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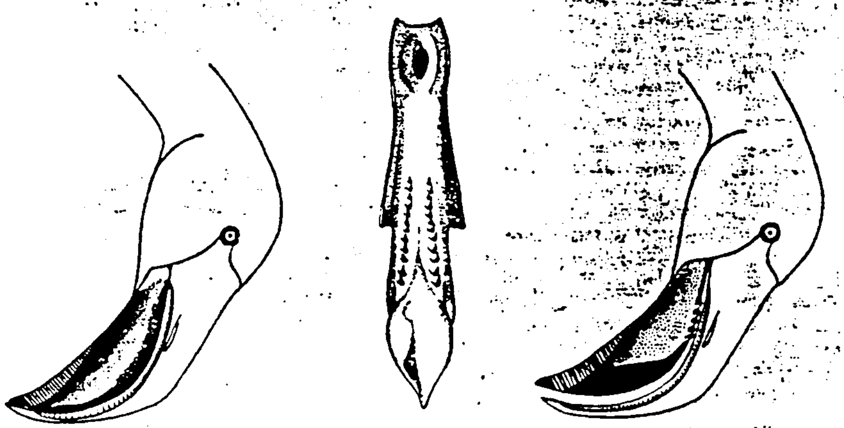

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Feeding Behavior, Aggression, and the Conservation Biology of Flamingos: Integrating Studies of Captive and Free-ranging Birds[1]

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SYNOPSIS. Flamingos (Aves; Phoenicopteridae) represent an ancient lineage of long-legged, microphagous, colonial wading birds. Although often perceived as tropical, flamingo distribution is more closely tied to the great deserts of the world, and to hypersaline sites, than it is to equatorial regions. Many aspects of flamingo behavior and ecology can be studied in captivity. Experimental studies involving captive birds, when combined with observational studies of free-ranging birds, offer researchers opportunities to address questions that are unanswerable with field work alone. Zoo populations of flamingos are prime candidates for such studies.

Here, we use samples of our own work to illustrate the synergistic effects of combining zoo and field research. Our first example describes how studies of salt tolerance in captive birds are playing a key role in assessing the impact of salt as an ecological determinant of flamingo distribution. Our second example describes how aggression and dominance interactions affect the feeding behavior of flamingos. We assess the implications of this research in terms of both avicultural practices and the fundamental ecology of the birds. We believe that similar collaborations involving other zoo animals would yield comparatively productive results.

INTRODUCTION

Flamingos (Aves, Phoenicopteridae) are large, long-legged, filter-feeding wading birds with historic distributions on all continents except Australia and Antarctica (Allen, 1956). Although frequently noted for their enormous feeding and breeding assemblages, two of four South American species of flamingos, the Andean (*Phoenicopterus andinus*) and Puna (*P. jamesi*), are listed by the International Council for Bird Preservation as threatened species; and many populations of all five extant species are considered to be at risk (*cf.* Kear and Duplaix-Hall, 1975; Collar and Andrew, 1988; Ogilvie and Ogilvie, 1986).

Although descriptions of flamingo biology date from Buffon (1781), numerous key features of flamingo aviculture, ecology, and conservation biology remain unstudied (*cf.* Allen, 1956; Jenkin, 1957; Kear and Duplaix-Hall, 1975; Rooth, 1965). Given the precarious nature of many of their populations, much remains to be learned about these birds.

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Captive Zoo Flamingos as Models of Their Wild Counterparts

Flamingos rank as one of the world's most charismatic megavertebrates. Indeed, more than half of all zoos maintain at least one species of flamingo in their display collections (Duplaix-Hall and Kear, 1975). To date, the potential value of this vast population of captive individuals has been overlooked by ecologists and conservation biologists (Bildstein, 1990).

Historically, most research conducted at zoos has been aimed at improving the health, welfare, and nutrition of wild-caught animals maintained in captivity (Hediger, 1950). More recently, zoos have begun to focus their research efforts on attempts to increase the reproductive output of animals within their collections, and many zoos are now at the forefront of conservation efforts (Conway, 1989). Even so, aside from questions of nutrition, zoos have paid comparatively little heed to the feeding and social ecology of the birds they hold.

