Flamingo Husbandry Guidelines

A Joint Effort of the AZA and EAZA in Cooperation With WWT

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Preface

Due to the unreliable reproduction of flamingos in captivity, aging population, and responsibility of captive managers to no longer depend on collecting wild birds; members of the AZA Ciconiiformes TAG, EAZA Ciconiiformes/Phoenicopteriformes EEP, and Joint Management of Species (JMS) collectively agreed on the need for a guide to assist captive managers and keepers with a collaborative approach to methods for managing flamingos in captivity. The Flamingo Husbandry Guidelines represents a global collaboration with many meetings, planning, and searching for information in order to provide the most comprehensive husbandry guide for flamingo managers.

In October 1998, Wetlands International/IUCN-SSC Flamingo Specialist Group met in conjunction with the annual Waterbirds Society meeting (Miami, Florida) to develop conservation recommendations, interface with field and captive flamingo biologists, and explore opportunities for captive managers to aid in situ flamingo conservation. It was at this meeting the idea of husbandry guidelines began to take on major importance. The AZA Ciconiiformes TAG facilitated the beginning of a workshop that would include zoo and aquarium professionals from North America and Europe to come together to produce husbandry guidelines for flamingos in captivity. Christopher Brown, AZA Ciconiiformes TAG chair (Dallas Zoo, U.S.A.), Catherine E. King, EAZA Ciconiiformes/Phoenicopteriformes EEP chair (Rotterdam Zoo, The Netherlands), and Tony Richardson, then of the Wildfowl and Wetlands Trust (Slimbridge, U.K), worked cooperatively to prepare for the process. To help facilitate information gathering, chapter coordinators were identified in 1999. The coordinators built teams of interested professionals who collaborated to collect pertinent information about the art and science of flamingo management. In June 2000, a workshop was facilitated by Christopher Brown and hosted by Disney’s Animal Kingdom (Orlando, Florida); with AZA Ciconiiformes TAG vice-chair, Sue Maher, acting as coordinator. Along with the chapter coordinators, zoo and aquarium flamingo managers, nutritionists, veterinarians, and keepers from all regions were invited. Catherine King represented EAZA and Tony Richardson represented JMS. Unfortunately, Mr. Richardson was unable to attend, but provided valuable information from his region.

During the meeting at Disney’s Animal Kingdom, those assembled focused on the most numerous of the flamingos in captivity. The four primary flamingos in captivity, Caribbean Phoenicopterus ruber ruber, greater Phoenicopterus ruber roseus, Chilean Phoenicopterus chilensis, and lesser Phoeniconaias minor are discussed in detail. Life histories and distributions of the remaining two flamingos, the Andean Phoenicoparrus andinus and Puna (James) Phoenicoparrus jamesi, are referred to, but as their captive populations are minimal they are discussed primarily in the Introduction chapter where their conservation, and special management concerns relative to small populations are noted.

While much data have been compiled for these guidelines, there is still much to be learned about the husbandry of flamingos. It is our intention that these guidelines be the catalyst for scientific inquiry into the management of flamingos in captivity. The guidelines represents recommendations of husbandry techniques for the successful maintenance of flamingos in captivity given the scientific data currently available and the successful experiences of our colleagues. With respect to exhibit design, guidelines are given for the renovation of existing facilities or the construction of new exhibits.

Additional information concerning these recommendations may be gathered by contacting the respective Population Management Plan coordinators and/or studbook keepers. It should be
emphasized that these recommendations are guidelines, and in all cases, common sense concerning enclosure design and routine captive animal management should be used. Parameters exclusive to an individual institutions and regions also need to be considered.

Our goal then was to initiate a collaborative effort by numerous zoo and aquarium professionals to compile and present the most up-to-date information possible on the art and science of captive flamingo management. We hope that this goal was met. Any comments are welcome and encouraged as this document is meant to be fluid and is intended to be updated periodically.

Acknowledgments

The editors would like to acknowledge the following people and organizations for their contributions to these guidelines:

Felicity Arengo, PhD, New World Chair for the Flamingo Specialists Group, Museum of Natural History, New York, N.Y.

Elizabeth Stevens, PhD, Vice-president Disney’s Animal Kingdom, for providing the facilities, equipment, and personnel in order to make the husbandry workshop possible.

Special recognition goes to:

Yvonne Clippinger and the Columbus Zoo for providing the resources for Catherine King to travel from The Netherlands to participate in the workshop at Disney’s Animal Kingdom.

Adelheid Studer-Thiersch, Basle Zoo, for her significant contributions to flamingo behavior, management, and exhibit design.

Nigel Jerrett, Wildfowl and Wetlands Trust, for providing numerous photographs in order to demonstrate management techniques and his experiences and knowledge of captive flamingo husbandry.

Kim Smith, Milwaukee County Zoo, for providing funding and dedicating staff time for the production of the guidelines.

Every one of the chapter coordinators, contributors, and husbandry workshop participants for their time, expertise and knowledge.

Fort Worth Zoo for recognizing the importance of the husbandry guidelines and providing the support to begin the process.

Dallas Zoo and Dallas Aquarium at Fair Park for dedicating staff time and resources to this important project. Especially Sherry Mossbarger, Avian Research Technician, who dedicated her spare time compiling information, proofreading, and contacting contributors.
Natural History
Facilitators: Tony Richardson and Simon Pickering, Wildfowl and Wetlands Trust; Peter Shannon, San Francisco Zoo

The flamingos are a particularly distinctive group. There are many close similarities between the six forms, some of which have been studied much more extensively than others. Therefore, in many sections of these guidelines the species are treated together as this seems to be the most effective way of drawing attention to known similarities and differences between them, as well as assisting the reader in extrapolating where necessary from one species to another without excessive cross-referencing.

Taxonomy

Flamingos are among the most ancient of bird taxa. The fossil record shows the earliest forms of modern flamingos appearing 40 million years ago during an era of rapid evolution for birds as a whole. Despite the antiquity of the group, their evolutionary origins remain unclear. Sibley and Ahlquist (1990) provide an excellent summary of the attempts to classify the flamingos from the mid eighteenth century to the present. In their words “One of the most controversial and long-standing problems in avian systematics has been the relationships of the flamingos.”

Beginning with Linnaeus, morphology has always played a key role in categorizing flamingos. He placed them in the order Grallae which included spoonbills, storks, cranes, herons, and ibises -- birds with long necks and legs. In the nineteenth century, close relationships were suggested between flamingos and storks (Ciconiiformes), wildfowl (Anseriformes) and waders (Charadriiformes). Evidence for one of these links is not conclusive enough to dismiss the others. Flamingos have also been considered as a sub-order of Ciconiiformes, on the basis of anatomical similarities to storks (Ciconiidae) and ibises (Threskiornithidae), though egg-white proteins suggest a link elsewhere in the Ciconiiformes with herons (Ardeidae). The wildfowl link is suggested by behavior and feather-lice, while a comparative study with the Australian Banded Stilt (Cladorhynchus leucocephalus) led to the suggestion that flamingos be included within Charadriiformes (Olson & Feduccia, 1980). Each author had his own theories based on a few selected traits. These same affinities, however, were often used by others to argue for a different classification. For instance, webbed feet and feeding apparatus have been used to place flamingos with either Anseriformes or Charadriiformes. Internal vs. external parasites have them categorized with either Anseriformes or Ciconiiformes. Flamingo skeletal characteristics, internal organs, and feather details have similarities to the Ciconiiformes. Downy young, vocalizations, swimming behavior, and nest building techniques are similar to those found in Anseriformes. One author makes an argument for grouping flamingos with seriemas, secretary birds, and thickknees based on similarities in pelvic musculature, carotid arteries, and caeca. Even same taxonomists changed views over time and moved flamingos between groups depending on what characteristic were deemed most important at the time.

As time passed, the minutiae used to validate classifications became more detailed and included feather structure, details of musculature, presence or absence of skeletal details,
arrangement of feather tracts, downy young that can swim shortly after hatch, intestinal characteristics, blood vessel arrangements, etc. Several authors have suggested that some of these shared characteristics could be attributable to evolutionary convergence rather than speciation.

In recent years, two major conflicting taxonomies focus on paleontological vs. DNA evidence for their proposed phylogeny. Olsen and Feduccia (1980) use the traditional fossil, morphologic and behavioral characteristics to argue that flamingos are derived from a flamingo-like ancestor within the charadriiformes. Sibley and Ahlquist reject this in favor of DNA analysis of related groups that place the flamingos within the Ciconiformes.

In general, most taxonomists seem to agree that the flamingos belong somewhere between the ciconiiformes and the anseriformes with affinities to the Charadriiformes. Some place them in their own order as a compromise. However, the notion of phylogeny requires that taxa emerge from some older form and thus be the result of a splitting and subsequent divergence. Therefore, the issue of relationships to other taxa and lines of descendency remains unclear.

