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ACTIVITY AND HABITAT-USE PATTERNS OF BREEDING CARIBBEAN FLAMINGOS IN YUCATAN, MEXICO[1]

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Abstract. A total of 405 and 12 hr was spent observing adult and immature Caribbean Flamingos (*Phoenicopterus ruber ruber*), respectively, in Yucatan, Mexico, from April through August 1987. Feeding (28.7–46.4%), preening (14.8–29.7%), and resting (8.8–19.3%) were the major activities of adults during each month. Incubation, nest building, and other activities associated with reproduction were highest during the nesting period of May and June. Immatures spent most of their time feeding (57.2–68.5%) and <1% of their time in activities associated with breeding. Adult activity varied somewhat among habitat types, with feeding being an important activity in man-made ponds associated with commercial salt operations. Conservation measures at this time should seek to maintain the integrity of the salinity regime within the estuary.

Key words: Activity patterns; behavior; breeding; Caribbean Flamingo; Mexico; Phoenicopterus ruber ruber; *Yucatan.*

INTRODUCTION

Most knowledge of flamingos stems from investigations during the breeding portion of the annual cycle whereby details of basic reproductive biology (e.g., pair formation, clutch size, incubation length) are understood reasonably well (see Kear and Duplaix-Hall 1975, Ogilvie and Ogilvie 1986). However, other aspects of their breeding ecology are less well-known.

Knowledge of activity and habitat-use patterns is important because natural selection should favor individuals that optimally allocate time within space (Caraco 1979). Activity patterns also have important ramifications for conservation, protection, and management, because such patterns should provide insight into the functional role of wetland habitats to flamingos.

We studied activity patterns of Caribbean Flamingos (*Phoenicopterus ruber ruber*) in Yucatan, Mexico, a population that constitutes the northernmost mainland flock of flamingos in the New World. This population was a focus of the classic study by Allen (1956), but has received almost no research attention since that time with the exception of irregular census and productivity estimates.

The objectives of this study were to document activity and habitat-use patterns of this population during the breeding portion of the annual cycle, and relate these data to flamingo conservation in the area.

STUDY AREA

The population of Caribbean Flamingos in Yucatan breeds at varying locations within the Rio Lagartos Estuary, which was designated a national park in 1979 due to the presence of these birds (Fig. 1). The location of the breeding colony during 1987 was approximately 3 km southeast of El Cuyo, but observations of flamingos were obtained throughout the estuary from El Cuyo to Coloradas.

The entire estuary is approximately 48,000 ha of shallow saline lagoons <2 m deep (Scott and Carbonell 1986), and is about 80 km in length and 0.02–3.5 km in width. There is a natural opening (boca natural) to the Gulf of Mexico near the town of San Felipe, and an artificial opening near the town of Rio Lagartos. Much of the system is fringed with red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), black mangrove (*Avicennia germinans*), and buttonwood (*Conocarpus erectus*). The es-

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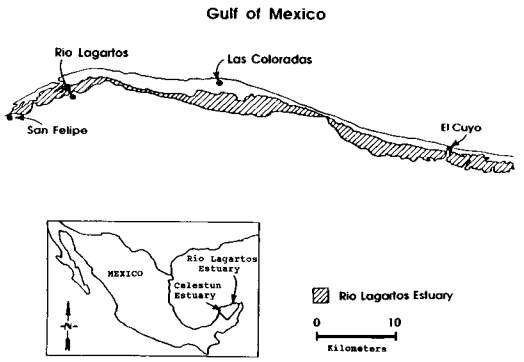

FIGURE 1. Study area map of the Rio Lagartos Estuary, Yucatan, Mexico.

tuary also is the site of a major commercial salt operation located in the vicinity of Coloradas.

METHODS

Activity-budget data were collected during diurnal hours (sunrise to sunset) from April through August 1987 using a 15–60× spotting scope. Behaviors were recorded using scan-sampling techniques (Altmann 1974) because flock activities of flamingos usually are synchronized (Kahl 1975), which minimizes potential bias associated with selecting a focal individual for activity budget sampling (Baldassarre et al. 1988). Sampling was conducted on three randomly selected days per week with each day divided into equal time blocks of: (1) early morning; (2) late morning; (3) early afternoon; and (4) late afternoon. Each time block was then divided into equal 30-min periods of which four were selected randomly for observation scans (three for adults and one for immatures). Observations were made from permanent blinds or a portable blind on a pickup truck.