There are several reasons for the lack of emphasis in this area (Bildstein, 1990). First is the question of adequate sample size (Conway, 1969). Although many zoos maintain large numbers of animals, the numbers of individuals representing each species can be quite small. Nevertheless, either to enhance the appearance of their displays, or to increase the potential for breeding activity, many zoos maintain large numbers of individuals of social or communal species (*cf.* Stevens, 1991). Flamingos, for example, are usually kept in flocks of 10 or more, and many zoos maintain 50 or more individuals (Stevens, 1990).

A second concern is the extent to which captivity affects the behavior of the animals being studied. Although it is true that large-scale aspects of behavior cannot be studied in zoos because of obvious space constraints, many small-scale aspects of feeding and social behavior, such as aggressive interactions, and "habitat"- and prey-choice decisions, can be studied in many species, including flamingos. In fact, researchers can actually take advantage of the "controlled" nature of captivity by integrating experimental studies of captive birds with observational studies of free-ranging individuals (Bildstein, 1990).

Here, we indicate how existing zoo populations of flamingos can be used to address questions of importance to both the fundamental ecology and conservation biology of these birds.

Flamingos and Salt

Thanks to Madison Avenue, most people think of flamingos as "tropical" birds. In reality, they are not. On a worldwide basis, the abundance and distribution of flamingos is much more closely tied to the great deserts and hypersaline regions of the world, than it is to the equatorial zone (Allen, 1956; Jenkin, 1957; Britton and Johnson, 1987). In the Western Hemisphere, flamingos range as far south as Tierra del Fuego in Chile, while in central Asia they occur as far north as the Aral Sea along the borders of Kazakhstan and Uzbekistan. Flamingos frequently spend a considerable amount of time filter feeding in highly saline waters (*cf.* Brown, 1959; Peaker and Linzell, 1975). In the Caribbean Basin, for example, the American Flamingo (*P. ruber ruber*) regularly feeds in commercial salt-extraction ponds (Rooth, 1965); and in the Peruvian Andes, the closely related Chilean Flamingo (*P. chilensis*) is known to feed in lakes where salinities exceed 7x that of ocean-strength saltwater (Hurlbert *et al.*, 1986). Because many potential vertebrate and invertebrate competitors are unable to withstand the rigors of such osmotically severe environments (*cf.* Jenkin, 1957; Hurlbert *et al.*, 1986; Britton and Johnson, 1987), occurring in these locales apparently benefits flamingos by reducing interspecies competition for food. How the birds manage to tolerate such extreme conditions remains enigmatic. Two possible solutions have been suggested.

Flamingos possess sophisticated filter-feeding mechanisms—somewhat analogous to those of baleen whales (Mammalia, Mysticeti)—which, anatomically, appear well suited to the task of restricting the intake of saline waters during the feeding process (Jenkin, 1957) (Fig. 1). Flamingos also possess salt glands (McFarland, 1959), paired supraorbital structures found in many