Despite taxonomic issues, it remains obvious that there are six different types of modern flamingo. Whereas Sibley and Ahlquist consider them closely related and place all six into a single genus Phoenicopterus, others continue to recognize the three traditional genera (Phoenicopterus, Phoeniconaias, and Phoenicoparrus). Some authors consider the Caribbean, greater, and Chilean to be subspecies of Phoenicopterus. Variations include the inclusion of the Chilean flamingo in Phoenicopterus ruber, and the inclusion of the lesser flamingo in Phoenicopterus. The greater flamingo has occasionally even been considered a separate species (Phoenicopterus roseus) (Walters, 1980).

Hybridization in captivity blurs the taxonomic distinctions even further. Hybrids have been produced in captive collections between Caribbean/greater, Caribbean/Chilean, Caribbean/Andean, Greater/Chilean, and greater/James’. Caribbean/Chilean and greater/Chilean offspring are known to be fertile with other Phoenicopterus (Shannon studbooks, pers. com. Adelheid Studer-Thiersch, Philipp Kessler). At the 1973 Slimbridge meeting, participants agreed (with the exception of Jean Delacour who preferred the single genera model) to the following nomenclature (Kear 1975):

- Caribbean (Phoenicopterus ruber ruber) -- also known as American, Cuban, Rosy, West Indian
- Greater (Phoenicopterus ruber roseus) -- also known as European, antiquorum
- Chilean (Phoenicopterus chilensis)
- Lesser (Phoeniconaias minor)
- Andean (Phoenicoparrus andinus)
- James’ (Phoenicoparrus jamesi) -- also known as Puna

Morphology

CARIBBEAN (or American or Rosy) FLAMINGO, Phoenicopterus ruber ruber

**Coloration:** Plumage is deep red-pink throughout, with the exception of the primary and most secondary flight feathers which are black (as in all species); darker and more orange than other flamingos; red deepest on wing coverts, palest on lower breast and belly. Long scapulars hang over folded wings onto flanks and tail. The bill is orange-
pink with black tip. The eyes are straw colored. Legs are grayish pink with joints and feet are brighter pink.

**Description:** Only slightly smaller than the greater flamingo, with the largest males standing approximately 1.6m high. As with all flamingos, males are larger than females, though there is some overlap in measurements and weight. The legs and neck are very long, the feet are webbed on three toes and the hind toe is reduced. The bill is deep and de-curved. Birds from the Galapagos are said to be slightly smaller and paler and have occasionally been considered as a separate race but this distinction is not generally recognized.

**GREATER FLAMINGO, *Phoenicopterus ruber roseus***

**Coloration:** The palest of the flamingos, the head, neck and body are white or pink; wing-coverts are red; primaries and secondaries are black. Legs are pink; bills are deep pink with black tip; and eyes are yellow.

**Description:** Similar in proportions to *P. r. ruber*. The largest individuals are slightly larger than *P. r. ruber*, but on average there is little difference in size between the two races. There may be more size overlap between the sexes in *P. r. roseus*.

**CHILEAN FLAMINGO, *Phoenicopterus chilensis***

**Coloration:** Plumage of head, neck and body is pale salmon pink, deeper on lower neck and upper breast. Scapulars and long back feathers are red, also the upper and lower wing coverts. Legs are gray with contrasting red-pink feet and joints. Bills have a more extensive black tip than *P. r. ruber* or *P. r. roseus*. The base of the bill is paler, almost white and the eyes are yellow.

**Description:** Shorter in neck and legs than *P. r. ruber* though otherwise only slightly smaller.

**ANDEAN FLAMINGO, *Phoenicoparrus andinus***

**Coloration:** Head, neck and upper breast are a deep mauve-pink, lower breast and back are paler pink mottled with red; wing-coverts are more heavily marked red. Remiges are black, more obviously so at rest than in other species, as not covered by back plumes. Legs are yellow; bill is black, pale yellow at base sometimes with pink flush on culmen; eyes are red-brown, with a small area of red skin on the lores.

**Description:** Similar in size to *P. chilensis*. No hind toe. The bill is more deeply keeled with a much finer filtering structure.

**JAMES’ (or Puna) FLAMINGO *Phoenicoparrus jamesi***

**Coloration:** Head and body are pale pink, neck often deeper pink. Upper breast is heavily spotted with red. Scapulars and wing-coverts are long, red-tipped, hanging over folded wings. Remiges, including inner secondaries, are black. Legs are orange; bill is yellow, tipped black, with red sub-terminal band on upper mandible; eyes are red-brown; lores are red and not feathered.

**Description:** Smaller than the preceding species but a little larger and stockier than the lesser flamingo. No hind toe.
LESSER FLAMINGO, *Phoeniconaias minor*

**Coloration:** Plumage is generally deep pink; wing-coverts are heavily mottled with crimson (feathers tipped crimson), crimson scapulars, black remiges. Bill is purplish, with black tip and red sub-terminal patch on lower mandible; eyes are bright orange-red; lores are purplish and not feathered; legs are dark red.

**Description:** The smallest flamingo.

It is generally agreed that the Caribbean flamingo is the nominate *Phoenicopterus* species. In historical zoo records, there is frequently confusion as to whether “greater flamingo” referred to Caribbean, greater, or both, especially in facilities which may have held both sub-species at some point in their history. It remains problematic that authors within the zoo community continue to incompletely identify the species with which they work. Even in the abstracts from the 1998 Flamingo Specialist Group Miami meeting, Caribbean is also called American and referred to as *P. ruber*, instead of the complete *P. ruber ruber*. In one paper, lesser flamingos are referred to as *Phoenicopterus minor*, presumably following the Sibley/Ahlquist model. The International Species Information System (ISIS) has long been a source of confusion for many species. The system is not intended to be an arbiter of taxonomic issues but is frequently used by the zoo community as the final authority. The database merely attempts to reflect the taxonomy in use by the zoo community.

**Voice**

Flamingos, particularly *Phoenicopterus* species, have loud, honking, goose-like voices and are extremely vocal. The calls of the lesser flamingo are much deeper and less strident.

**Longevity**

Flamingos appear to be among the longest-lived birds. Many captive birds are of unknown age but Studer-Thiersch (1998) records a female greater flamingo as not only alive but breeding successfully at 53, and eight birds in the same flock have lived to at least 44 (Johnson & de Boer 1984). In another instance, a Caribbean flamingo at Philadelphia Zoo died at 44 (Duplaix-Hall & Kear 1975). There are individuals of all species at Slimbridge which are at least 20 and probably 30 years old.

Longevity records for wild birds are held by greater flamingos ringed as chicks in the Camargue. One female was resighted feeding a chick 33 years and 10 months after being ringed at a few weeks old (Johnson & de Boer 1989), and birds at least 23 years old are not uncommon (Johnson & de Boer 1984). In January 1985, almost 3000 greater flamingos were collected dead following extreme weather. Of these, 155 were ringed, including seven birds over 27 years old. The two oldest were 28 years 5 months and 30 years 4 months (Johnson & de Boer 1986).
Field Data

Zoogeography/Ecology

Ecology/Biology

Despite their fragile, exotic appearance, flamingos forage and breed in generally inhospitable habitats. They exploit habitats ranging from tropical coastal lagoons to high altitude lakes, with occurrence tied directly to food resources. They occupy large shallow lakes or lagoons, which may be alkaline, with pH value of as much as 10.5, or saline, sometimes with more than twice the salinity of seawater (del Hoyo 1992). It is in these alkaline/saline waters that each species finds its preferred food resources; however, they also require fresh water sources for drinking. Frequently, fresh water is found at inlets to salt/soda lakes or in coastal estuaries.

Flamingos are probably best known for their colonial habits both while foraging and nesting. The spectacle of hundreds of thousands of birds congregating on the African Rift Valley lakes is one of the truly spectacular sights of the natural world.

As a group, flamingos are widespread. In the Old World, they range from India, across southern Europe and down to southern Africa. In the western hemisphere, flamingos cover the Caribbean and the southern half of South America. The James’ and Andean have the most restricted ranges with greateres being the most widespread.

Distribution (Ogilvie & Ogilvie 1986)

CARIBBEAN FLAMINGO, *Phoenicopterus ruber ruber*
- Bahamas, Cuba, Yucatan, Bonaire, Venezuela, Colombia. Feral in Florida. Apparently isolated population on Galapagos Islands.
- Breeds at four main sites: Greater Inagua, Bahamas; Rio Lagartos, Yucatan Peninsula, Mexico; Bonaire, Netherlands, Antilles; James Island, Galapagos, and sometimes other Galapagos islands. Birds from the Bahamas population also breed less regularly at Archipelago de Camaguey, Cuba; Acklins Island, Bahamas and in the Dominican Republic. There are regular and irregular seasonal movements from these breeding sites, with wintering flocks in the Bahamas, Cuba, Dominica and Haiti, around the coasts of the Yucatan Peninsula, and in Venezuela, Colombia and Surinam where birds from Bonaire spend the winter. Most breeding sites have some non-breeding birds present at all times of the year.

