African Journal of Fisheries Science ISSN 2375-0715 Vol. 7 (11), pp. 001-008, November, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Aquaculture ponds, a Jamaican study: The impact of birds on fish production

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Accepted 19 July, 2019

The increasing use of freshwater fish farms by water birds poses conservation and economic problems as birds compete with man. This study sought to assess bird species diversity of an artificial wetland and the impact of birds on Tilapia production. The farm had a relatively high diversity (0.714) as 16 species of birds foraged on the farm as either residents or visitors each day. Eight of these birds were previously identified as problem species on aquaculture farms and may result in large losses in fish crops. Predation loss per grow-out period (PLOP) was calculated to be 20.92% for the fish farm and was due mainly to the Brown Pelican, Great Egret, Least Tern and Snowy Egret. This was 2.95% less than the average loss per pond and may be higher as loss due to Black-crowned Night Herons at nights was not assessed. There was a positive correlation with success, fish density and distance from the farm house. The findings indicate that bird predation has a negative impact on Tilapia production. Farm construction, stocking densities, the length of the grow-out period, and the use of non-lethal depredation strategies are important factors in reducing loss associated with bird predation.

Key words: Tilapia, aquaculture, negative impact, predation, water birds.

INTRODUCTION

Populations of many birds are declining, due to human-induced changes in the landscape (Terborgh, 1989). The primary source of habitat loss has been the accelerated conversion of natural habitat (including wetlands) to land for industrial and agricultural uses. This often has negative effects on wildlife (Vitousek et al., 1997). The creation of artificial wetlands through the conversion of natural habitats to irrigated fields and aquaculture ponds, on the other hand, has had a beneficial impact on populations of water birds that forage in these new habitats (Stickley, 1990; Fleury and Sherry, 1995; Fasola and Ruiz, 1996; Fasoal et al., 1996). The rapid growth of crayfish aquaculture has provided wading birds with over 50,000 hectares of high quality supplemental foraging habitat (Fleury, 1996). Similarly, in Jamaica freshwater fish aquaculture ponds covering an estimated 526 ha, which predominantly grow Tilapia – *Orechromis niloticus* and other *Oreochromis* species (Aiken et al., 2001) are providing supplemental foraging habitats for several species of water birds. Expanding populations of these birds have created new problems for the conservation and management of water birds. Wading birds respond opportunistically to large-scale changes in habitat quality (Frederick et al., 1996; Fleury, 1996; Fasola and Ruiz, 1996) and may relocate in response to regional stress (Frederick et al., 1996) . Such regional population shifts may put predatory birds in direct conflict with aquaculture farmers. Man and bird have been in direct competition for fish for as long as man has farmed fish. Both humans and water birds are at the top of the aquatic food chain, and even share similar taste in prey species. This conflict has become more important in the past decades as aquaculture has developed into a major global industry (Boyd, 1991; Huner, 1994; Price and Nickum, 1995).

Many species of birds prey on aquaculture products causing significant losses, which have led to the development of several strategies to deter or reduce predation (Draulans, 1987; Littauer, 1990; Cezily, 1992; Littauer et

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Abbreviations: DO; dissolved oxygen concentration.

al., 1997). Several bird species have been identified as "problem species" on aquaculture farms, these include: Double-crested Cormorant (*Phalacrocorax auritus*), American White Pelican (*Pelecanus erythrorhynchos*), Hooded Merganser (*Lophodytes cucullatus*), Great Blue Heron (*Ardea herodias*), Great Egret (*Casmerodius albus*), Snowy Egret (*Egretta thula*), Tricolored Heron (*Egretta tricolor*), Green-backed Heron (*Butorides striatus*), Black-crowned Night Heron (*Nycticorax nycticorax*), Yellow-crowned Night Heron (*Nycticorax violaceus*), White Ibis (*Eudocimus albus*), Belted Kingfisher (*Ceryle alcyon*), Osprey (*Pandion haliaetus*), and various species of gulls and terns (Stickley, 1990). This SRAC publication and AGRI-FACTS Agdex 485/685-1 (1999) give information on the potential loss farms can expect from these and other bird species. Continued declines in the quality and quantity of foraging habitat in natural wetlands due to drainage, pollution, and other human influences or land transformations highlight the importance of understanding how and why birds use artificial wetlands such as flooded fields or aquaculture farms. The use of aquaculture ponds by wading birds and other water fowl also raises important legal and conservation issues, both locally and internationally. The problem of bird predation in aquaculture ponds involves: tropical-fish farms in Florida; Catfish farms in California, Arkansas, and Mississippi; Tilapia farms in Jamaica; and fish farms in Europe (Draulans, 1987; Stickley and Andrews, 1989; Boyd, 1991; Cezilly, 1992; Stickley et al., 1992; Mott and Brunson, 1995; Aiken et al., 2002; Bruske, 2006). Wading birds are currently treated as agricultural pests under the Department of Agriculture's Animal Damage Control Programme (USA). Depredation permits have been issued in several states for lethal control of several migratory bird species (including herons, egrets, pelicans, and cormorants) that feed at Catfish farms and other aquaculture facilities. All water birds are protected in Jamaica under the Wildlife Protection Act, which makes it illegal to use lethal depredation strategies on these birds.

