the timing and level of use of catfish ponds by night herons. Observers used spotlights to quantify night heron presence and behavior. Spotlights were used rather than night vision scopes because scopes were inadequate on some ponds due to size and lighting situations.

In 2004, observers located ponds with birds present and observed the birds for one hour per pond at 10-minute intervals. We used this method in the first year to observe patterns of night heron behavior at each pond. In 2005 and 2006, we used a random number generator to select individual ponds for observation. We used this method of pond selection to observe night heron behavior across the entire facility, regardless of pond stocking density or health status. Ponds were selected without replacement, so no pond was surveyed more than once nightly. If a selected pond had been drained, we randomly-selected an alternate pond. Approximately 5%–6% of all ponds were observed nightly. Observers spotlighted birds from a vehicle parked on one levee of the selected pond. Spotlights were only on long enough to identify behavior of all birds on the pond, then were off until the beginning of the next 10-minute interval. We believe the vehicles and spotlights did not alter night heron behavior because they were accustomed to vehicles and spotlights used by employees monitoring dissolved oxygen every night and because herons did not abandon ponds due to our presence. However, one night heron response to disturbance is a crouched and stationary posture to avoid detection, which could have biased our behavior observations toward standing and waiting or loafing categories.

For one hour at each pond, an observer scanned a selected pond with a spotlight at 10-minute intervals and recorded number of birds in each of the following activities: loafing (standing still more than one foot from water's edge), standing and waiting (standing still less than one foot from water's edge), stalking (walking and pausing along levee), swimming, flying, or handling fish. We conducted six scans on each selected pond on each census night. Observations were conducted two nights weekly from 2000 hours to 0450 hours CST so that the duration of normal night heron foraging time was included.

We summarized data by summing observed number of night herons in each behavior category. Numbers were summed across all ponds observed in a given hour for all scans throughout that year. Behaviors assumed to indicate foraging included all behavior categories associated with capturing and consuming prey including stalking, standing and waiting, swimming, and handling fish. Loafing and flying were not considered foraging behaviors.

We conducted a baseline survey during alternating weeks October 2004–September 2006 to determine seasonal night heron use of the facility. These surveys consisted of an observer following a pre-determined, road-based route through the entire facility and recording number and activity of birds seen on each pond. The activity categories were the same as for the observations, and the route was run in a vehicle using a spotlight. Time of survey depended on observer schedule, but usually occurred within the hour after sunset. Multiple detections could have resulted from use of spotlights and trucks, but we feel that flushing and subsequent recounting birds was a minimal concern because night herons tended to crouch and hold still to avoid detection. Few birds flushed in response to any of the observation methods and those night herons that did flush usually returned to the same spot or to an adjacent levee on the same pond.

We used descriptive statistics to characterize the relative proportions of night heron behaviors observed in each year. We used Chi-square goodness of fit tests ($\alpha = 0.05$) to determine if mean hourly observations of foraging behavior per scan, or mean hourly observations of all behavior categories per scan, differed during nocturnal observations.

Diet Analysis

To quantify diet of free-ranging night herons, we collected 25 birds annually. We collected no more than five night herons in a single night and conducted collections only one night weekly. There was no indication that collections affected behavioral observations. Specimens were collected following U.S. Department of Agriculture, National Wildlife Research Center (USDA NWRC) Standard Operating Procedure FP 016.00 using 12-gauge shotguns (Glahn et al. 1998). We collected night herons July–August after young had fledged. Because our field observations showed night herons to be less easily disturbed during the middle of the night and we wanted them to have time to forage, collections were conducted primarily from 2200 hours to 0300 hours CST. Basic criterion for collection was presence on a pond at Harvest Select Farms. Night heron age classes were not easily detectable under night conditions; therefore, samples included adults, sub-adults, and juveniles of both sexes. Furthermore, samples were taken with no prior knowledge of pond health (i.e., dissolved oxygen levels or presence of fish disease) or stocking (i.e, size class or density). We recorded the date and pond identification number for each sample.