Activity-budget data were collected from six major habitat types in the Rio Lagartos Estuary defined by salinity regime. Habitat 1 (natural high salinity) was a 9-km section of estuary beginning approximately 2 km south of El Cuyo. The extreme eastern end of this habitat type contained the breeding location for the population. Habitat 2 (natural intermediate salinity) was the next approximately 10-km stretch of estuary heading west toward Coloradas. Habitat 3 (low salinity salt ponds) consisted of two adjacent ponds of approximately 30 and 70 ha that were constructed in the estuary. These ponds represented the first in a series associated with the commercial salt operation in the estuary. Salinity in the ponds increases progressively as water is concentrated for eventual evaporation to salt at Coloradas. Habitat 4 (intermediate salinity salt ponds) consisted of three major ponds west of habitat 3. These ponds were approximately 80, 100, and 140 ha and occurred among 15 similar ponds of various sizes. Habitat 5 (natural low salinity) was an 8-km stretch of natural estuary that fronted the final series of ponds near Coloradas. Habitat 6 (high salinity canal) was a 10-m × 500-m canal that transported saltwater from ponds in habitat 4 to the last series of ponds (crystallizers) from which salt ultimately was extracted; flamingos did not use the crystallizers.

Salinity (ppt) within each habitat type was sampled using a portable refractometer on 1 day in April, 3 days in May and June, and 2 days in July and August. There were six sample sites in habitats 1 and 2, eight in habitat 3, 12 in habitat 5, and six in habitat 6. Sample sites were selected to provide an evenly spaced coverage within each type, but not all sites were available for sampling each day.

Habitats were sampled by randomly assigning 1 day to each habitat, depending on the numbers of flamingos present. For example, if few or no flamingos used a given habitat, that habitat was

TABLE 1. Percent time spent in each activity by adult Caribbean Flamingos in the Rio Lagartos Estuary, Yucatan, Mexico, from April through August 1987.[a]

Month	Number of observation days	Observation time (hr)	Activity										
			Feeding	Resting	Flying	Walking	Preening	Courtship	Comfort	Aggression	Alert	Nest building	Incubation
April	12	65.1	46.4^{A}	12.9^{A}	2.5^{C}	4.4^{C}	$19.7^{B,C}$	9.8^{A}	0.6^{B}	$1.5^{B,C}$	1.9^{B}	0.1^{B}	0.1^{B}
May	13	99.5	28.7^{A}	18.8^{A}	$5.8^{A,B}$	8.7^{A}	14.8^{C}	2.1^{B}	1.3^{A}	6.0^{A}	1.2^{B}	4.9^{A}	7.7^{A}
June	12	86.7	33.0^{A}	8.8^{A}	6.4^{A}	$5.8^{B,C}$	$19.5^{B,C}$	2.9^{B}	1.8^{A}	$3.4^{A,B}$	3.2^{A}	1.3^{B}	14.0^{A}
July	14	92.6	38.6^{A}	19.3^{A}	4.1^{B}	$8.0^{A,B}$	$25.1^{A,B}$	0.1^{C}	1.9^{A}	1.3^{C}	1.5^{B}	0.1^{B}	0.1^{B}
August	10	61.2	34.3^{A}	16.6^{A}	$4.9^{A,B}$	9.2^{A}	29.7^{A}	0.1^{C}	2.1^{A}	$1.7^{B,C}$	1.2^{B}	0.1^{B}	0.1^{B}

[a] Means within a column denoted by the same capital letter are not different ($P > 0.05$).