This study was conducted during the months of July and August 2000 on a Tilapia fish farm which utilized little to no depredation strategies as would be the case in a natural wetland habitat. The study represents the first of its kind in Jamaica and sought to dispel some of the beliefs of the impact of birds on fish production.

MATERIALS AND METHODS

Data for the study were collect during July and August 2000. Dissolved oxygen concentration (DO) and water temperature were measured with a YSI Dissolved Oxygen Meter (Aquatic Ecosystems, Inc). Bird counts and attacks on fish ponds were recorded. Attacks were grouped into attempts – attack without a capture, and success – attack and capture. From this data set the success rate was calculated for the major fishing species.

Birds were positively identified with the aid of Raffaele's (1998) A guide to birds of the West Indies.

Site description

As mentioned previously, the farm studied employed little to no depredation strategies thus mimicking the para-meters of a natural wetland habitat. The fish farm was located at Fellowship Hall, Hill Run St. Catherine close to the Hellshire Hills on the south of Jamaica. Sugar cane fields bordered the north, east, and west sides of the farm. To the south there was an Acacia scrubland. There were 30 rectangular ponds on the farm. Only 15 ponds were involved in production during the study period, these ranged from 4,852 - 7,177 m^2 in size, and were stocked with fish at densities of 7,934 - 58,446 fish per pond depending on fish and pond size. All the ponds on the farm were "green water" ponds, which aided in providing oxygen during the day (Szyper and Ebeling, 1993). In addition, each pond was fitted with an aerator, which was turned on at 2000 h and then turned off at 0800 hours. All ponds were earthen ponds with an average depth of 1 m. Ponds on the periphery of the farm were surrounded by grass, Acacia, and reeds several metres tall. Several of the ponds, which were not involved in production, were overgrown with reeds and some parts carpeted with floating water plants. The ponds were ranked in relation to distance from the farm house and grouped into clusters such that all the ponds in a cluster could be adequately covered from a vantage point. Data were collected over a twelve hour period each day from 0600 - 1800 h EST.

Data analysis

Data analysis was carried out using the SPSS 12.0 Statistical software for Windows and Microsoft Office Excel 2003. Various non-parametric analyses were carried out for the farm; these include the Simpson's Diversity Index and the Spearman's Rank Correlation Coefficient (Simpson, 1951; Hogg and Craig, 1995) to assess the diversity and the impact of bird predation of fish production.

RESULTS

There was an overall increase in average DO and average temperature throughout the day as observed previously (Szyper and Ebeling, 1993; Egna and Boyd, 1997; Boyd and Tucker, 1998). In the early morning the DO was lowest and averaged below 1.0 mg/l up until 0800 h each day as seen in Figure 1A. This low DO was due to increased oxygen demand as both algae and fish respire at nights and hence compete for available oxygen (Egna and Boyd, 1997; Boyd and Tucker, 1998) . The figure also shows that the maximum average DO (3.45 mg/l) was reached between 1400 and 1730 h due to increase light intensity coupled with the ability of the algae to produce oxygen via photosynthesis (Szyper and Ebeling, 1993). Difference in stocking densities between ponds resulted in large variations in the average DO across the farm (Boyd and Tucker, 1998). Average water temperature gradually increased throughout the day from a low of 27.25°C in the morning to a high of 32.23°C in the late afternoon as daytime temperatures increased (Figure 1B). These temperatures, however, varied slightly from pond to pond and are indicative of the dynamics of relatively large bodies of water.