Night herons were necropsied in the field to remove digestive tracts. Samples were bagged individually after being injected with 10% buffered formalin, frozen, and transported to the NWRC Mississippi Field Station in Starkville. Contents from the digestive tract below the esophagus to the intestine were removed and a magnifying lamp was used to identify the contents to the lowest taxonomic level possible. All diet items were enumerated, and when possible, total lengths of fish were measured to the nearest mm. In most cases, catfish were easily discerned from other fish due to the distinct pectoral spines and absence of scales. More than 60% of catfish from night heron stomachs were intact enough to directly measure lengths. We also measured pectoral spines from complete specimens to develop a regression for fish length as a function of pectoral spine length that could be used to estimate lengths of partial specimens (total length [mm] = 14.47 + 6.27 spine length [mm]), df = 152, r2 = 0.77, $P < 0.0001$). To ensure that directly measurable fish were representative of the lengths of all fish consumed, we compared the length distributions of directly measurable catfish to the distribution that included 32 additional lengths estimated from pectoral spines. We saw no differences between distribution of lengths of catfish consumed by night herons that could be directly measured and the distribution including lengths predicted from spine lengths (Kolmogorov-Smirnov two-sample test, D = 0.048159,191, $P > 0.20$), so mean lengths reported are based only on fish that were directly measured. We used frequency of occurrence of diet items to determine relative importance of each taxon in night heron diets. For catfish, we also calculated mean number and mean length consumed per bird. Because catfish at HSF during this study were susceptible to channel catfish virus disease, enteric septicaemia, columnaris disease, and various other diseases from bacteria, fungi, helminths, and parasitic copepods, we cross-referenced our collection samples with pond health data to determine if herons were foraging on diseased ponds. We tested for differences in mean number of catfish consumed as a function of pond health (diseased or healthy) using a paired *t*-test.

Results

Behavior of Night Herons on Catfish Ponds

In 2004, for ponds selected for observation based on bird presence, a total of 15,413 night herons were observed in 1,174 scans between June and September (Table 1). The most common behaviors observed were standing and waiting (72.3%) and loafing (24.4%). The remaining night herons observed in 2004 were flying (1.8%), swimming (1.0%), handling fish (0.4%), and stalking (0.1%; Table 1).

In 2005 and 2006, for ponds selected randomly, most scans indicated no night herons present (87.9% and 83.3%, respectively). However, the most commonly observed behavior for both years was standing and waiting (59.3% and 64.0%) followed by loafing (37.7% and 33.9%; Table 1). No night herons were observed stalking in either year. Only 2.6% of night herons were observed flying in 2005, while 1.7% were observed flying in 2006. Of 1,609 scans

Table 1. Relative proportions of black-crowned night heron (BCNH) behavior observed by category and year on Harvest Select Farms in Inverness, Mississippi, June–September 2004–2006.[a]

Year	Total scans	Total BCNH observed	Percent swimming	Percent stalking	Percent standing and waiting	Percent loafing	Percent flying	Percent handling fish
2004	1,174	15,413	0.01	<0.01	0.72	0.24	0.02	<0.01
2005	1,609	1,022	<0.01	0.00	0.59	0.38	0.02	<0.01
2006	1,620	1,985	<0.01	0.00	0.64	0.34	0.02	<0.01

a. Pond selection in 2004 was based on bird presence. Pond selection in 2005 and 2006 was random.

Table 2. Mean (SE) number of black-crowned night herons (BCNH) per scan observed in foraging behaviors[a] by hour for each year on Harvest Select Farms in Inverness, Mississippi, June–September, 2004–2006.[b]

	2004		2005		2006	
Time (CST)	Mean BCNH/scan	SE	Mean BCNH/scan	SE	Mean BCNH/scan	SE
2000	10.63	0.71	0.14	0.04	0.96	0.24
2100	8.99	0.79	0.73	0.15	0.85	0.20
2200	8.40	0.68	0.45	0.13	0.46	0.13
2300	10.10	0.75	0.06	0.03	1.21	0.25
0000	11.67	0.97	0.23	0.06	0.63	0.17
0100	10.16	0.84	0.80	0.22	1.00	0.26
0200	10.13	0.86	0.43	0.14	0.33	0.10
0300	8.75	0.66	0.23	0.06	0.41	0.13
0400	9.54	0.94	0.30	0.06	1.21	0.33

a. Foraging behaviors included handling, stalking,standing/waiting, and swimming.
b. Pond selection in 2004 was based on bird presence. Pond selection in 2005 and 2006 was random.