TABLE 2. Percent time spent in each activity by immature Caribbean Flamingos in the Rio Lagartos Estuary, Yucatan, Mexico, from May through August 1987.[a]

Month	Number of observation days	Activity											
		Observation time (hr)	Feeding	Resting	Flying	Walking	Preening	Courtship	Comfort	Aggression	Alert	Nest building	Incubation
May	5	5.9	57.2[A]	22.1[A]	2.4[A]	3.4[A]	13.5[A]	0.1[A]	0.7[A]	0.4[A]	0.1[A]	0.1[A]	0.0[A]
June	4	2.4	68.5[A]	9.1[A]	0.3[A]	3.3[A]	15.8[A]	0.1[A]	1.4[A]	0.9[A]	0.5[A]	0.1[A]	0.0[A]
July	8	2.8	57.2[A]	12.8[A]	1.6[A]	5.7[A]	16.8[A]	0.1[A]	3.8[A]	1.5[A]	0.4[A]	0.1[A]	0.0[A]
August	4	1.1	63.2[A]	6.0[A]	0.6[A]	7.6[A]	16.8[A]	0.1[A]	1.9[A]	2.6[A]	1.2[A]	0.1[A]	0.0[A]

[a] Means within a column denoted by the same capital letter are not different ($P > 0.05$).

not sampled during a given week. This sampling scheme allowed activity-budget data to be collected from each habitat at least once every 14 days. Activities were categorized as feeding (Rooth 1975), resting, locomotion (flying and walking), preening, comfort, courtship (Kahl 1975), aggression, and alert. Age class (adults or immatures) was determined by plumage characteristics (Bent 1926, Allen 1956, Rooth 1965). The determination of age classes from plumage characteristics has not been resolved completely, however, thus adults in our study were those individuals having bright red plumage (no white or gray); all others were classified as immatures.

Activity patterns were compared among months and habitats using analysis of variance following arcsine transformation of the nonnormal percentage data (Zar 1974). Duncan's multiple range test separated means where appropriate. Sample size within months and habitats was the number of days flamingos were observed within each category. All statistical tests followed procedures outlined by Steel and Torrie (1980).

The flamingo population using the estuary was censused every 14–16 days during the study. The area censused included all habitat from El Cuyo to Coloradas.

RESULTS

ACTIVITY PATTERNS

A total of 405 hr was spent observing adult Caribbean Flamingos in the Rio Lagartos Estuary from April through August 1987 (Table 1). Feeding (28.7–46.4%), preening (14.8–29.7%), and resting (8.8–19.3%) were the major activities during each month. Time spent feeding and resting did not vary ($P > 0.05$) among months, whereas preening was highest ($P < 0.05$) in August. Incubation, nest building, and aggression were highest during the peak of nesting activity in May and June, however, courtship activity was highest ($P < 0.05$) in April and decreased ($P < 0.05$) thereafter.

Immature Caribbean Flamingos were observed for only 12 hr from May through August

TABLE 3. Daily activity patterns (percent time) of adult and immature Caribbean Flamingos in Yucatan, Mexico, from April through August 1987.[a]

Activity	Time periods							
	Early morning		Late morning		Early afternoon		Late afternoon	
	Adults	Immatures	Adults	Immatures	Adults	Immatures	Adults	Immatures
Feeding	44.3[A]	70.2[A]	33.8[B]	59.2[A]	32.3[B]	52.3[A]	35.7[B]	59.5[A]
Resting	11.5[B]	7.7[A]	20.1[A]	16.8[A]	18.6[A]	18.4[A]	10.6[B]	7.9[A]
Flying	5.0[B]	0.5[A]	3.5[C]	0.8[A]	3.8[C]	1.5[A]	6.6[A]	2.6[A]
Walking	6.2[C]	5.9[A]	6.3[C]	4.6[A]	7.6[B]	4.5[A]	9.1[A]	5.7[A]
Preening	19.0[B]	12.8[A]	20.8[A]	14.6[A]	21.5[A]	15.5[A]	21.7[A]	20.5[A]
Courtship	3.3[A]	0.1[A]	3.2[A]	0.1[A]	2.7[A]	0.1[A]	2.8[A]	0.1[A]
Comfort	0.9[D]	1.3[A]	1.3[C]	1.7[A]	1.8[B]	5.4[A]	2.3[A]	1.5[A]
Aggression	2.8[A]	1.0[A]	2.8[A]	1.6[A]	3.1[A]	1.5[A]	3.0[A]	1.6[A]
Alert	1.4[A]	0.4[A]	1.9[A]	0.4[A]	2.0[A]	0.7[A]	1.7[A]	0.5[A]
Nest building	1.5[A]	0.1[A]	1.4[A]	0.1[A]	1.3[A]	0.1[A]	1.7[A]	0.1[A]
Incubation	4.1[A]	0.0[A]	5.0[A]	0.0[A]	5.3[A]	0.0[A]	4.9[A]	0.0[A]