GREATER FLAMINGO, *Phoenicopterus ruber roseus*
- The most widely distributed flamingo, ranging from the western Mediterranean, where it occurs in Spain and southern France as well as in North Africa (primarily Tunisia, Algeria and Morocco), into West Africa, and in the eastern Mediterranean and eastward to Iran and the former USSR, India and Sri Lanka, and also in East and Southern Africa.
- The main concentrations are in the Camargue, Provence, France; Fuente de Piedra and Coto Donana, Andalucia, Spain; Chott Djerid, Tunisia; Banc d’Arguin, Mauritania; Djoujd, Senegal; Cyprus; Tuz Golu, Turkey; Lake Rezaiyeh, Iran; Lake Tengiz, Kazakhstan;
Rann of Kutch, Bombay, India; Lakes Elmenteita and Nakuru, Rift Valley, Kenya; Lakes Natron and Magadi, Rift Valley, Tanzania and Kenya; Makgadikgadi Pan, Botswana; Etosha Pan, Namibia; Lake St. Lucia, Natal, South Africa. Most of these are breeding sites though the list also includes some major wintering sites, and there are many more sites which are used by smaller numbers of birds, or which are used less regularly.

- Most breeding sites hold some birds throughout the year, but most populations are at least partially migratory, with some of the movement patterns being more or less regular. It is obvious from ring recoveries, however, that other movements also occur involving interchange between distant populations and more irregular patterns of movement. In the Camargue, for instance, up to 25,000 birds are present in the summer but birds start to leave in September and by December only a few hundred, or at most 2000-3000 are present for the winter. First-year birds ringed as chicks in the Camargue have been recovered in Spain, Portugal, Morocco, Algeria, Tunisia, Libya, Sardinia and Italy, and older birds have also been found in Mauritania, Senegal and Turkey. Young birds assumed to be from North Africa also frequently turn up in the Camargue before the Camargue (or Spanish) young have fledged. Chicks ringed in Iran have been recovered in India, Libya and Ethiopia in their first winter.

CHILEAN FLAMINGO, *Phoenicopterus chilensis*

- The most widespread of the three South American flamingos, ranging from the highlands of central Peru to Tierra del Fuego. Breeding occurs mainly on the Andean altiplano of northern Chile and western Bolivia, also southern Peru and northwest Argentina. Major sites include Lake Junin, Peru; Salar de Uyuni and Lakes Poopo, Loromayu, Colorada and Chalviri, Bolivia; Lake Pozeulos, Argentina and Salar de Surire, Chile. There are also at least two breeding sites at lower altitudes in Argentina. Non-breeding birds may be found at other, including coastal, sites. In some areas, regular seasonal movements occur; in others, the pattern is less clear and at least some birds may be resident.

ANDEAN FLAMINGO, *Phoenicoparrus andinus*

- The Altiplano of southern Peru, northern Chile, western Bolivia and north-west Argentina, using sites in the northern part of the range of the Chilean flamingo. One regular breeding site is known, at Salar de Atacama in Chile, with breeding also recorded at other lakes in Chile, Bolivia and Argentina, usually with Chilean and/or James' flamingos. Large-scale movements occur frequently, but no regular patterns have been documented.

JAMES' FLAMINGO, *Phoenicoparrus jamesi*

- Also restricted to altiplano salt-lakes, in southern Peru, western Bolivia and the north of Chile and Argentina. Previously thought to have a much more restricted distribution than andinus, but several range extensions have been recorded more recently. J. & C. Munoz (1975) observed and photographed two birds in Chubut Province, Argentina (with Chilean flamingos) but this is well outside the normal range. No breeding site was known to ornithologists until Laguna Colorada in Bolivia was visited in 1957 (Johnson et al 1958). Other breeding sites now known include Lakes Poopo and Chalviri, and Salar de Uyuni, also in Bolivia, Lake Vilama in Argentina, and in Chile at Salar de Surire, Salar de Tara (Conway in litt.), Aguas Calientes and Lagunas Brava. Hurlbert (1982) found
that this species occurred on average at higher elevations than *P. andinus*, though with considerable overlap.

**LESSER FLAMINGO, Phoeniconaias minor**

- Sub-Saharan Africa and India, often with greater flamingos. The largest flocks are found in the East African Rift Valley, particularly in the central section at Lakes Bogoria (formerly Hannington), Elmenteita, Nakuru and Magadi in Kenya, and Natron and Manyara in Tanzania, but also at Lake Rudolf in northern Kenya and Lake Abiata in Ethiopia, and farther south at Lake Rukwa in southern Tanzania and Lake Mweru in Zambia. Breeding takes place most regularly at Lake Natron, but has occurred at all these sites.
- In Southern Africa there are sizable concentrations, and breeding, at Etosha Pan in Namibia and Makarikari Pan in Botswana, and at other sites in South Africa, are also used regularly. There is one West African colony in Mauritania and one in the Rann of Kutch in north-west India. This is a regular breeding site for greater flamingos, but though lesser flamingos have been seen there with recently fledged young, nesting sites have yet to be found and may be in Pakistan (Palmes 19??). Birds are frequently recorded at the southern ends of both the Red Sea and Arabian Gulf, suggesting possible movements between the African and Asian ranges. Brown (1975) considered movements between the East and South African populations to be extremely unlikely, but Tuite (1979) believed that increased numbers at Etosha and Makarikari in the mid 1970's arose through migration from East Africa.

**Migration**

All flamingo species are highly nomadic with their movements apparently driven by food availability as opposed to the traditional notions of migration based on climatic changes. The greater flamingos in the Camargue region of southern France are one of the best studied populations with 15,000+ birds having been banded over the last 21 years. Along with banding projects in Spain, Iran, and Kazakhstan, 240,000+ resightings have expanded the knowledge of how far individual birds actually wander during their lifetimes (Johnson 1998). Since they are capable of such long distance movements (especially in their first five years of life), it has been proposed that greater flamingos be considered one large meta-population.

There is much less known about the movements of lesser flamingos. This is due in large part to the general inaccessibility of the breeding sites and the lack of long-term banding studies. Because of periodic rapid increases or decreases in some populations (especially the appearance of large numbers of young when no breeding was evident in the traditional nesting locations), it is suspected that the entire African continental population may be interconnected. The migratory routes are unclear but could include both direct north/south routes along the rift valley and a less direct west/south route which might explain the occasional disappearance of large numbers of birds. Since large migrations are seldom seen in daylight, it could be that they travel great distances at night to avoid daytime heat or to make use of celestial cues. Movements for African species appear to be a product of rainfall patterns that drive the prey production (and they somehow know how to follow the rains over great distances), dispersal of young, aggregation at breeding sites, and disturbance at feeding grounds. It was proposed at the 1998 Flamingo Symposium that a Pan-African survey be conducted in the year 2000 to help answer questions of population size and migration patterns.
As with the lessers in Africa, it is unclear how the various major population centers of the Caribbean flamingo might be connected. Despite previous banding projects in the Bahamas, it is not known how much, if any, movement there is between this population and those in Cuba, the Yucatan, and the southern Caribbean. The Galapagos group is quite likely an isolated population without contact with the Caribbean flocks. As with other species, movement of Caribbeans is tied to food resources.

In the Andes, movement of the James’ and Andean flamingos are restricted to high altitude lakes whereas Chileans seem to range much further and move from high altitude to lower altitude in search of food. Recent multi-country efforts to identify feeding and nesting sites for each species are beginning to shed light on the population numbers and movements of these species.

Habitat

Flamingos are “confined to shallow soda lakes and salt lagoons with a high pH (up to 10.5), usually barren of vegetation and surrounded by almost desert-like wastes” (Kear 1985).

The Caribbean flamingo is found on coastal mudflats and salt pans, including man-made salt works, while the greater flamingo occupies similar habitats but is also found at inland salt or alkaline lakes, some at quite high altitudes, e.g. lakes at apex. 2000m in Kenya and Lake Dasht-e-Nawar at 3100m in Afghanistan (Koning & Rooth 1975). In East Africa, the greater flamingo frequents less alkaline areas than the lesser flamingo, probably because of differences in diet, but both species regularly fly to fresh water if available to drink.

The Chilean flamingo is principally a bird of salt lakes, mainly at altitudes of 3500-4500m, but also frequents highland peat bogs and coastal mudflats. The Andean flamingo is found in the same highland habitats, while James’ flamingo is confined to altiplano salt-lakes, not moving out to feed in freshwater lakes and bogs as do the other two species (McFarlane 1975).

The lesser flamingo is found in similar habitats to the greater and is possibly even more tolerant of alkaline conditions. Lake Nakuru, the main display site for lesser flamingos, has a pH of 10.5 (Hopcraft 1975), whereas pH readings of 8.6 - 8.8 have been obtained at Lake Elmenteita, the main East African breeding site for greater flamingos (Brown 1958). Berry (1975) recorded pH at 9.2 while lesser flamingos bred at Etosha - greater flamingos having bred earlier when water levels were higher- however, both species are often found together, and Brown (1958) points out that pH varies widely both spatially and temporally within a single lake.

Diet and Feeding Behavior

All flamingos have feeding structures design to filter food from the mud and water. The larger species will also choose larger food items which are selected and swallowed, bypassing the filtering mechanism. Prey availability seems to be the main factor affecting occurrence of flamingos within a habitat.