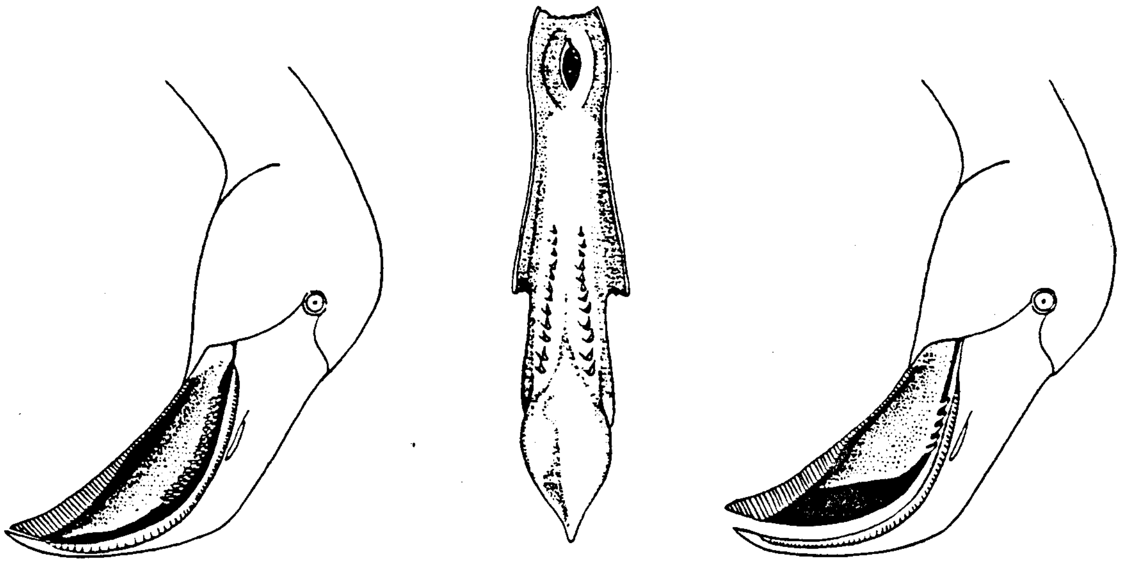

FIG. 1. Head of the Greater Flamingo shown with the bill closed and tongue extended during the filtering stage of filter feeding (left), and with the bill open and tongue retracted during the intake stage (right). Note the large recurved spines on the flattened upper surface of the tongue used to retain food (middle), as well as the lamellae along the articulating edge of the uncut upper mandible (complementary structures are also present on the lower mandible, which has been cut away in this illustration to expose the mouth cavity). Water is forced from the mouth cavity during the filtering stage by the piston-like action of the large, fatty tongue. (After Jenkin, 1957.)

marine species of birds, that are capable of secreting hyperosmotic solutions of sodium chloride (Peaker and Linzell, 1975). The efficacy of these organs in hypersaline environments, where salinities sometimes exceed seven times that of normal seawater, remains unstudied. It also remains to be seen whether salt glands are capable of secreting the bicarbonate ions that are present in the many soda lakes flamingos inhabit (Peaker and Linzell, 1975).

What *is* known about flamingos is that some individuals filter upwards of 20,000 l of water per day (Vareschi and Jacobs, 1984). How the birds manage to do so in saline waters while maintaining their osmotic integrity remains unknown.

Although observations of free-ranging flamingos suggest that individuals often interrupt their filter feeding to travel long distances to drink and bathe at relatively freshwater sites (Allen, 1956; Jenkin, 1957; Brown, 1958, 1959; McFarlane, 1975), many flamingos inhabit areas that lack freshwater (Berry, 1975), and many are known to drink ocean-strength seawater (Rooth, 1965). Indeed, the native inhabitants of southern Cuba were maintaining captive flocks of American Flamingos solely on ocean-strength saline drinking water almost five hundred years ago (Las Casas, 1951 edition of a 1556 manuscript).

Studying the salinity tolerances of captive American Flamingos

In 1989 at the St. Louis Zoo we began to study the feeding behavior of captive American Flamingos that were simultaneously offered food suspended in fresh- and saltwater.

American Flamingos at the St. Louis Zoo are maintained on a mixed diet of commercially prepared flamingo chows (Flamingo Fare and Mazuri® Flamingo Complete) and fresh-frozen krill (Crustacea, Euphausiacea) suspended in tapwater in 32 × 51 × 15-cm stainless-steel pans. During our experiments, flamingos were offered a simultaneous choice of this diet suspended in either freshwater or in saline solutions of known concentrations prepared using Instant Ocean® aquarium salt. In the first of three experiments, flamingos were offered a choice of food soaked in either freshwater

TABLE 1. *Rates at which American Flamingos switched from feeding in one tray to feeding in another during three experiments at the St. Louis Zoo.*