Two categories of water birds were present on the farm: resident, which included the Moorhens, Stilts,

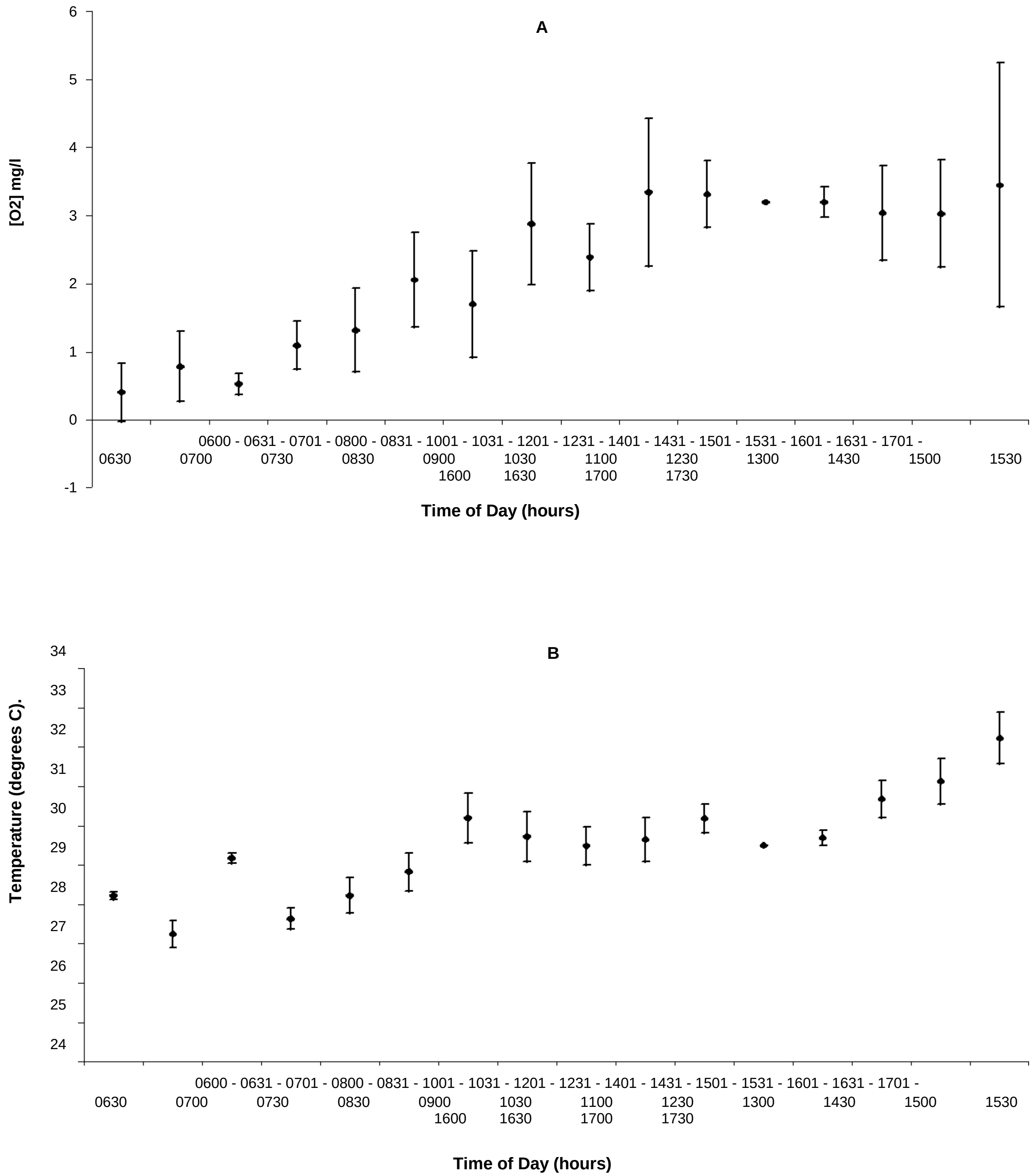

Figure 1. Average dissolved oxygen and temperature for the ponds over a 12 h data collection for period from 0600 - 1730 h each day. Average dissolved oxygen (A) and average temperature (B). ($P < 0.05$).