Table 3. Mean (SE) number of black-crowned night herons (BCNH) per scan observed in all behaviors[a] by hour for each year on Harvest Select Farms in Inverness, Mississippi, June–September, 2004–2006.[b]

	2004		2005		2006	
Time	Mean BCNH/scan	SE	Mean BCNH/scan	SE	Mean BCNH/scan	SE
2000	13.53	0.86	0.22	0.06	1.50	0.35
2100	12.10	0.92	0.75	0.15	1.28	0.24
2200	12.04	1.04	0.65	0.20	0.77	0.22
2300	13.76	1.06	0.11	0.03	1.77	0.36
0000	14.78	1.10	0.29	0.08	1.33	0.32
0100	14.23	1.32	2.20	0.59	1.35	0.32
0200	15.13	1.35	0.43	0.14	0.45	0.13
0300	10.94	0.74	0.51	0.14	0.88	0.29
0400	13.64	1.44	0.51	0.20	1.66	0.46

a. All behaviors included flying, handling, loafing, stalking,standing/waiting, and swimming.
b. Pond selection in 2004 was based on bird presence. Pond selection in 2005 and 2006 was random.

in 2005 and 1,620 in 2006, 2 birds (0.02%) were observed swimming each year. Only 2 birds (0.02%) were observed handling fish in both years as well (Table 1).

The mean number of night herons/scan foraging did not vary as a function of time of night, June–September in 2004 ($n = 1143$, X82 = 0.85, $P = 0.99$), 2005 ($n = 1609$, X82 = 1.36, $P = 0.99$), or 2006 ($n = 1620$, X82 = 1.80, $P = 0.98$; Table 2). For night herons observed in all behavior categories (foraging and non-foraging), there was no difference in the mean number of birds/scan from hour to hour (Table 3, 2004, $n = 1143$, X82 = 1.15, $P = 0.99$; 2005, $n = 1609$, X82 = 4.87, $P = 0.77$; 2006, $n = 1620$, X82 = 1.24, $P = 0.99$).

No night herons were observed during bi-weekly surveys from January to March (Figure 1). During the months sampled (October 2004–September 2006), we observed peak abundance in October 2004 ($n = 142$), September 2005 ($n = 428$), and September 2006 ($n = 501$, Figure 1).

Throughout 2005, average bird abundance was 0.166 birds/ha or 0.285 birds/pond ($n = 26$; Table 4). Seasonal observations conducted bi-weekly in 2004 ($n = 4$) and 2006 ($n = 19$), produced similar qualitative results yielding an average bird abundance of 0.161 birds/ha (0.281 birds/pond) and 0.168 birds/ha (0.297 birds/pond), respectively (Table 4).

Table 4. Results of the biweekly black-crowned night heron survey (BCNH) conducted October 2004–September 2006 on Harvest Select Farms, Inverness, Mississippi.

Year	BCNH counted	Number of scans	Total ha observed	Total ponds observed	Birds/ha	Birds/pond
2004	172	4	1068	153	0.161	0.281
2005	1184	26	7124	160	0.166	0.285
2006	887	19	5282	157	0.168	0.297

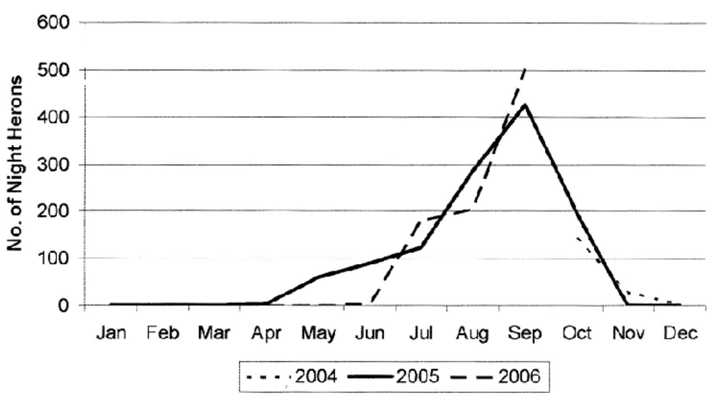

Figure 1. Number of black-crowned night herons counted during biweekly surveys by month on Harvest Select Farms in Inverness, Mississippi, October 2004–September 2006.

Diet Analysis

Of 75 stomachs examined, 12 (16%) were empty, 63 (84%) contained food, and 54 (72%) contained catfish. Out of the 63 stomachs that contained food, 56 (89%) stomachs contained fish and, of those, 54 (96%) included catfish. Out of 269 total fish removed from all stomachs, 249 were catfish (92.6%), 5 were minnows (*Cyprinidae*, 1.9%), 3 were bluegill (*Lepomis macrochirus*, 1.1%), 8 were unidentified scaled fishes (3%), and 4 were unidentified to any level (1.5%). Some stomachs also contained crayfish (2.7%) and insect parts (12%). Catfish composed 94% of fish identifiable to at least the catfish/non-catfish level.

The observed range in number of catfish in a single stomach was 0–26 fingerlings. Mean number of catfish in stomachs of birds with food was 3.95 fingerlings/bird ($n = 63$, SE = 0.58). The range of observed total lengths of catfish consumed was 6–21.5 cm, with a mean of 9.8 cm ($n = 159$, SE = 1.85). Weight of individual catfish consumed ranged from 2.2–95.7 g, with a mean of 11.0 g ($n = 159$, SE = 0.59).