Experiment	Percent (n) switching from Freshwater tray	Percent (n) switching from Saltwater tray	P^{a}
Freshwater *versus*:			
1 × ocean-strength saltwater	13% (75)	7% (69)	>0.10
2 × ocean-strength saltwater	14% (29)	21% (39)	>0.10
3 × ocean-strength saltwater	16% (69)	19% (59)	>0.10

[a] Probability of significantly different switching rates using a χ^2 test for heterogeneity.

or ocean-strength saltwater (*i.e.*, 32–36 ppt saltwater). In the second and third experiments, birds were offered a choice between food soaked in freshwater and that soaked in either 2×-(Experiment 2) or 3×-(Experiment 3) ocean-strength saltwater (*i.e.*, 64–72 ppt and 96–108 ppt saltwater, respectively).

Pairs of trays (one fresh- and the other saltwater) were placed within a shallow 4.2 × 6.8-m concrete basin filled with approximately 24 cm of freshwater at its deeper end. The location of fresh- and saltwater trays was assigned haphazardly at the beginning of each day of observation. Because there were 6 flamingos in our captive flock during experiments 1 and 2, but 29 birds during experiment 3, and because flock size appears to affect certain aspects of flamingo feeding behavior (see below), we limited our comparisons of potential "salt-effect" to differences within each experiment. Differences in feeding behavior among the three experiments are discussed later in the paper.

Our experiments were designed to answer two questions. First, when given a choice, would American Flamingos avoid filter feeding on food suspended in saline and hypersaline solutions similar to those regularly confronted by free-ranging birds; and second, would the filter-feeding behavior of the birds change in response to the salinity of the water in which their food was suspended. Before initiating our observations, one of us (KLB) spent several weeks in Venezuela, observing and recording the behavior of American Flamingos filter feeding in a shallow, brackish-water salina near the coastal town of Chichiriviche (Bildstein *et al.*, 1991*a*). We used these observations to determine which aspects of the feeding behavior of our captive flock to monitor and compare.

At the onset of each experimental run, flamingos were first allowed two days to accustom themselves to the choice of feeding in fresh- and saltwater trays, after which data were collected during 2- to 7-day periods of observations. Individual focal birds (*sensu* Altman, 1974) were observed for one-min periods, and no one bird was observed more than 3 times within a single day. For each observation, we initially haphazardly selected and identified a focal bird (all of the birds were wearing numbered leg bands) from within the flock, and then waited until that bird began to feed from one of the available trays. In many instances, 1–4 additional birds were simultaneously feeding from the same tray. Once the focal bird had begun to feed, we recorded the tray from which the bird was feeding (either fresh- or saltwater), as well as (1) whenever it submerged its bill and was filter feeding in the tray, (2) whenever it withdrew its bill from the tray, (3) whenever it rinsed its bill in the freshwater basin surrounding the tray, and (4) whenever it withdrew its bill from the basin. Observations were recited into a cassette tape player, and were transcribed at the end of each day.

Experimental results

In all three experiments, flamingos failed to show a significant preference for either fresh- or saltwater trays (χ^2 tests for goodness of fit, $P > 0.10$). During most observations, flamingos remained at, and continued to feed from, the tray that they had started at, and there was no indication that birds were more likely to switch from either fresh- or saltwater trays (Table 1). Thus, it appeared that flamingos were neither attracted to, nor repelled by, food suspended in 1–3× ocean-strength saltwater.

Although fewer than 5% of the birds lifted their heads and actually drank freshwater during our observations, flamingos fed less frequently, and for shorter durations, and they rinsed their bills more often, when filter feeding in saltwater trays than when filter feeding in freshwater trays (Table 2). Although not all of the changes in behavior were significantly different in all three experiments, with the single exception of feeding-bout duration in Experiment 2, all reflected a move toward reduced feeding and increased rinsing behavior as a result of contact with saltwater (Table 2).