Vilina and Martinez (1998) found that the presence of James’, Chilean, and Andean flamingos was correlated to food abundance within the wetland under study. Where the high Andes birds co-exist, they seem to exploit different food resources and thus do not compete. James’ were the most selective in terms of habitat and were associated with shallow highly saline lakes which are rich in diatoms and cyanophytes but poor in zooplankton. Chileans are found in deep
lakes with macrophytes and dense zooplankton with more diverse waterfowl communities present than at the shallow lakes. Andean flamingo populations were generally less dense than the others but typically found in lakes with intermediate characteristics (Caziani and Derlindati 1998).

Differential exploitation of food resources also holds true for the old world species. Greaters can feed throughout the water strata eating a variety of items including aquatic invertebrates, mollusks, insects, algae, and diatoms. Lesser flamingos, on the other hand, are largely dependent on blue-green algae (such as *Spirulina*) and diatoms and thus do not generally compete with greaters within the same habitat.

As in the high Andes, the concentration of birds in East Africa can be correlated with prey availability. Densities of blue-green algae, *Spirulina*, and benthic diatoms correlate to the density of lesser flamingos. The productivity and density of benthic diatoms is one to two orders of magnitude less than *Spirulina* and explains the much lower flock densities and more dispersed pattern at times when the population is dependent on benthic diatoms as its primary food resource (Tuite 1998).

**Food Preference**

Flamingos can be divided into two groups according to their diets: the *Phoenicopterus* species feed primarily on arthropods and mollusks, while the other species take algae and diatoms.

Important foods of the Caribbean flamingo include brine fly (*Ephydra pupae, Ephydra gracilis* at Bonaire), shrimps (*Artemia sp.*) and mollusks (*Cerithium lutosum, Gemma purpurea* and *Cerithidea costata* at Bonaire)(de Boer 1979). When these foods are not available at sufficiently high densities it will also feed on seeds of wigeon grass (*Ruppia maritima*) and tubercles of musk grass (*Chara sp.*) (Schmitz & Baldassarre 1992b) and will take amphipods and mollusks from *Ruppia* beds, and even fish when these are concentrated or disabled by falling water levels (de Boer 1979, Bildstein et al 1991). All species also obtain food by ingesting mud with a high organic content.

*Artemia* is also an important food for the greater flamingo in Europe (Britton et al 1986). In East Africa the copepod lovelula and chironomid larvae are the major foods. The chilean flamingo probably feeds on *Artemia*, chironomid larvae, amphipods and corixids (Hurlbert 1982).

The Andean flamingo takes diatoms and algae, particularly the large diatoms of the genus *Surirella* (Hurlbert & Chang 1983), while James' flamingo takes smaller diatoms and algae.

The lesser flamingo feeds primarily on blue-green algae, particularly *Spirulina platensis* in East Africa. At Etosha the dominant blue-green alga is *Anabaena sp.* (Berry 1975), with *Nodularia* and *Oscillatoria*, which is also present in some East African lakes. Diatoms are also taken, particularly *Navicula* in East Africa (Ridley et al 1955), which was also found at Etosha. Diatoms are thought to be a particularly important food in East Africa when *Spirulina* densities are unusually low (Tuite 1980).
Feeding Behavior

All flamingos feed mainly by filtering large numbers of their small food organisms from water or mud using their bills which are highly adapted for filter feeding. The *Phoenicopterus* species have "shallow-keeled" bills with which they take their animal prey from at or just above or below the surface of the substrate, either below water or in soft exposed mud. Of the "deep-keeled" species, *Phoenicoparrus* also feed largely at or near the mud surface, while *Phoeniconaias* feeds primarily near the water surface.

The bills of all species are held upside-down when feeding, and have "the lower jaw large and trough-like and the upper small and lid-like" (Jenkin 1957). All species also have spined or ridged tongues which act as pistons to pump food-rich mud or water through the bill and over the internal lamellae which trap food. In the shallow-keeled forms this filter network is relatively coarse, but deep-keeled species have the inner surfaces of the bill finely laminated, and lamellae at the edges to exclude large particles. In these species, the mandible is markedly keeled to fit into a "V" inside the maxilla, with the tongue running in a groove at the base of this "V".

*Phoenicopterus* "walk-feed", moving forward with the bill in the substrate, or "stamp-feed", treading on the spot to disturb food, and may also feed by upending while swimming. Walk-feeding is usually the most common technique (Hurlbert 1982, Bildstein et al 1991). Schmitz and Baldassarre (1992b) suggest that walk-feeding is more common where invertebrate food is plentiful, and stamp-feeding more common where food is in short supply and secondary food sources such as seeds and tubers must be exploited. This study was carried out following a hurricane which was thought to have made the (Caribbean) flamingos' usual food unobtainable. McFarlane (1975) observed Chilean flamingos at a salt lake walk-feeding in belly-deep water and stamp-feeding in shallow water.

Greater and Caribbean flamingos feed mainly at night (Rooth 1965, Studer-Thiersch 1972, Britton et al 1986). This last study, of greater flamingos feeding on *Artemia* in the Camargue, found that the prey was actually easier to collect in quantity during the day, and suggested that nocturnal feeding helped either with thermoregulation or the avoidance of human disturbance. Brown (1975) found greater flamingos to be less nocturnal than lesser flamingos in East Africa, which may suggest that disturbance is more important than thermoregulation.

The two *Phoenicoparrus* species often feed at the same lakes and with Chilean flamingos. Competition is avoided through differences in food preference, bill adaptation and feeding behavior. *P. andinus* takes diatoms over 0.8 mm in length, while *P. jamesi*, with more closely-spaced lamellae, takes items under 0.6 mm (Hurlbert 1982). Hurlbert found upending to be a common technique only in the Andean flamingo; walk-feeding was the principal method with all three species, the Chilean at 40-60 steps/minute, Andean 20-30 and James' 10-15. McFarlane also found both *Phoenicoparrus* walk-feeding with Chilean flamingos in deep and shallow water and on exposed mud.

The lesser flamingo feeds by holding its bill at the surface of the water with the mandibles partially submerged to a depth of about 3 cm. The bulbous and cellular lower mandible may act as a float to help maintain a constant feeding depth in turbulent water (Ogilvie & Ogilvie 1986). Spaces between the excluder lamellae are 1.0 x 0.4 mm and between the finest inner lamellae are only 0.01 x 0.05 mm. In East Africa feeding takes place mainly at night, probably because water conditions are usually calmer then (Brown 1975). Birds regularly swim while feeding and
are thus able to use the whole area of the lakes, while greater flamingos at the same lakes feed only around the edges (Brown 1975). Brown (1958) observes that both greater, and particularly lesser flamingos, regularly go to sources of fresh water to drink and bathe, but Berry (1975) found both species, and particularly lessers, breeding successfully without access to fresh water.

Reproduction

The flamingo breeding cycle is well known and is dependent on appropriate available nesting site, temperature, and rainfall. The typical breeding cycle consists of group display, nest building, egg laying, and hatching. Since initiation of breeding seems to be dependent on these sometimes unpredictable environmental conditions, the group display presumably serves to quickly synchronize reproductive condition so that a large number of birds are in the right physiological state to nest together at the same time.

Flamingos living in areas with clearly defined seasons usually breed in spring (France, Spain) or during or after the rainy season (e.g. Etosha pan Namibia, Simmons 1996, Sambhar Lake India, Johnson 1998). High Andes species breed in January and February when temperatures are the highest. Species living in areas with constant weather can initiate breeding attempts throughout the year. Flamingos may become reproductively active as a result of an increase in rainfall which changes food quality or abundance and induces or increases flooding of the areas around breeding islands.

Traditional breeding sites are well known for some species, probably due to their consistently appropriate conditions (e.g. Lake Natron, Sua Pan, Etosha Pan in Africa, Camargue in southern France, etc.). In many other areas, breeding sites develop randomly when the conditions are suddenly appropriate.

Seasonality

The timing of breeding may depend on a number of factors, some of which are poorly understood. The greater flamingo, in the northern parts of its range, would find it impossible to breed through the winter; but in other places, and for some other species, breeding may depend on less seasonal variations in water level and chemistry which affect food supply and the availability and suitability of nest sites and material. The number of birds present may also be important, and even when all known factors appear to be favorable breeding may not take place.

In the Caribbean flamingo breeding is erratic and only loosely seasonal at some sites; on Bonaire breeding often begins in December or January, but in some years also commences in March, April, May or July, or may not occur at all (Rooth 1975, de Boer 1979).

Egg-laying in the greater flamingo has occurred in mid-February in Tunisia, early May in the Camargue, and late May in Iran and Mauritania. In East Africa it is less seasonal, at Lake Natron egg-laying usually occurs in October and November, but also in February; and at Lake Elmenteita, laying has been recorded in every month but September, December and January, with primary laying occurring in April, June and July (Brown 1975). In southern Africa, breeding is linked to seasonal rains and has occurred from February through May at Etosha (Berry 1975) and between October and April in South Africa (Broekhuysen 1975).
For the Chilean flamingo Munoz & Munoz (1975) report regular seasonal breeding in Argentinean Patagonia with laying in mid-November. Egg-laying has occurred between March and June in northern Chile (McFarlane 1975), where Conway (in litt.) found James' flamingo breeding in January. In Bolivia, Johnson et al (1958) also found *P. jamesi* breeding in January and Hurbert (1982) found birds incubating in mid-December.