[a] Within each row, values denoted by the same letter are not different ($P > 0.05$) for adults and immatures, respectively.

TABLE 4. Flamingo use of habitat types in the Rio Lagartos Estuary as determined from bimonthly censuses, 1987.

Month	Habitat types						
	Natural high salinity	Natural intermediate salinity	Natural low salinity	Low salinity salt ponds	Intermediate salinity salt ponds	High salinity canal	Total
April	2,486	843	211	304	2,791	0	6,635
May	8,693	1,164	170	502	2,414	0	12,943
June	12,946	189	478	37	3,629	527	17,806
July	6,648	79	2,622	26	2,157	723	12,255
August	1,449	445	5,703	43	1,619	1,318	10,577
Total	32,222	2,720	9,184	912	12,610	2,568	—

during which time feeding (57.2–68.5%) was the dominant activity (Table 2). Feeding did not vary ($P > 0.05$) among months and was always greater (by 19–36%) than time spent feeding by adults. The disparate observation time between adults and immatures makes statistical comparisons difficult, however, differences in feeding time between age classes were significant (t-test; $P < 0.05$) during May, June, and August.

Resting (6.0–22.1%) and preening (13.5–16.8%) were the other major activities of immatures and did not vary ($P > 0.05$) among months. Time spent resting was not different ($P > 0.05$) from adults during any month, but preening was lower ($P < 0.05$) than adults during August (16.8 vs. 29.7%). Nest building, incubation, and courtship were minor activities (0.1%) during all months; immatures did not incubate eggs. All other activities except walking during July and August accounted for <3% of time spent during each month.

Adults and immatures generally did not exhibit dramatic changes in activity patterns throughout the day (Table 3). Adults did spend about 10% more time ($P < 0.05$) feeding during early morning and rested about 10% more ($P < 0.05$) during late morning and early afternoon. Courtship, aggression, alert, nest building, and incubation behavior did not vary ($P > 0.05$) during the day for either age class.

MIGRATION CHRONOLOGY AND HABITAT USE

Flamingos were present in the Rio Lagartos Estuary by the first census in April (6,635), with peak numbers (17,806) occurring in June (Table 4). Flamingo use was highest in the habitat type of natural high salinity (Table 5), followed by intermediate salinity salt ponds and natural low salinity (Table 4).

Activity patterns of adult Caribbean Flamingos varied ($P < 0.05$) somewhat among habitat types (Table 6). Of the dominant activities, feeding was highest ($P < 0.05$) in the natural high salinity canal and lowest ($P < 0.05$) in the natural high salinity estuary, but not different ($P > 0.05$) within the remaining four habitat types. Resting did not vary ($P > 0.05$) among habitats. Activities associated with reproduction (i.e., courtship, aggression, nest building, incubation) were highest in the natural high salinity estuary, which was the site of the breeding colony. Flying and walking also were highest ($P < 0.05$) in this habitat type. Habitat-associated variation in activity patterns was not determined for immatures because of the limited hours of observation (12 hr).

TABLE 5. Salinity readings (ppt) within the six major habitat types of the Rio Lagartos Estuary during 1987.