Our experiments demonstrate that flamingos are able to detect and respond behaviorally to the presence of saltwater while filter feeding in it. We plan to continue the experimental sequence using higher salinity water to assess the ability of the birds to discriminate among different levels of concentration. The fact that flamingos continue to feed in saltwater when freshwater is available nearby suggests that they may be able to avoid, or at least significantly reduce, salt-loading by periodically rinsing their bills in freshwater. Whether they would be able to do without the availability of local freshwater will be tested in a subsequent series of experiments in which the "rinsing" basin surrounding the feeding trays will be filled with saltwater.

TABLE 2. *Feeding and bill-rinsing behavior of captive American Flamingos at the St. Louis Zoo feeding from freshwater and saltwater trays.*

Experiment and behavior	Freshwater tray (Mean ± SE)	Saltwater tray (Mean ± SE)
Freshwater *versus* 1× ocean-strength saltwater		
Feeding bouts/min	4.1 ± 0.3	3.3 ± 0.3*
Sec/feeding bout	8.3 ± 0.7	5.7 ± 0.4*
Sec feeding/min	38 ± 3.4	17 ± 1.8*
% birds bill-rinsing	34	55*
Bill rinses/min	0.6 ± 0.1	1.1 ± 1.7*
Freshwater *versus* 2× ocean-strength saltwater		
Feeding bouts/min	4.5 ± 0.5	2.8 ± 0.3*
Sec/feeding bout	5.4 ± 1.0	8.0 ± 1.4
Sec feeding/min	27 ± 4.8	19 ± 3.7
% birds bill-rinsing	32	68*
Bill rinses/min	0.4 ± 0.2	0.9 ± 0.2*
Freshwater *versus* 3× ocean-strength saltwater		
Feeding bouts/min	7.7 ± 0.4	7.6 ± 0.6
Sec/feeding bout	5.1 ± 0.5	3.0 ± 0.2*
Sec feeding/min	32 ± 1.6	22 ± 1.8*
% birds bill-rinsing	88	100*
Bill rinses/min	4.3 ± 0.5	6.7 ± 0.5*

* Significantly different at $P < 0.05$, using one-way analysis of variance (for mean values) and χ^2 tests for heterogeneity (for percentages).

AGGRESSION AND DOMINANCE IN FLAMINGOS

It is widely recognized that flamingos maintain a well-developed suite of aggressive displays, and that during both courtship and mating, neighboring flamingos squabble almost continually, occasionally to the point of drawing blood (Brown, 1958; Gallet, 1950). It has also been reported that Greater Flamingos (*P. ruber roseus*) maintain individual distances while foraging (Swift, 1960). More recently, our observations of American Flamingos foraging in mixed-age flocks in Venezuela demonstrated that the feeding behavior of flamingos can be affected by frequent aggressive interactions, and that smaller and less experienced juvenile flamingos suffer disproportionately in this regard (Bildstein *et al.*, 1991*a*). Nevertheless, the extent to which aggression occurs in both free-ranging and captive individuals, as well as its potential impact on those birds, is typically mentioned only in passing in the literature (*cf.* Middlemiss, 1953; Hurlbert and Keith, 1979; Kear and Palmes, 1980; Espino-Barros and Baldassarre, 1989).

Historically, most zoo flamingos were caught in the wild, and even today, except for American Flamingos, most individuals maintained in U.S. zoos represent wild-caught birds (Silveri, 1990). Increasing difficulties associated with obtaining wild-caught birds, many of which are protected in their countries of origin, together with the fact that few captive populations are self sustaining, have emphasized the need to improve captive-breeding techniques. Although much remains to be learned in this regard, a recent survey of U.S. zoos suggests that captive flamingos are more likely to breed when maintained in large (*i.e.*, ≥20 bird) rather than smaller flocks (*i.e.*, <20 bird) (Stevens, 1990, 1991). In light of this finding, several zoos are now attempting to increase the size of their flocks, even to the point of combining flocks of several species. The impact of such schemes on the levels of aggressive behavior within these flocks is unclear.