Kildeer, Jacana, and the visitors, which included all the fish predators. A total of 16 species of water birds were observed on the farm during the study period, (Table 1).

The most abundant bird species present on the farm was the Glossy Ibis, which accounted for over 48% (1250) of the total number of birds sighted on the farm for the entire period. On the other hand the Osprey was seldom present on the farm accounting for less then 0.2% of the total number of birds sighted. The diversity of birds on the farm as calculated by Simpson's Diversity Index was 0.714 and indicated that this artificial wetland is a diverse habitat.

The nocturnal Black-crowned Night Herons (Raffaele et al., 1998) were only observed on the farm in the early mornings at the start of the data collection period just as the birds were left the farm. This accounted for infrequent

Table 1. Bird species list and numbers on the fish farm with their relative proportions.

Bird species	Scientific name	Totals	Proportion (P)	P^2
Black-necked Stilt	*Himantopus mexicanus*	298	0.116044	0.013466
Black-crowned Night Heron	*Nycticorax nycticorax*	6	0.002336	0.000005
Brown Pelican	*Pelicanus occidentali*	145	0.056464	0.003188
Cattle Egret	*Bubulcus ibis*	17	0.006620	0.000044
Glossy Ibis	*Plegadis falcinellus*	1250	0.486760	0.236935
Great Egret	*Casmerodius albus*	303	0.117991	0.013922
Green-backed Heron	*Butorides striatus*	19	0.007399	0.000055
Kildeer	*Charadrius vociferous*	16	0.006231	0.000039
Least Tern	*Sterna antillarum*	45	0.017523	0.000307
Little Blue Heron	*Egretta caerulea*	30	0.011682	0.000136
Moorhen	*Gallinula chloropus*	18	0.007009	0.000049
Northern Jacana	*Jacana spinosa*	52	0.020249	0.000410
Osprey	*Pandion haliaetus*	4	0.001558	0.000002
Pied-billed Grebe	*Podilymbus podiceps*	6	0.002336	0.000005
Snowy Egret	*Egretta thula*	342	0.133178	0.017736
Tri-coloured Heron	*Egretta tricolor*	17	0.006620	0.000044
Total		2568		0.286345

Diversity: $1 - P^2 = 0.714$.

Table 2. Characteristics of each pond involved in production during the study period with the total number of attempts made by birds.

Pond	Distance	Area (m^2)	Density (No. of fish/ pond)	Fish size (g)	Attempts
A4	3	5,740	18,717	138.2	344
A5	2	5,371	7,934	179.3	6
A6	1	4,852	9,162	145.5	38
B1	3	5,904	14,007	195.7	6
B2	3	5,371	11,346	159.0	23
B3	3	5,740	13,837	125.0	15
B4	2	5,740	17,001	162.0	64
B5	2	6,150	14,216	158.7	25
B6	2	6,175	13,443	318.0	33
B7	1	4,961	10,848	212.0	39
B8	1	7,177	20,061	143.1	10
B9	1	6,683	15,063	107.6	8
R5	3	6,150	58,446	22.9	31
R6	2	6,014	14,450	273.2	57

Ponds were ranked from 1 to 3 (1: closest, 2: intermediate, 3: farthest) based on their relative distance from the farm house.

sightings and overall low percentage of these birds during the day however; large numbers were observed at night. Fish stocking density, fish size, and relative distance each pond was from the farm house varied (Table 2), and was shown to have a relationship with the attacks made by the major predatory species.

Of a total of 788 attacks only 89 successful captures were observed (11.3% success rate) over the study period, with Brown Pelican accounting for 65% of the total successes (Table 3). The table also shows that the Brown Pelican and the Great Egret had relatively high success rates of 30 and 32% respectively. There was a fluctuation in total attacks on the ponds throughout the day for the entire period (Table 3). It was observed that attacks were the lowest early morning and between 1200 and 1330 h, and highest between 1400 and 1700 h. This

Table 3. Total number of attempts, success and success rate by the four major predatory species during the study period from 0600 - 1700 h each day.