In the lesser flamingo in East Africa seasonality is not marked; eggs have been laid at Lake Natron in January, February, March, June, July, August, October, November and December (Brown & Root 1971), but breeding peaks in October and November (Brown 1975). In Mauritania, breeding has been recorded in July (Trotignon 1975) and at Etosha starting in May, with laying continuing until July (Berry 1975).

**Nest**

The nest is similar in all flamingo species. It consists of a mud mound with a cupped top. The nest is built by both sexes, although building is often initiated by the male. Most building is performed by a bird sitting or standing on the nest drawing up material with its bill, though its mate may add material while standing beside the nest. Building may start several weeks before laying. Studer-Thiersch (1975a) examines the roles of male and female in nest-building and related behavior in a captive colony of greater flamingos.

In suitable conditions the nest may be over 30 cm high, though it is usually much lower at laying, with building continuing into and sometimes throughout incubation if suitable material is available. In some situations the mound may be important in providing protection from flooding; in others, it provides shelter from the very high temperatures sometimes experienced at the surface of the surrounding mud. Nest-building is not always followed by breeding.

Brown & Root (1971) found that lesser flamingo nest mounds varied from six to 40 cm high with basal diameter apex. 40 cm and the depression on top seven to nine inches across. The smaller nests were built from soda crystals, while the larger ones were built where mud was available. Temperature was found to be significantly lower at the top of the nests than on the surface of the surrounding mud or soda, where conditions were far too hot for successful incubation. Broekhuysen (1975) found that two samples of greater flamingo nests averaged 10.3 and 7.6 cm high, with the mean cup diameter 33.5 cm in both cases. Mean basal diameter of the lower nests was 44.4 cm.

In the greater flamingo at least breeding may occur where mud is not available, in which case the nest may be a low rim of stones and any other available debris around a shallow scrape or eggs may even be laid in natural depressions on bare rock (Scott 1975).

Flamingos are highly colonial when nesting. In South Africa several very small colonies of greater flamingos have been reported (Broekhuysen 1975), and even a successful single nest (Middlemiss 1961). Caribbean flamingo colonies on the Galapagos Islands may also consist of as few as five pairs, but colonies consisting of thousands, or in the case of the lesser flamingo sometimes hundreds of thousands, of nesting pairs are more usual. These colonies may include virtually all the birds in the area, but often the breeding birds form only a small proportion of a much larger concentration. In all species nest densities within colonies may be very high. Brown & Root (1971) noted two types of nest grouping, dictated by ground conditions. Where the mud was suitable nests would be built in clusters with five nests/m², but where the mud was covered with a hard coat of soda nests would be arranged linearly along
cracks in this coating. The breeding area was large but consisted of numbers of smaller colonies with spaces between.

Eggs

The egg in all species is a rather elongated and symmetrical oval, white or pale blue with a white chalky coating. On mud nests the egg quickly becomes heavily soiled. The yolk is deep red or orange in color. Egg dimensions are given in Reproduction, Chapter 4, Table 5.

Laying

Generally closely synchronized within a colony of several thousand birds, with late eggs often being deserted when the bulk of the birds leave the nesting area with their chicks. The dropping of eggs onto the mud around colonies is not unusual (Brown & Root 1971). The female leans forward on the nest to avoid depositing the egg over the rim (Studer-Thiersch 1975a).

Clutch Size

The normal clutch is one in all species. In studies of a number of species frequencies of two-egg clutches have been found to be 0.2-2.0%, but in no case is it known whether these clutches result from one female laying two eggs, or from two females laying in the same nest. In captivity, at least some two-egg clutches are known to originate from two females (Studer-Thiersch 1975a).

Incubation

In the lesser flamingo the incubation period is 28 days (Brown & Root 1971), 28-30 days for all other species. Incubation is shared by both sexes. Incubation shifts are variable in length, in some cases linked to the distance which the "off-duty" bird needs to fly to find food. Most authors report peaks of shift-change in the morning and late afternoon, but Brown (1958) notes decreasing regularity as incubation advances in the greater flamingo. There is no elaborate behavior at changeover. Birds arriving at the nest shake mud and water from their feet before commencing incubation.

Hatching

Flamingo chicks may call loudly, often some time before the egg is pipped externally. Hatching usually takes 24-36 hours from external pip.

Brown & Root (1971) estimated hatching success at two lesser flamingo colonies to be 85-90% and 70-80%, with failure being caused by desertion of late eggs, laying of eggs out of nests, eggs falling from nests or being lost in cracks through the collapse of nests, as well as predation.

Development

Chicks of all species hatch with pink or red legs and bills and white or pale gray down, and with eyes open. The chick stays on the nest for approximately five to eight days and is fed on crop
milk by both parents, and brooded by either parent for most of this time. Chicks often eat large quantities of eggshell in the first two days if this remains in the nest.

Crop milk is a glandular secretion which is passed from the bill tip of either parent into that of the chick. In a captive greater flamingo it contained 15% fat, 8-9% protein and 0.1-0.2% carbohydrate (Studer-Thiersch 1975a). It is initially dark red and later pink.

On leaving the nest chicks can walk and swim, and are initially attended by one or both parents and may return to the nest (if accessible) to be brooded, but later form large groups attended by small numbers of adults, though parent birds arrive regularly to feed their own chicks. Chicks may begin to exhibit feeding behavior at two weeks, and may be able to feed themselves effectively from about a month old (Sprunt & Crego-Bourne, 1975), but are usually fed at least partly by their parents until fledging at 75 days. The bill is straight and shallow on hatching, gradually acquiring the typical deep, down-curved shape up to fledging.

The first, pale gray down is replaced by a darker gray down at about two weeks. Legs and bill turn black within the first week. The juvenile plumage is gray marked with darker brown, and is developing noticeably by 30 days, with the body feathering complete at 50 days. There is some pink suffusion in the juvenile plumage, particularly in those areas which are brightest in adults.

The lesser flamingo chick is unable to stand for 24 hours. On the second day it can stand but remains on the nest. From the third day it will leave the nest if disturbed, but will otherwise not do so until the fifth or sixth day, as it cannot climb back onto the nest before this. Chicks leaving the nest early may come to no harm if the substrate at the base of the nest is reasonably solid, but they cannot cope with thick slushy mud. Large groups of chicks begin to form from about eight days. These may number hundreds of thousands, but break up into smaller groups at regular times of the day, probably returning to the vicinity of their hatch sites to meet their parents for food. Fledging takes 65-90 days, in good conditions usually 65-75 days. The natal down is on average darker than in the greater flamingo, and the bill is black-tipped. The legs turn black at about six days, and the bill, which begins to curve quite early, also becomes black. The bill has a pronounced curve by 20 days. The darker second down appears at about two weeks, to be followed by a juvenile plumage which is darker than that of the greater flamingo (Brown & Root 1971).

Greater flamingo chicks observed by Brown (1958) could move out of the nest at two to three days (but the nests were low at the colonies studied). Unwilling to take to water until 12 days, they formed large groups from 14 days. Legs were dark pinkish brown by five days and black or dark brown by seven days. Groups of chicks revisiting nesting areas ate eggshell and shell membrane and were seen stamp-feeding. Wing-flapping was frequent from 60-70 days with fledging at 75-78 days. Feeds increased in length and decreased in frequency as chicks grew. Feeds on the nest lasted 5-15 seconds, just before fledging feeds lasted 11-18 minutes.

Adults may fly daily to feeding sites up to 90 km away from the breeding sites, and chicks are often fed early in the morning and again in the evening (Brown 1958, Munoz & Munoz 1975, de Boer 1979).

Chicks may also move long distances. Berry (1975) describes an 80 km trek by a large group of lesser flamingo chicks following receding water at Etosha.
Sexual Maturity

Full adult coloration is usually attained at three years in all species, but this can be variable, and sexual maturity and the age of first breeding are not necessarily closely linked to plumage and leg color. In captivity Caribbean flamingos have been recorded breeding at two years (Duplaix-Hall & Kear 1975) and Berry (1975) records lesser flamingos breeding in immature plumage in Namibia. Nest-building by immature birds is commonly seen in captivity and has been recorded in the wild (Broekhuysen 1975). Captive-bred Chilean flamingos at Slimbridge first breed between two and 10 years of age (mean = 4.8 years, S.D.= 2.8 n= 15, Pickering 1992).

Behavior

Activity

In most species there seems to be a reduction in feeding and a corresponding increase in resting and comfort behaviors during the middle of the day (Brown 1971, Britton et al 1986, Bildstein et al 1991), though this is also the time of peak display activity (Brown 1971).