TABLE 3. *Numbers of captive American and Chilean flamingos at the Riverbanks Zoo feeding together with the focal bird.*

	Numbers of	
Focal species	American Flamingos (Mean ± SE)	Chilean Flamingos (Mean ± SE)
American Flamingos	0.35 ± 0.04	0.09 ± 0.02*
Chilean Flamingos	0.20 ± 0.05	0.56 ± 0.04*

* Significantly different at $P < 0.05$, using χ^2 tests for heterogeneity.

TABLE 4. *Feeding and bill-rinsing behavior of a mixed-species flock of captive American and Chilean flamingos at the Riverbanks Zoo.*

Behavior	American Flamingos (Mean ± SE)	Chilean Flamingos (Mean ± SE)
Feeding bouts/min	6.9 ± 0.3	7.4 ± 0.2
Sec/feeding bout	3.8 ± 0.1	2.7 ± 0.1*
Sec feeding/min	24 ± 0.9	19 ± 0.5*
Bill rinses/min	2.6 ± 0.2	4.7 ± 0.2*
Sec/bill rinse	1.3 ± 0.1	1.6 ± 0.1
Sec bill rinsing/min	3.6 ± 0.3	6.8 ± 0.3*

* Significantly different at $P < 0.05$ using one-way analysis of variance.

In the section that follows, we briefly outline several studies designed to assess the extent to which aggression and dominance shape the behavior of captive flamingos. We also discuss how such studies might play a role in developing a clearer understanding of flamingo competition in the wild.

Studying the potential impact of aggression and dominance in captive flamingos

In early 1990, we began studying the potential impact of aggression and dominance on the feeding behavior of 35 Chilean and 18 American flamingos maintained in a mixed-species flock at the Riverbanks Zoo, in Columbia, South Carolina. Male and female American Flamingos are substantially heavier, and are approximately 30% taller than their Chilean counterparts (Blake, 1977; Richter *et al.*, 1991). Given our experiences with free-ranging American Flamingos, we were especially interested in determining whether or not the presence of American Flamingos affected the feeding behavior of the smaller Chilean Flamingos.

Our studies of feeding behavior at the Riverbanks Zoo employed the same sampling scheme used in the St. Louis Zoo, except that at Riverbanks, we also noted the number of additional birds present at the time of each observation. Our results suggest that the presence of American Flamingos affected the feeding behavior of Chilean Flamingos. Although Chilean and American flamingos sometimes fed together at the two sets of feeding trays available to them, the two species tended to feed in segregated flocks (Table 3). In addition, American Flamingos had significantly longer feeding bouts, and spent more time feeding, overall, than did Chilean Flamingos (Table 4). On the other hand, Chilean Flamingos spent more time with their bills submerged in the water surrounding the feeding trays than did American Flamingos, and it was our impression that Chileans used the water surrounding the feeding trays to further process food obtained within the trays (Table 4).

Overall, Chilean Flamingos appeared to defer to American Flamingos more so than vice versa. However, many interspecies interactions were subtle and difficult to detect, and we did not attempt to quantify them during our observations. Nevertheless, that the species differences we observed resulted, at least in part, from interspecies dominance behavior is supported by the fact that the presence of increasing numbers of American Flamingos (*i.e.*, 1–4 additional birds) at the feeding trays negatively affected the feeding behavior of Chilean Flamingos, while the reverse did not occur (Table 5).

The results of this ongoing study suggest that the presence of larger American Flamingos noticeably affects the feeding behavior of the smaller Chilean Flamingos. The impact of such species interactions on individual birds is unclear. Since the flock is fed *ad libitum*, it seems unlikely that the nutritional status of individual Chilean Flamingos is in jeopardy. On the other hand, a second study of aggressive behavior, currently underway at the St. Louis Zoo (Bildstein *et al.*, unpublished data), suggests that subordinate birds can be stressed under certain circumstances. For example, when the