Hour	Brown Pelican	Great Egret	Least Tern	Snowy Egret	Total
0600	6	2	1	0	9
0700	15	1	58	2	76
0800	11	1	17	17	46
0900	12	0	8	0	20
1000	26	5	31	0	62
1100	33	3	15	23	74
1200	18	0	3	2	23
1300	2	0	0	0	2
1400	47	2	34	9	92
1500	6	4	50	0	60
1600	10	17	210	10	247
1700	7	2	38	30	77
Total success	58	12	11	6	89
Grand total success	193	37	465	93	788
Rate (%)	30	32	2.4	6.5	11.3

reduction in the number of attacks early morning and midday coincided with a very low success rate for these periods. This was observed over the entire study period and could indicate a pattern in the birds foraging habits. There was a dramatic increase in the total number of attacks between 1500 and 1700 h with the highest number of attacks occurring at 1600 h each day. This may be a foraging strategy to maximize foraging effort just before the birds leave the farm. All the visiting diurnal birds left the farm between 1730 and 1900 h each day.

There was an increase in the number of successful capture as distance, and fish density increased, (Figure 2). The farther ponds were from the farm house the greater the number of attacks and successful capture, (Figure 2A). Holding ponds were located close to the farm house and had fingerlings and intermediate sized fish, and were preyed on mainly by Great Egrets and Snowy Egrets. Figure 2B shows that there was a preference for fish between 125 - 170 g with the 138 g fish being captured the most. The Brown Pelican and the Great Egret were the only species that had a high success rate in capturing fish greater than 250 g (data not shown). Birds are visual predators and dense populations of fish increase the chance of birds seeing and capturing fish. It was observed that ponds stocked at high densities received numerous attacks compared with ponds stocked a lower densities, (Figure 2C).

Successful capture as it related to the distance the ponds were from the farm house, fish density and fish size was analysed based on the data obtained to ascertain if either was directly related to a successful capture. Spearman's Rank Correlation Coefficient shows that there was a positive correlation between success and distance from farmhouse (r_S = 0.596, α = 0.032), and success and density (r_S = 0.574, α = 0.038). However, fish success correlated negatively with fish size since success is based on the bird's ability to capture fish (Terres, 1980; Pitt and Conover, 1996).

DISCUSSION

As a result of an increasing global population and a drive to provide more food, more wetlands are being lost by land conversions for homes, industrial and agricultural uses, and aquaculture ponds (Terborgh, 1989; Vitousek et al., 1997) . As wetlands disappear, water birds flock to the artificial wetlands provided by aquaculture farms for supplemental foraging, which puts birds in direct conflict with man (Stickley and Andrews, 1989; Stickley, 1990, Huner 1994; Price and Nickum, 1995; Aiken et al., 2002). Bird predation, though detrimental to aquaculture can also be beneficial to the farmer as predation on weak or sick fish (Roy and Chattopadhyay, 2005), and competitive fish, can increase the quality of the fish stock and allows the fish to attain their maximum production size in the shortest time (Stickely, 1990; Fleury and Sherry, 1995; Ashkenazi and Yom-Tov, 1996).

Parker (2000) outlined that Tilapia must have access to the water surface as they can use atmospheric oxygen and can tolerate suboptimal DO down to 0.0 mg/L. At nights, as fish and algae respire oxygen is used up and by products of their respiration are released into the surrounding water. This subjects fish to increase predation as they are weakened and travel to the surface for oxygen making it easier for birds to see and capture them (Cezily, 1992).