Month	Habitat type											
	Natural high salinity			Natural intermediate salinity			Natural low salinity			Low salinity salt ponds		
	$\bar{x}$	Range	n	$\bar{x}$	Range	n	$\bar{x}$	Range	n	$\bar{x}$	Range	n
April	104	88–132	6	79	69–88	6	62	49–70	8	80	77–83	2
May	122	100–154	24	95	81–115	16	75	42–85	20	94	90–98	6
June	133	98–170	24	89	75–96	17	60	37–106	23	98	88–116	9
July	123	104–144	12	105	74–140	12	64	37–144	16	106	94–120	6
August	129	100–155	15	81	66–114	12	50	37–68	16	83	78–88	6

DISCUSSION

ACTIVITY PATTERNS

Feeding was the dominant activity each month among adult flamingos, but feeding decreased during the nesting period in May and June as time spent nest building and incubating increased. This decrease was not significant ($P > 0.05$), but nevertheless could imply that Caribbean Flamingos rely (at least partially) on nutrient reserves acquired before the onset of nesting as reported for several species of geese (Ankney and MacInnes 1978, Raveling 1979). If Caribbean Flamingos are accumulating nutrient reserves prior to initiation of nesting activities, then factors influencing the availability of food upon arrival at the nesting area would be an important event in the annual cycle. Johnson (1975) speculated that spring rains may influence breeding of Greater Flamingos (*Phoenicopterus ruber roseus*) in the Camargue, France.

Although reproductive behaviors (i.e., incubation and nest building) varied inversely with feeding time, time spent incubating probably was underestimated because flamingos engaged in other activities while sitting on nests. For example, nearly all resting activity and about 85% of preening activity during May and June was done while birds were on nests, which would increase incubation activity to about 40%. Using observational data just from the birds in the nesting area increased incubation values alone from 7.7 to 14.0% in May and from 14.0 to 27.8% in June. This would increase activities associated with incubation to about 45–55% of the diurnal time budget. Much aggression, alertness, flying, and walking behavior also occurred among adults in association with incubation (see Ogilvie and Ogilvie 1986, p. 84). In contrast, very few immatures were observed nesting (none incubated eggs), thus time allocated to associated activities during May and June (i.e., aggression, preening, etc.) was less than adults, whereas feeding time was higher. Overall, however, more accurate information on both adults and immatures could be obtained from observation of marked individuals.

Preening was the second or third most important activity each month for both adult and immature flamingos. No flamingos were observed flightless at any time, which adds to the disagreement among published reports as to whether flamingo molt is synchronous or asynchronous (Ogilvie and Ogilvie 1986, p. 15). Indeed, de Boer (1979) proposed that both types of molt occur, but may vary by age classes. Our observations at Rio Lagartos did not resolve the controversy conclusively, but indicate that an asynchronous molt probably occurred in both age classes of the population.

It would seem unlikely that a bird allocating so much time foraging (28.7–46.4% for adults) to meet a high food intake requirement (Rooth 1976) could afford the restriction of undergoing a flightless period for any length of time. Regardless, preening occupies a high proportion of the daily time budget of breeding (13.5–29.7%) and nonbreeding flamingos (Espino-Barros and Baldassarre 1989). In contrast, waterfowl seldom allocate more than 10% of daily time budgets to preening activity (Paulus 1988). Perhaps the hypersaline conditions at Rio Lagartos necessitate that flamingos must frequently preen salt accumulations from their plumage.

ACTIVITY PATTERNS AND HABITAT TYPES

The average time spent feeding by adult Caribbean Flamingos was 36%, however, feeding ranged from 41.0–80.1% within the three habitats created by commercial salt operations. This is significant because many populations of flamingos breed in areas where commercial salt operations could impact habitats and/or alter patterns of activity (Johnson 1975, Rooth 1975, de Boer 1979). Thus, artificial habitats created by salt operations in Rio Lagartos are suitable feeding sites for flamingos. Johnson (1975) noted that Greater Flamingos in the Camargue, France benefitted from the food production associated with salt ponds constructed in association with the salt industry. The population of Caribbean Flamingos on Bonaire also has fed in man-made ponds associated with commercial salt opera-

Table 5. Extended.