St. Louis Zoo's population of 19 American Flamingos was almost doubled by the arrival of 14 additional American Flamingos, a previously established, and relatively linear, dominance hierarchy was substantially disrupted, and the two most subordinate birds in the new hierarchy died within 6 mo (Bildstein *et al.*, unpublished data). In addition to being of immediate avicultural interest, dominance studies such as these are also useful in determining the potential for competitive interactions among free-ranging birds. The extent to which aggression affects habitat choice in flamingos is unknown; however, aggression is known to affect distributions within and among many species of birds (Cody, 1974). Although the ranges of American and Chilean flamingos do not overlap, those of Chilean, Andean, and Puna flamingos do overlap; as do those of Greater and Lesser (*P. minor*) flamingos (Allen, 1956). The literature suggests that smaller species of flamingos defer to larger species (Kear and Palmes, 1980; Hurlbert and Keith, 1979).

The long-term consequences of behavioral interactions in free-ranging populations of anonymous individuals are often difficult to assess. Our observations of individually recognizable, color-banded zoo flamingos suggest that studies of captive flocks may prove quite useful in this regard.

ASSESSING THE VALIDITY OF USING CAPTIVE ZOO FLAMINGOS TO MODEL THE BEHAVIOR OF FREE-RANGING BIRDS

A major concern associated with the use of captive birds is that their behavior may not accurately reflect the behavior of free-ranging birds. To assess the validity of using captive flamingos as models for the feeding behavior of free-ranging birds, we compared feeding behavior recorded for American Flamingos at the St. Louis and Riverbanks zoos with that of American Flamingos we had observed feeding in the wild in coastal Venezuela. Since the birds we observed in Venezuela were feeding in brackish-water that was well below the salinity of full-strength seawater, for the purposes of these comparisons, we limited our analysis of captive individuals to those that were feeding from freshwater trays. Also, since the size of our captive flocks differed considerably among the four experiments involving captive birds, we compared values from each experiment separately with those collected for free-ranging birds.

TABLE 5. *Summaries of regression analyses of the impact of the presence of additional feeding flamingos on the feeding behavior of focal American and Chilean flamingos at the Riverbanks Zoo.*

Focal species behavior	Impact of additional[1] American Flamingos	Impact of additional[1] Chilean Flamingos
American Flamingo		
Feeding bouts/min	NS[2]	NS
Sec/feeding bout	NS	NS
Sec feeding/min	NS	NS
Chilean Flamingo		
Feeding bouts/min	NS	+
Sec/feed bout	–	–
Sec feeding/min	–	NS

[1] One to 4 additional birds.
[2] Relationship at $P < 0.05$ using a general linear regression model: NS = no significant relationship; – = significant negative relationship; + = significant positive relationship.

The numbers of feeding bouts per min, as well as the total amount of time flamingos spent feeding per min, tended to be significantly greater in free-ranging birds than in captive individuals (Table 6). We believe that these differences reflect the fact that food is considerably scarcer in the wild than in zoos, where flamingos are maintained on superabundant, *ad libitum* diets. On the other hand, the mean duration of individual feeding bouts for free-ranging birds fell within the range of values recorded for captive individuals, suggesting that in captivity, this pattern, at least, is representative of what occurs in the wild (Table 6).

The longest feeding bouts in captive flocks were recorded during our first experiment in St. Louis, when there were only 6 flamingos in the flock, while the shortest feeding bouts we recorded were at Riverbanks, where the flock consisted of 18 American and 35 Chilean flamingos. Intermediate values were recorded during Experiments 2 and 3 at St. Louis when flocks consisted of 6 and 29 birds, respectively. Given the observed

TABLE 6. *A comparison of the feeding behavior of captive American Flamingos at the St. Louis and Riverbanks zoos feeding from freshwater trays with that of free-ranging birds in coastal Venezuela.*

Feeding situation	Feeding bouts/min (Mean ± SE)	Sec/feed bout (Mean ± SE)	Sec feeding/min (Mean ± SE)
St Louis Zoo			
Experiment #1	4.1 ± 0.3*	8.3 ± 0.7*	38 ± 3.4
Experiment #2	4.5 ± 0.5*	5.4 ± 1.0	27 ± 4.8*
Experiment #3	7.7 ± 0.4*	5.1 ± 0.5	32 ± 1.6*
Riverbanks Zoo	6.9 ± 0.3*	3.9 ± 0.3*	25 ± 0.9*
Free-ranging birds	9.6 ± 0.3	5.3 ± 0.4	42 ± 0.8