Locomotion

Flamingos are strong flyers. As well as long-distance migrations, birds at some colonies make long flights daily from breeding to feeding sites. They fly with their necks and legs extended. Take-off is achieved by running on land or on the bottom in shallow water. Take-off from or landing onto deeper water is uncommon. Flamingos walk on land or in shallow water, and can swim very well in deeper water. The lesser flamingo swims more regularly than other species.

Predation

In the larger species predation of healthy adults is probably rare, and predation of eggs and chicks is largely by avian predators, as the environment at breeding sites is usually inhospitable or inaccessible to mammals.

In greater flamingo colonies in East Africa, marabou storks (Leptoptilos crumeniferus) cause major losses of eggs and chicks. In some cases flamingos react aggressively to marabou storks and are successful in defending eggs or chicks, but in others the presence of small numbers of storks can cause mass desertion of breeding colonies. Great white pelicans (Pelecanus onocrotalus) also affect breeding by competing successfully for nesting islands, but are not direct predators. The African fish eagle (Cuncuma vocifer) takes chicks and tawny (Aquila rapax) and steppe eagles (Aquila nipalensis) take eggs, but principally following disturbance by other predators. The eagles also take chicks but mainly as carrion (Brown 1958). In South Africa, the water mongoose (Atilax paludinosus) took 50% of the chicks at one colony (Broekhuysen 1975).

Herring gulls (Larus argentatus) are major predators of eggs and chicks at the Camargue colonies, where they will work on the ground, sometimes in pairs, pecking at the leg joints of incubating birds from behind to make them stand so that nests can be robbed, and will even hover over nests inciting sitting birds to make threat displays and then lift them off nests by the
bill. If wind conditions are not right for hovering they may use a similar technique on the ground at the edges of a colony. As many as half the eggs laid in the Camargue may be predated by gulls.

Little is known about predation in South America. McFarlane (1975) lists potential predators at a site in Chile but found no evidence of predation.

Adult lesser flamingos are regularly taken by African fish eagles and possibly other eagles in East Africa, and by marabou storks, while mammalian predators include lions (*Panthera leo*), leopards (*Panthera pardis*), cheetahs (*Acinonyx jubatus*), jackals (*Canis sp.*), ratels (*Mellivora capensis*) and particularly spotted hyenas (*Canis crocuta*). The level of predation however is not thought to be high, though disturbance by mammals such as hyenas can cause large-scale panic and desertion of nests.

Breeding sites are usually inaccessible to mammals but eagles and vultures are also predators of chicks and eggs. In East Africa vultures may also take adults. The Egyptian vulture (*Neophron percnopterus*) is the most serious egg predator, but lappet-faced vultures (*Torgos tracheliotus*) and white-headed vultures (*Trigonoceps occipitalis*) more frequently take chicks and adults. Lesser flamingos are more persistent in defense of their eggs or chicks than are greater flamingos, and are sometimes capable of driving away Egyptian vultures, but may be killed by the larger vultures if they take persistence too far; however, the soft substrate around many of the breeding colonies makes them inaccessible to the larger vultures (Brown & Root 1971).

### Social Behavior

Flamingos are highly gregarious at all times of the year. Territoriality when breeding is confined to the immediate area of the nest. Antagonistic behavior consists of raising the scapulae and back-feathers in an imposing chrysanthemum-like effect, accompanied by HOOKING, in which the neck is stretched forward but the bill held down so that it points backwards; or in higher-intensity threats, by NECK-SWAYING where the head is waved at an opponent with bill gaping. A recent study of non-breeding Caribbeans found that adult males initiated and won more aggressive encounters than females and juveniles flamingos (Schmitz and Baldassarre 1992a).

### Sexual Behavior

Sexual and social behavior are closely associated in flamingos as the displays which precede breeding are performed in large groups. This helps with the synchronization of breeding, ensuring that all birds breed when environmental conditions are most favorable, probably in relation to food supply, but with the additional benefit that predation of eggs and chicks is almost certainly lower that it might be if breeding was spread over a longer period.

Displays are performed by both sexes, but are usually initiated by males. Male and female displays are similar, but display by males is often more intense and protracted than that by females. Ritualized behavior is "contagious", with a particular display by one bird being followed by similar displays from others. Display may precede breeding by months (or may occur after breeding) and may occur at sites where breeding does not take place. In lesser flamingos at least, the number of birds present may be significant in triggering display (Brown & Root 1971), but display may not involve all birds in a large concentration, and only some of the birds that do display may go on to breed.
Population

Population Trends in the Wild

Estimating population numbers for wild flamingos has always been problematic because their generally remote and inaccessible haunts are frequently spread over vast geographic areas. The difficulty of counting is compounded by the bird’s ability to travel great distances in short periods of time. The general consensus is that, in many parts of the world, flamingos are at risk due to loss of feeding and breeding sites and, as it becomes more difficult for them to breed successfully, populations are destined to decline.

At the time of the Slimbridge Symposium in 1973, the best population estimates for all species were compiled by Kahl (Kear 1975). At that time, the numbers were:

<table>
<thead>
<tr>
<th>Species</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caribbean</td>
<td>60,500</td>
</tr>
<tr>
<td>Greater</td>
<td>790,000</td>
</tr>
<tr>
<td>Chilean</td>
<td>500,000</td>
</tr>
<tr>
<td>Lesser</td>
<td>6,000,000</td>
</tr>
<tr>
<td>Andean</td>
<td>150,000</td>
</tr>
<tr>
<td>James’</td>
<td>50,000</td>
</tr>
</tbody>
</table>

The best current population numbers for any species come from a comprehensive multi-country survey of flamingo sites in 1997 and 1998 in Bolivia, Argentina, Chile and Peru. In this study, the authors came up with high counts of 63,143 for James’ and 33,927 for Andean (Valqui, M. 1998). This would be a significant contrast to Kahl’s estimates of 150,000 for Andean and 50,000 for James’.

Recent estimates of five million for lesser flamingos in east and southern Africa (Arinaitwe 1998) seem to be consistent with historical numbers. So, considering the extent of the species’ range through the middle east and southern Asia, it is likely that Kahl’s estimate of 6,000,000 is probably still accurate.

Allen chose 95,000 for Caribbean historically with a reduction to 21,500 by 1955. Kahl’s estimate of 60,500 may be low considering the recent estimated counts of 25,000 in the Yucatan and 37,000 on the Venezuelan coast (Arengo et al 1998, Espinoza 1998) in addition to the estimate of 60,000 birds on Inagua in the Bahamas. Lacking data from Cuba, it still seems plausible that the species may well exceed Allen’s historic estimate.

Current estimates for Chilean flamingo populations are also problematic due to the extent of their range and difficulty of access to many areas. Recent estimates of 200,000 are more likely than Kahl’s estimates of 500,000 but it remains difficult to verify numbers.

Because of their wide distribution across three continents and numerous political boundaries, the size of greater flamingo populations are also difficult to estimate. Specific populations are very well known and numbers seem to be consistent from year to year as long as conditions are appropriate. Overall, 750,000 to 790,000 (Kahl’s number) are probably realistic.
Current Captive Populations

It is a bit easier to judge population numbers of captive flamingos than it is their wild counterparts. The numbers for North America are probably the most accurate due to the extent to which membership in ISIS has saturated the region along with the presence of studbooks for all species. Nearly all significant collections are accounted for via those two repositories of data. The populations in Europe are most certainly under reported in ISIS but over time, as more facilities participate, better estimates will be available. A recent survey of European collections indicates that the region holds at least a third more birds than North American facilities (King, pers. comm.) Data from Africa and South America is sketchy at best, and there are large groups of flamingos in Asia which are not represented in the ISIS database.

The worldwide captive populations documented in either the North American Regional Studbooks or the ISIS database for each species through the end of the 20th Century are:

<table>
<thead>
<tr>
<th>Species</th>
<th>North American</th>
<th>European</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regional numbers</td>
<td>Regional numbers</td>
</tr>
<tr>
<td>Caribbean</td>
<td>~1800</td>
<td>~1500</td>
</tr>
<tr>
<td>Greater</td>
<td>~200</td>
<td>1400 +</td>
</tr>
<tr>
<td>Chilean</td>
<td>1800 +</td>
<td>~3000</td>
</tr>
<tr>
<td>Lesser</td>
<td>~600</td>
<td>~430</td>
</tr>
<tr>
<td>Andean</td>
<td></td>
<td>~90</td>
</tr>
<tr>
<td>James'</td>
<td></td>
<td>~25</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>~500</td>
</tr>
</tbody>
</table>

Total regional numbers in the databases (for Europe, total is from the survey and does not represent ISIS data):

<table>
<thead>
<tr>
<th>Region</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>4400</td>
</tr>
<tr>
<td>Europe</td>
<td>6869</td>
</tr>
<tr>
<td>Africa</td>
<td>413</td>
</tr>
<tr>
<td>Asia/Aust</td>
<td>761</td>
</tr>
<tr>
<td>South America</td>
<td>87</td>
</tr>
<tr>
<td>Total</td>
<td>12,530</td>
</tr>
</tbody>
</table>

It is likely that undocumented birds would bring the worldwide captive population to an estimated 13,000 to 13,500 individuals.