We compared the disease records from Harvest Select Farms to the pond and date of collection for each night heron. Of 75 birds collected, 35 (47%) were on healthy ponds and 40 (53%) were on diseased ponds. The number of fingerlings found in stomachs of night herons collected on diseased ponds ranged from 0 – 26 with a mean of 4.36 (SE = 0.99). The range on healthy ponds was 0–6 fingerlings with a mean of 2.14 (SE = 0.37). Differences in mean number of catfish consumed as a function of disease status of ponds were significant ($t40 = 2.09$, $P = 0.043$).

Discussion

Behavior of Night Herons on Catfish Ponds

During summer and early fall 2004, we observed a mean of 85 night herons per biweekly survey. The relative proportion of standing and waiting observations suggests that night herons were attempting to capture catfish on the farm. In 2005 and 2006, though farm-level numbers remained consistent, most of our pond-level observations were of no birds present (87.9% and 83.3%, respectively). One explanation may be related to stocking sizes among ponds. While we can attribute many of our observations to fingerling ponds, we can not account for size classes in every pond. The addition of such details would allow us to determine if night herons avoided food fish and brood fish ponds. Nevertheless, regardless of the difference between systematic (2004) and random approaches (2005–2006), the most observed behavior during nocturnal observations each year was standing and waiting. Though standing and waiting is a widely-used foraging strategy for most wading birds, including night herons, it also is possible that these birds were reacting to observer presence and the spotlight by holding still in an attempt to avoid detection. However, results from stomach content analysis indicated relatively few empty stomachs, and a companion study of captive animals (Cooper 2007) indicates that most birds were engaging in a foraging behavior when we observed them standing and waiting.

Another explanation for the high number of no observations per scan in 2005–2006 could be related to pond health. It is possible that herons may have been visiting ponds with low dissolved oxygen or a disease outbreak on ponds that were not selected for observation. Disorientation of fingerlings under these conditions makes them more susceptible to predation by wading birds. Future studies such as this should include detailed records of stocking size and pond health in order to test for selection and/or avoidance of ponds proportional to their availability.

In 2004, no significant difference in bird abundance was detected from hour to hour over the course of the night. This result may be because we selected ponds based on bird presence, and the ponds with more birds were likely to be noticed. However, we found similar results in 2005 and 2006 when ponds were selected randomly for observation. These results indicate that night heron presence was fairly constant throughout the night. Thus, effective management cannot focus on a peak foraging window. Managers should consider initiating management activities for night herons early in the night and continuing throughout the night during periods when night herons are present.

Night herons began departing the study site in November and were gone by January each year. Birds returned in late spring (April 2005) or summer (June 2006). As peak abundance occurred in September 2005 and 2006, we believe that migratory populations of night herons added to a resident population using the study site as a foraging area. This timing coincides with the known migratory patterns of black-crowned night herons (Davis 1993). Each year, we observed more juvenile birds in late summer, indicating that a resident population was rearing young and the fall migration increased numbers further. This confirms the thesis that Mississippi is an area of year-round residency as well as part of their migration corridor (Davis 1993). In addition, number of birds seen on the farm during surveys doubled from August to September 2005 and 2006, indicating an influx of either migratory night herons from the northern United States or fledglings from local colonies. Numbers of birds dramatically decreased from September to November, suggesting a departure from the area.

Over the three years, average night heron abundance from our biweekly surveys was 0.165 birds/ha. Assuming an average farm size in the Mississippi Delta of 127 ha, that translates to 21 birds/farm during the three years. Estimates for great blue heron abundance from a similar study was 0.17 birds/ha or 22 birds/farm (Stickley et al. 1995). These numbers are startlingly similar. The maximum negative impact from this number of blue herons was estimated at $30/ha (Stickley et al. 1995). However, this estimate is based on the assumption that the blue herons were the primary source of fingerling mortality. Subsequent studies have questioned this assumption, as great blue herons concentrate on diseased and dying fingerlings that would have been lost to producers even without heron foraging (Glahn et al. 2002). The same question must be addressed with night herons before impact estimates can be made.