Bird occurrence ranged from a high of 48% for the Glossy Ibis to a low of 5% for the Brown Pelican and less than 0.2% for the Osprey. The Glossy Ibis is a colonial wading bird (Terres, 1980; Fluery and Sherry, 1995;

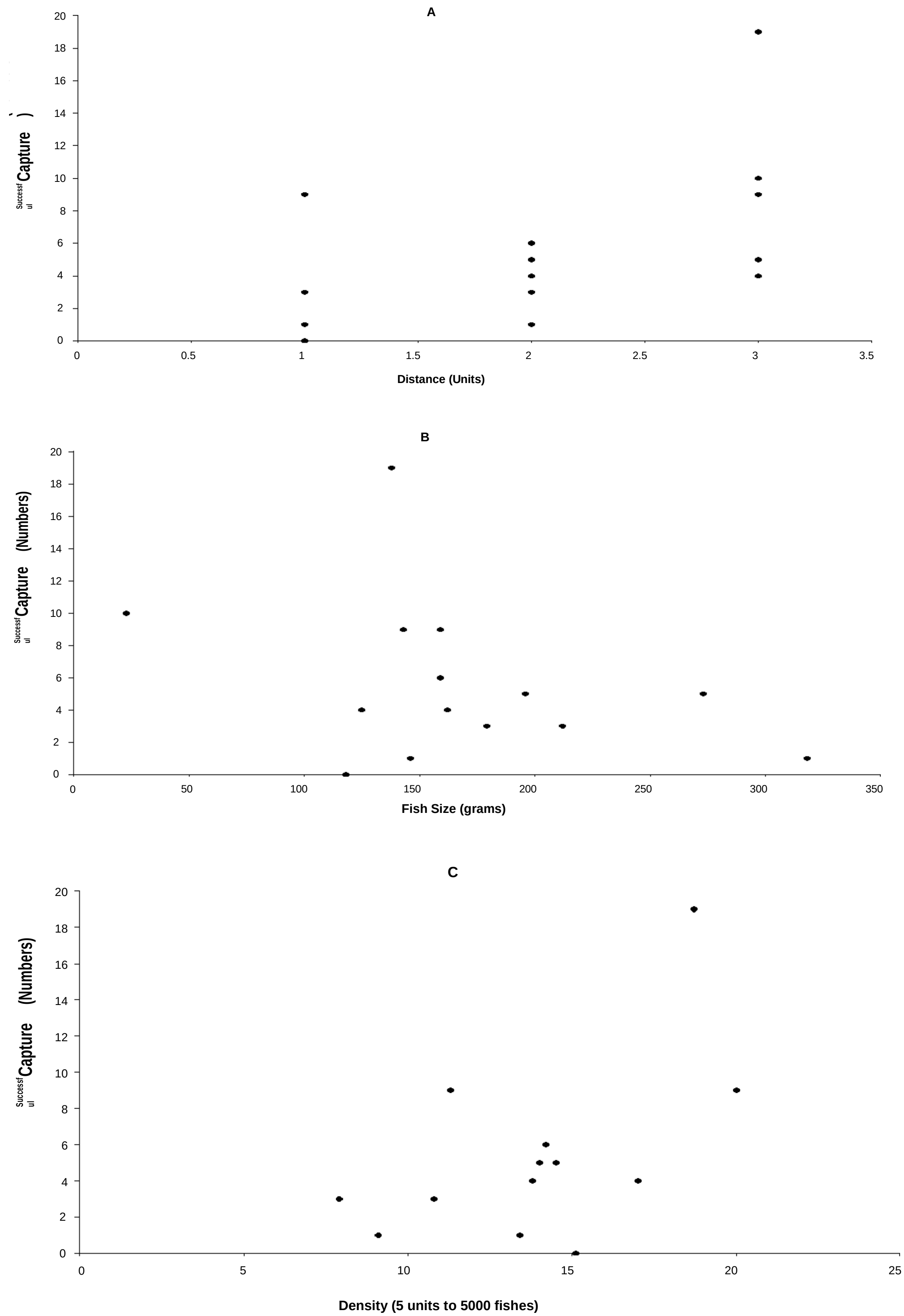

Figure 2. Total number of successful capture by the major predatory bird species in relation to distance from farm house (A), fish size (B) and density (C).