The existence of studbooks makes the North American population the easiest about which to make broad statements. Flamingos have been found in North American collections since at least 1899. Until the mid 1960’s, none were held in significant numbers and many collections held a few specimens of several species. The first captive reproduction occurred at the Hialeah Race Track in 1937 but it was not until 1953 that a second facility hatched a chick. It took an
additional twenty years before a significant number of collections began successfully raising offspring.

Rapid expansion of the North American populations thirty years ago represented significant importation of birds over a period of a few years as opposed to improved reproduction. The development of animal oriented theme parks beginning in the mid 1960’s through the early 1970’s accounts for the increase in Caribbean flamingo numbers. When U.S. legislation afforded Caribbeans more protection, Chilean flamingos became the most readily available alternative for filling exhibits. The government of Argentina put restrictions on Chilean flamingo exports in the mid 1980’s and lesser flamingos then became and remain the most easily acquired species for importation. Greaters have never been common in U.S. collections. Their increase in the mid 1980’s was due largely to confiscation of birds being illegally imported. At this point in time, Chileans (1800+) are the most numerous species in our collections followed by Caribbeans (~1800), lessers (~600), and greaters (~200).

In Europe, Chileans (~3000) are also the most common species, followed by Caribbeans (~1500), greater (1400+), lessers (~430), Andean (~90), and James’ (~25). These numbers are approximate to account for the non-responding facilities to the King survey.

Despite recent increases in reproduction for all species, only Caribbeans are approaching self-sustaining status in North American collections. Facilities holding Chileans are seeing increased success. Lessers are only just beginning to be bred. Greaters occur in such small numbers that they are unlikely to ever be sustainable. Although birds are probably capable of reproducing at three years of age, stimulating reproduction of captive flocks remains problematic and frequently birds do not begin to breed until they are much older. The same problems with reproduction occur in the European collections. As the populations age, without greater breeding success, there is likely to be a significant decline in all species in the next 10-15 years since importation of wild birds in both regions have been largely reduced and are having a minimal impact. A majority of captive birds worldwide have not been sexed.

Population estimates vary widely for most species. In some cases, this difference is because of counting problems caused by the mixing of two or three species at the same site. In others, it is because of the combination of irregular large-scale movements with the lack of coordinated counts at known sites and the likely existence of unknown sites. The variation between estimates makes the identification of trends very difficult, but the Caribbean flamingo is the only species thought to be increasing (in relation to population levels 30 years ago, but still lower than those 200-300 years ago (Allen 1956)).

Earlier estimates of Chilean flamingo populations have been higher, even as high as 1,000,000 (Cordier 1968), but it is not certain whether current figures represent a decline or inaccuracies in past or present estimates. The Andean flamingo has almost certainly declined markedly in recent decades for reasons which are unclear. Lower recent estimates are unlikely to be due to undercounting as the known range and population estimates for James’ flamingo, which occurs at many of the same sites, have increased during the same period.

Conservation Status

The available breeding and feeding sites for flamingos around the world are decreasing in size and quality due to many factors. As ecological specialists, flamingos are very vulnerable to even
subtle changes in the environment, but they are also very quick to adapt when new appropriate conditions appear where they did not occur previously.

Fluctuation in water levels from both natural patterns of weather instability and man-made alterations can have a variety of effects on nesting sites and food resources. Changes in the hydrology of wetland areas are often a by-product of dams and reservoirs. Rising water levels can either flood existing nest sites or create new ones. Falling water levels frequently degrade existing nest areas or expose the sites to increased predator access (including natural predators, dogs, cats, and humans). Reclamation of wetlands for agriculture by expanding human populations reduces feeding and drinking sites. Although salt/soda production plants may become useful feeding sites for birds, the associated intrusion from roads, fences, power lines, human population growth, etc. can negate any positive impact from the industrial activities. Complete loss of water resources via desertification is sometimes a result of removal of forest for firewood and cattle grazing.

In addition to alterations to the physical environment, changes in water level and quality also affect salinity and thus prey production. The more specialized flamingo species are most at risk from changes in food resources resulting from changes in water quality. This, in addition to drain off of pesticides, heavy metals, mining activities, and industrial chemicals from increased human activity can significantly alter the ecology of feeding/nesting sites. Pollution in and of itself may be more significant in terms of its affect on food resources than a direct impact on the birds -- if the food is not there, the birds won’t be either. It is also unclear how the flamingos themselves affect the ecology of the water resources on which they depend. Due to the enormous biomass that flamingos represent in their environment, it has been suggested that a reduction of flamingos in Botswana and Mauritania could impact the blue-green algae bloom and possibly disrupt the health of the entire ecosystem of these areas.

Hunting and egg collecting has a significant effect on nesting colonies in the New World but does not generally seem to be a factor in the Old World except in parts of eastern range where nest areas are more accessible or areas on the African continent embroiled in civil unrest. Ingested lead shot was identified as a major factor in a die off in the Yucatan following Hurricane Gilbert in 1989 but use of lead was subsequently banned (Arengo 1998). Disease does not seem to be a significant factor in flamingo populations.

Despite the negative impacts on flamingo populations from resource exploitation for human use, there are management techniques that can be employed which seem to facilitate co-existence. In several parts of the world, salt production has been managed to the benefit of flamingos, but even when the salt pans are managed for flamingos, they leave when the food is depleted. Modification of water control projects could be beneficial for both people and birds. The Ramsar Convention, Convention on Biological Diversity, and Convention on Wetlands of International Importance attempt to protect wetlands of global importance benefiting flamingos along with the many other species that are dependent on these sites. Work in the Camargue has shown that by artificially managing water levels and restoring/maintaining nest sites, birds can be encouraged to recolonize previously abandoned sites.

The recent cooperation between agencies across country borders in South America has resulted in tremendous increases in the knowledge of population numbers and ecology of the high Andes flamingo species. The proposed Pan-African survey will help address issues of migration and population numbers on that continent. Lack of information on greater and lesser flamingos in the eastern part of their range might be due to a lack of personnel, interest, or
money. Development of contacts in those regions could facilitate the sharing of information and/or deployment of resources for both basic data collection and education.

Tourism in all areas can help local economies but can easily disrupt flamingo populations when appropriate controls on access are lacking. Lake Nakuru in East Africa has long been a regular stop for tourists on safari but pollution from agricultural activities around the park may be affecting the water quality and thus food production for the birds. At Laguna Pozuelos in Argentina, a survey over a five year period indicated that 98% of the visitors came to the lake exclusively to see the three flamingo species, with 70% of foreign origin. There are concerns that growing tourism is beginning to degrade the local natural resources and education is necessary, not only for visitors, but for locals who depend on the visitation in order to maintain sustainable use (Clark et al 1998). In the Yucatan, an increase in boat tours to view flamingos over the past ten years decreased flamingo feeding time by 60%; however, by educating the tour operators and with some modification to the way in which boats approach the birds, the disturbance has been all but eliminated, thereby improving the experience for the visitors with seemingly little impact on the birds (Arengo et al 1998). Low flying aircraft providing a spectacle by scaring birds into flight has been a problem historically in some locations (Bonaire, Camargue, East Africa), but this practice appears to be less prevalent now.

A global action plan for flamingos is being developed following the 2nd International Flamingo Symposium held in October 1998. Zoo based Taxon Advisory Groups (TAGs) in both North America and Europe are developing regional collection plans to improve management of captive populations. Facilities holding flamingos have the opportunity to help flamingo conservation through public education, basic research on biology, and raising funds to support conservation efforts in countries where flamingos occur. For current and proposed research, see the Research Chapter.

None of the flamingos are seriously threatened, but all are essentially vulnerable because of the kinds of ecosystems they inhabit. These are characterized by high productivity and low biodiversity, and are thus very susceptible to damage through environmental change. Flamingos are highly adapted to these ecosystems and are poorly equipped to survive in other environments. The irregularity of breeding and occasional mass mortality in many flamingo populations is an indication of the already marginal suitability of their usual habitats and their narrow tolerance of change in these habitats. The greater flamingo, for instance, is numerous and has a large range, but few of the sites at which it occurs regularly provide suitable conditions for breeding.

Habitat loss through human activity does threaten flamingos in a number of areas. The number of breeding sites for Caribbean flamingos has declined from possibly 35 to around five, though on Bonaire the development of a salt works at one of these five has not been the disaster that it might have been through enlightened cooperation between commercial interests and conservationists (Rooth 1965, 1975), though de Boer (1979) sounds a note of caution regarding the need for monitoring and management of environmental change in the future. Caribbean flamingos in Inagua and Yucatan, and greater flamingos in the Camargue, have also been affected by, and now depend on favorable management by, the salt extraction industry (Sprunt 1975, Johnson 1975).

For all flamingos the presence of a good food supply and the occurrence of suitable conditions for nesting often depend on the maintenance of water levels and salinity or alkalinity within narrow limits. The occurrence of favorable conditions is often naturally cyclic or sporadic and dependent on levels of rainfall, which of course affect not only water levels but also salinity and
alkalinity. Flamingo sites around the world are threatened by or vulnerable to human management of water levels for agricultural, industrial or domestic water supply, and are also at risk from pollution (Hopcraft 1975).