Diet Analysis

Based on our findings, catfish fingerlings were by far the most common food item in the 63 stomachs that contained food, occurring in 86% of the birds that had food and 96% of those that had fish. We collected night herons with as many as 26 fingerlings in their stomachs, but we also collected 12 that were empty. In a similar study conducted on great blue herons, only 47% of stomachs that contained fish had catfish (Stickley et al. 1995). However, Stickley's study was conducted on various catfish farms in Humphreys County, Mississippi. These farms were multiple batch systems, where ponds are seldom drained. The time between drainage allows alternate prey communities to develop which could explain the prevalence of sunfish (*Lepomis sp.*), shad (*Dorosoma cepedianum*), and gambusia (*Gambusia sp.*) in the diet of collected blue herons in Stickley's study. Harvest Select is primarily a single batch system, and ponds are drained nearly every year, which prevents alternate prey communities from developing, and would account for the small percentage of items other than catfish in our night heron stomachs.

Catfish accounted for most of the fish in the diet of the night herons we sampled. This result was not surprising, as sampling was predicated by presence on catfish ponds. The number of catfish we found in stomachs varied (range = 0–26), which makes estimating catfish consumed per bird difficult. Possible explanations for this range include an individual's foraging experience and skill, time of night (and thus length of foraging opportunity) collected, behavior or size of fingerlings in the pond, pond environment (disease and oxygen levels), and pond edge factors such as depth of bank, overhanging weeds, and slope of the pond floor. Our data do not allow determination of what percentage of night herons successfully foraged to satiation over the course of an entire night.

Overall average presence of night herons on the facility for the three years was 0.165 birds/ha. As the birds have only been seen May–November, we estimate only 214 days of presence/year. Assuming each night heron consumes four 10-cm fingerlings/night (mean was 3.95 from diet collections) and producers grow these fish to a harvestable size of 1.5 lbs valued at $0.80/lb, the estimated impact from night herons on Harvest Select Farms was $169.49/ha a year. Observations in captivity documented night herons consuming 22 fingerlings per foraging event (Cooper 2007). If each night heron consumes 22 10-cm fingerlings per night, and producers grow these fish to a harvestable size of 1.5 lbs valued at $0.80/lb, the total maximum possible impact from night herons on Harvest Select Farms is $932.18/ha/year. However, these numbers assume no natural mortality in these fingerlings and that the night herons are consuming an amount of fingerlings comparable to that observed in captivity. In comparing our collection data with disease data on the ponds, it appears night herons had greater success foraging on diseased ponds. If night herons are concentrating on diseased fingerlings, their economic impact may be reduced due to compensatory mortality. In addition, the dollar amount is a reflection of the current price for catfish in the United States.

Another concern, which was not addressed in this study, questions to potential role of night herons and other wading birds in transmission of catfish diseases between ponds. Catfish producers deal with a variety of diseases caused by viruses, bacteria, fungi, helminths, and parasitic copepods. With quick identification and response times, some diseases can be treated, thus saving thousands of fish per pond. If wading birds consume stressed fingerlings at the onset of a disease outbreak, they potentially delay the managers' response time for treatment. Additionally, if the disease agent attaches to, or is consumed and passed through night herons, it is possible for individuals to move diseases from pond to pond and farm to farm.

Management Implications

This study demonstrates that night herons will take channel catfish fingerlings in a production setting. However, our conclusions are based on research conducted at only one farm. Catfish farmers within the Mississippi Alluvial Valley should assess if and when night herons are on their facilities. Because these birds both reside in, and migrate through the Mississippi Alluvial Valley, timing of use may differ greatly from farm to farm and could be influenced by proximity to roost sites.

Future night heron studies should include multiple production facilities to assess prevalence of night herons throughout the Mississippi Alluvial Valley. They also should test if dissolved oxygen levels or the presence of diseased fish in ponds influence night heron foraging habits. A better understanding of additive and compensatory morality on catfish by night herons would support estimates of economic loss. Simulated disease outbreaks could be tested following methods used by Glahn et al. 2000 and replicated at production facilities on a larger scale. Finally, future research should address the potential role of wading birds, including night herons, in disease transmission. If birds can transfer disease between ponds, all size classes of catfish would be susceptible.

If further research finds night herons pose an economic threat to catfish producers, employing harassment and dispersal techniques may be appropriate strategies, especially for fingerling producers. Although shooting, guard dogs, and lighting have been ineffective for night heron harassment, playback of distress calls has been successful at dispersing night herons (Spanier 1980). During the summer months when night herons are present, on most production facilities night workers monitor dissolved oxygen levels throughout the night; these same workers could harass birds if necessary. Any dispersal activities should be focused on aggregations of healthy fish near the surface of the water such as temporary holding pens and socks and congregations of feeding fish. Previous recommendations from other studies to feed fish at night to lessen impacts by great blue herons and great egrets would likely increase consumption by night herons.

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