Frederick et al., 1996) while the Brown Pelican may live in colonies but may also feed solitarily (Raffaele et al., 1998). Although the Brown Pelican (endangered) preys on several fish species (Terres, 1980), they have been shown to concentrate in areas where Tilapia occurs (Chattopadhayay and Bairagi, 2001; Sarkar et al., 2001), therefore fish ponds in Jamaica, which predominantly stock Tilapia (Aiken, 2002), may be enhancing their survival. Lethal depredation strategies by farmers however, will also have an impact on the survival of these birds. Similarly the Osprey lives and feeds solitarily; however they occur in large numbers on fish farms that are on their migratory route, and are also subjected to lethal depredation strategies (Bruske, 2006) . Other colonial water birds like the Great Egret and the Snowy Egret (Fluery and Sherry, 1995) also occurred in relatively high proportions on the farm, 12 and 13% respectively. Therefore, species composition and proportions on a fish farm are related to the species way of life, whether it is colony or solitary. A diversity of 0.714 for the farm suggests that the richness weighted by the evenness for this artificial wetland habitat is high as the farm encourages several water bird populations (Fleury and Sherry, 1995; Fasola and Ruiz, 1996) in the absence of depredation strategies. This figure (0.714) represents that of an isolated study as no comparable study has been conducted on aquaculture farms in Jamaica to give a reference figure for diversity. Diversity however, will vary from farm to farm as farm lay and the depredation strategies employed will affect bird species composition. Similarly, as factors such as migration, spawning, stress, and seasons change there will be changes in the bird species composition on the farm (Fleury and Sherry, 1995; Frederick et al., 1996, Bruske, 2000).

Assessing bird predation

Although birds were present on the farm throughout the twelve hour assessment period each day, attacks on the ponds were not continuous and fluctuated throughout the day (Table 3). Some ponds were attacked with more frequency by particular birds, which may have been dependent upon the size of fish in that pond, daily fish requirement, and relative size of the attacking bird (Terres, 1980; Stickley, 1990; Pitt and Conover, 1996; Raffaele et al., 1998; AGRI-FACTS, 1999; Sarkar et al., 2001). Although ponds with smaller fish were attacked predominantly by egrets, herons and terns, fish size correlated negatively with success. The positive correlation of stocking density with success suggests that with higher densities birds were more likely to see and catch fish (Cezily, 1992). This could have serious implications for fish farms that tend to stock ponds at high densities resulting in fish taking longer to attain market size (Boyd and Tucker, 1998; Parker, 2000) and hence increasing the number of fish taken over time.

The farm recorded loss on average of 23.85% of the fish crop per pond over a 150 day grow out period, therefore the loss due to birds was assessed per fish crop. Predation loss was assessed using the formula adopted from AGRI-FACTS (1999). The formula was modified to take into account the total grow out period per fish crop. This was done as the farm was on a continuous crop cycle and birds were present year round (Farmers personal communication).

Predation Loss per Grow-out Period (PLOP) = Average number of birds observed/h × bird feeding rate (fish taken/h) × number of hours that birds are present on the farm/day × number of days in grow out period.

PLOP was calculated to be 2,898 fish representing 20.92% of the average density of fish/pond, and was 2.95% lower than the average crop loss. This figure could be much higher as the impact of nocturnal bird species was not assessed. This loss though different from that reported previously (Pitt and Conove, 1996; IUCN, 1997; Littauer et al., 1997; Bruske, 2006) represents the first assessment of predation on a fish farm in Jamaica and gives an estimate of loss associated with the bird species assessed. In Tilapia aquaculture male monosex cultures are stocked (Bocek, 2000; Parker, 2000; Aiken et al., 2002), however not all fry are converted to males by the method used. Breeding in ponds increases competition for food, space, DO, and increase the time taken to attain market size (Boyd and Tucker, 1998; Parker, 2000). As a result egrets and herons may be taking fish hatched in the ponds and not only stocked fish and could be improving the fish stock (Stickely, 1990, Fleury and Sherry, 1995; Ashkenazi and Yom-Tov, 1996), and hence, their impact may be less than that observed. With this in mind, fish farmers should make informed decisions as to the stocking densities, farm construction, and the length of the grow out period as all these factor will affect the number of fish taken by birds. Attention must be paid to bird numbers as large numbers of birds will significantly increase production losses. These losses can also be mitigated by employing non-lethal depredation strategies. Particular attention should the paid to the Brown Pelican as although their relative proportions on the farm were low, they accounted for 65% of the total successful fish captures. Therefore, large numbers of these birds on a fish farm may be devastating.

ACKNOWLEDGEMENTS

The authors would like to thank Birdlife Jamaica for various resources and support during the data collection period. To Dr. Peter Vogel, your legacy will live on.

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