Habitat type					
Intermediate salinity salt ponds			High salinity canal		
$\bar{x}$	Range	n	$\bar{x}$	Range	n
154	136–173	12			
153	127–179	12	187	178–203	6
166	144–196	8	204	185–215	7
169	156–178	8	206	190–222	8

TABLE 6. Activity patterns (percent time) of adult Caribbean Flamingos within the six major habitat types of the Rio Lagartos Estuary in Yucatan, Mexico, 1987.[a]

Activity	Habitat types					
	Natural high salinity	Natural intermediate salinity	Natural low salinity	Low salinity salt ponds	Intermediate salinity salt ponds	High salinity canal
Feeding	20.7^{C}	48.2^{B}	53.0^{B}	41.0^{B}	49.3^{B}	80.1^{A}
Resting	18.8^{A}	17.6^{A}	11.4^{A}	17.3^{A}	15.6^{A}	2.1^{A}
Flying	6.0^{A}	2.1^{C}	4.5^{A,B}	2.7^{B,C}	3.0^{B,C}	3.0^{B,C}
Walking	8.0^{A}	4.0^{B}	6.3^{A,B}	5.4^{A,B}	5.0^{A,B}	4.4^{A,B}
Preening	26.3^{A}	16.1^{B}	19.6^{A,B}	19.3^{A,B}	18.7^{A,B}	8.0^{C}
Courtship	3.2^{B,C}	8.6^{A}	0.1^{C}	8.4^{A,B}	5.0^{A,B}	0.1^{C}
Comfort	1.7^{A}	0.7^{B}	2.0^{A}	0.7^{B}	0.7^{B}	0.6^{B}
Aggression	3.8^{A}	1.6^{A,B}	1.3^{A,B}	1.4^{A,B}	1.4^{A,B}	0.8^{B}
Alert	1.9^{A}	1.1^{A}	1.8^{A}	3.8^{A}	1.3^{A}	0.9^{A}
Nest building	2.2	0.0	0.0	0.0	0.0	0.0
Incubation	7.5	0.0	0.0	0.0	0.0	0.0

[a] Means within each row denoted by the same letter are not different ($P > 0.05$).

tions, although the formation of a gypsum crust precluded feeding during some years (Rooth 1965, de Boer 1979).

The salinities within the three man-made habitats ranged from 80 ppt (low salinity salt ponds) to 206 ppt (high salinity canal), however, flamingos never were observed in the final series of ponds (crystallizers) where salinity readings exceeded 206 ppt. Feeding time was low within the habitat type of natural high salinity, but this area contained the breeding colony where other activities were dominant. Feeding time was highest in the canal presumably because salinity conditions (187–206 ppt) may be optimum for growth of brine fly larvae (*Ephydra* spp.) and brine shrimp (*Artemia* sp.); both organisms were abundant in this habitat. On Bonaire, de Boer (1979) reported the highest percent occurrence of brine shrimp at salinities of 45–90 ppt. Overall, however, feeding activities within habitat types were similar ($P > 0.5$) over a wide range of salinities, thus documentation of available food resources (vs. salinity regimes) might better explain flamingo activity patterns.

CONSERVATION RECOMMENDATIONS

The activity budget data from Rio Lagartos provided an initial description of activity patterns of flamingos during the breeding season. Habitat types had little effect on the major activities (i.e., feeding and resting), and commercial salt operations do not appear to be adversely affecting behavior of Caribbean Flamingos at this time. Indeed, salt operations appear to enhance feeding habitat, which is important because management techniques exist to provide nesting habitat within areas of salt exploitation (Rooth 1975, Johnson 1975).

Certainly a major management objective should be to maintain current salinity levels in the estuary. This would be of particular concern at El Cuyo where a proposed man-made connection between the Gulf of Mexico and the estuary (to provide boat anchorage) would mix open ocean (35 ppt salinity) with high salinity water in the estuary. Such an action could have potentially disastrous impacts on flamingo food resources, but impacts could be negated easily by constructed dikes or levees to prevent ocean water from entering the estuary. Any expansion of the salt industry must determine the potential impact on the salinity of the estuary beforehand. The impacts on the hydrology of the estuary from Hurricane Gilbert (September 1988) also should be assessed and corrective action taken if warranted.

Further research at Rio Lagartos should seek to better understand habitat requirements of breeding Caribbean Flamingos. Best results would be obtained from research on feeding ecology, food production (i.e., brine shrimp and brine fly) from salt ponds, reproductive physiology of breeding birds, and a detailed description of the hydrology of the estuary.

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