* Significantly different from free-ranging birds at $P < 0.05$ using a Tukey's Studentized Range Test in conjunction with a four-way analysis of variance.

intra- and interspecies differences in feeding-bout length reported in the previous section, these results suggest that aggressive behavior may be responsible for the recorded differences in feeding-bout duration.

CONCLUSIONS

Collaborations between zoo and academic scientists are playing an important role in describing and detailing the feeding ecology and aggressive behavior of flamingos. We believe that captive populations of flamingos can serve as realistic models of free-ranging birds, and that by integrating experimental studies of captive populations with more observational studies of free-ranging populations, researchers can successfully address questions that are unanswerable in the field or laboratory alone.

Given the obstacles that face academic scientists attempting to acquire and maintain captive populations of exotic birds, zoos are fast becoming extraordinarily attractive sites for studying captive individuals. While requiring an appropriately diplomatic demeanor, the use of zoo collections often obviates, or at least reduces to manageable levels, maintenance costs, and space requirements, as well as the need for avicultural expertise and the acquisition of collecting, import, and holding permits. Furthermore, such collaborations also substantially reduce concerns associated with the humane care and treatment of the birds in question.

In light of this, we strongly recommend that research scientists considering the prospect of establishing colonies of certain exotic birds investigate the possibility of using existing zoo collections. When such populations do not already exist, it may be possible to negotiate with zoos to acquire them.

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Studies of carotenoid recycling through preening in American Flamingos

Project narrative: Flamingos are large, long-lived, filter-feeding wading birds with historic distribution on all continents except Australia and Antarctica (Allen 1956). More than half of all zoos maintain at least one species of flamingo in their display collections (Duplaix-Hall and Kear 1975). For captive populations, research has focused on improving health, welfare, and nutrition of wild-caught flamingos, and on increasing their reproductive output (Bildstein et al. 1993). Early successes in increasing reproductive output focused on improving the feather color of captive birds, first by feeding the birds vegetables (e.g., carrots) rich in carotenoid, and eventually, by supplementing their diets with synthetic carotenoid (Duplaix-Hall and Kear 1975). More recently, attempts to enhance breeding success have focused on increasing flock size (Stevens 1991).

Flamingos feed their nestlings a diet of esophageal milk (sloughed eepithelial cells from their esophagus, in much the same way pigeons feed young nestlings crop milk. They probably do so to reduce salt toxicity to their young, since their young lack developed filter-feeding mechanisms needed to reduce salt toxicity early in development (cf. Bildstein 1993). In addition to being osmotically benign, esophageal milk is especially rich in carotenoid (Duplaix-Hall and Kear 1975). Although the ultimate origins of these carotenoid are dietary, the manner in which adults secure sufficient amounts of these pigments while raising young is unstudied. What is known, is that adults often loss feather color while doing so, while none breeding individuals do not (cf. (Duplaix-Hall and Kear 1975).

We propose to investigate the possibility that parental flamingos recycle carotenoid they have deposited in their feathers for the purpose of courtship and mating, by selectively preening their feathers--and reinfecting carotenoid-- after their young hatch. We will do so by microscopically examining feather to determine where in the shaft carotenoids pigments are deposited, and whether these portions of the shaft are selectively preened and reinjested by parental birds.

Schedule of completion: We anticipate beginning our microscopic analyses of flamingo feather structure at Muhlenberg College in September 1997 and completing those studies in December 1997. Upon completion of these studies we plan to present our initial findings at the 1998 meeting of the American Ornithologists' Union in St. Louis in April.

Budget: We are requesting no funding on the part of the St. Louis Zoo, other than costs associated with mailing feathers to us.

Curriculum vitae: Attached.