Hunting may also still be a potential threat to some populations. Several species have been harvested for food as eggs or adults over a long period (Ogilvie & Ogilvie 1986) and at a few locations these practices continue, in some cases in breach of legal protection. In general, this is not at a level which threatens populations, but in Bolivia special measures were introduced in 1987 to stop the taking of eggs of James’ flamingo at Laguna Colorada (Johnson & de Boer 1988). The increased demand for food arising from the development of mining settlements in the Andes poses similar threats at other sites.

The taking of flamingos from the wild for zoos and other collections has greatly reduced in recent years, but the two African species at least are still regularly collected in Tanzania, and young birds of both species said to originate from chick rescue operations on drying salt pans have been offered for export from Botswana.

Disturbance has been a major problem at a number of sites (Brown 1958, Brown & Root 1971, de Boer 1979, Hopcraft 1975), particularly disturbance by aircraft. Light aircraft carrying tourists eager to see flamingos are sometimes flushing birds deliberately to improve the spectacle have repeatedly caused breeding failures by disturbing nesting birds. At a number of locations, including Bonaire, the Camargue and East Africa, restrictions have been introduced to control the use of airspace over colonies, though enforcement can be a problem (de Boer 1979). Susceptibility to disturbance varies between species and locations and also with the activity patterns of the birds. Greater flamingos in some East African Lakes are used to regular high-altitude traffic but may be disturbed by low-level flights. When breeding, their reaction to disturbance, whether by aircraft, humans on foot or in boats, or avian predators, varies according to the stage of incubation or age of chicks (Brown 1958). Lesser flamingos breeding at Lake Natron were not unduly disturbed by a light aircraft circling at apex. 150m, but non-breeding birds on the same lake would take flight when flown over at 300 or, in one case, 600m (Brown & Root 1971). Caribbean flamingos on Bonaire may desert sites before or during breeding in response to quite a low level of disturbance by humans on foot, but birds from the same population may tolerate much greater disturbance at feeding sites in Venezuela. Flamingos can be an important resource for eco-tourism, but can also be very difficult to exploit (de Boer 1976).

References


Management of Flamingos in Captivity
Chapter 2

Housing and Enclosure Requirements
Facilitator: Kim Smith, Milwaukee County Zoo

Introduction

Unfortunately, most current exhibits are open-air enclosures creating the need for the birds to be rendered flightless to prevent escape. Most common methods for restricting flight are pinioning and wing feather clipping. It has been shown that reproduction is severely hindered by pinioning, due to the male’s difficulty in balancing himself during copulation. The recommendation is to keep flamingos full-winged and design new exhibits to accommodate a full-winged flock. Sadly, there are very few exhibits that are designed for full-winged flocks. There are advantages to keeping full winged or pinioned birds in an aviary. These include minimal threat of predation, reduced food stealing by gulls and mallards (Crieighton & Stevens-Woods 1990) and increased fertility (Yoshitake, M. Suuki, T., Yasufuku, M. & Murata, K. 1988). The same basic principles of exhibit construction apply to aviaries. Special care is needed to reduce the risk of injury to flamingos attempting to fly in large aviaries. An exhibit of this type would be very educational, have considerable public appeal, and would increase the likelihood of reproduction within a flock. The zoos that are successfully exhibiting full-winged birds are Sacramento (U.S.), San Antonio (U.S.), Basel (Switzerland), Kobe (Japan) and Xcaret (Mexico). Flamingos are colonial and are best kept in large flocks of at least 20 birds. Reliable breeding occurs with flocks of 40+ birds. A facility should be designed to hold the future desired number of birds and be able to accommodate potential offspring. “Display only” birds are not recommended, but some facilities will only house birds for exhibit purposes. Consideration should be made to ensure that these birds are housed in small flocks and not kept alone or in pairs. Most flamingo exhibits are large outdoor enclosures with some sort of pool or pond. In cold weather areas an indoor facility will need to be built to house the flock on cold days.

Enclosure Requirements

In creating an enclosure for flamingos, the prime consideration must be to ensure the best possible conditions for the birds while taking into account the impact of the exhibit on the viewing public. The nesting area should be visible to the public and where possible designed in such a way that the public feels they are not just viewing a stage set but approaching a flamingo colony (Ounsted 1990).

Outdoor Exhibits

Acceptable Minimal and Optimal Enclosure Sizes

Outdoor exhibits should be built with the maximum desired flock size in mind vs. the current flock size. There should be enough land space to allow a flamingo flock to engage in courtship displays and breeding activities. Areas for sunning and nesting should be taken into account. The recommended size for an outdoor enclosure is 1.4 m² or 15 ft² per bird, and hard abrasive
substrates should be avoided. The pool should be large enough for the entire flock to occupy the area at the same time. Water should be able to flow freely in all areas to avoid any possible buildups of botulism. Also, this area should be large enough to allow the flock to engage in any courtship displays. A nesting area should be large enough to accommodate the entire flock, with room to allow for potential aggression. A recommended size for a nesting area is 9m² or 10 ft² per bird. Always allow enough space to accommodate offspring and any future acquisitions. Additionally, where prevailing winds are common, windbreaks should be added to prevent even the pinioned birds from taking short flights. Enclosure orientation should also be looked at in these cases to eliminate long runs into the wind. If possible, also include a built-in catching and holding area.

Aesthetics

Outdoor exhibits usually have natural plantings to help enhance the aesthetics of the enclosure. The plant density should be kept to a minimum to allow the birds to move unobstructed through the area. Flamingos are very prone to injuring themselves on bushes and trees. Several bird safety issues should be considered when placing plants inside an exhibit:

a) Does the location of the vegetation pose a hazard for the birds?

b) Low bushes should be avoided due to trip hazards, and the potential for a bird to get caught up in the vegetation.

c) Plantings should be placed in areas that do not hinder flock movements. Flamingos have very long legs and can easily fracture a leg by tripping over low-lying plants.

d) A large area should be free of plants to allow normal movement of the flock to occur.

e) Large boulders and rocks are not advisable due to the trip hazard

f) Problem plants: There are several species of plants that have proven to be problematic in flamingo exhibits. These plants are: Flax - birds can become trapped; Palms - potential eye injury; Coral trees and roses - can cause foot problems; Osier willows – cause sooty mold on feathers (see Health and Medicine Chapter).

g) Tall grasses have worked well and do not pose any hazards.

In addition to enhancing an exhibit's visitor appeal, plants can also provide necessary shade and relief from the hot summer sun in warmer climates. Public barriers can be created through the use of vegetation to add a buffer zone between the birds and zoo visitors.

Mixed Species

Many outdoor exhibits in zoos are mixed species, combining bird and mammal species to show the diversity in a specific habitat. Unfortunately, this theme is not a good idea for flamingos. It is not recommended to mix flamingos with any mammal species, especially hoof stock. These types of mixed species exhibits have the potential for injury to the flamingo flock, and the birds are more likely to be disturbed during their breeding cycle. Some flamingo exhibits do, however, mix other species of birds with their flamingos. There are some bird species that should be avoided, such as
swans and geese. These types of birds have a tendency to be aggressive and can cause injury to the flock and interfere with breeding activity. Some suitable species of birds to mix with flamingos are non-aggressive waterfowl species and ibis. There have been varied degrees of success using tree ducks in flamingo exhibits. Some institutions report aggression problems by tree ducks, and other zoos say that they mix well with flamingos. When considering a mixed avian species exhibit, special consideration should be made to separate feeding areas for species other than flamingos. There have been several incidences of Lesser flamingos becoming impacted on the sand and grit used in various waterfowl diets.

Exhibit Maintenance

The maintenance of the exhibit should always be considered when designing a facility. Several zoos have reported a cessation in breeding activity with their flamingos during routine pool cleaning. The exhibit should be designed with potential nesting behavior and courtship displays in mind. Potential exhibit repairs and gardening should be taken into account. Many exhibits have substrates of grass that will need to be frequently mowed.

Nesting Area

The future desired flock size should be considered when constructing a nesting area. It is better to err on the side of more space than less. A recommended size for a nesting area is .9 m² or 10 ft² per bird. Some institutions have nesting areas that are smaller than this and still get breeding from their flocks. Many species prefer to nest near shrubs and trees as well as areas that are in full sun. The nesting areas should be located in such a manner to offer the flock a choice and be located out of the general traffic pattern for the enclosure. The choice of substrate in a nesting area can be a very important decision. Some zoos have used clay, a clay/sand mixture, leaf mulch, and native soil from surrounding areas with success. The nesting area should be located in a secluded portion of the exhibit as far away from the general public as possible. Visitors should not be able to access the nest area. Several institutions have nesting areas located on islands, pool edges and on dry land in close proximity to the pool. The location of the nesting area in relation to daily exhibit servicing should be taken into account. Enough space should be provided for the keepers to do their daily work without disturbing nesting birds. Plants should not obstruct access to the area. A water source close to the nest site is vital to allow birds to construct their nest mounds. The nest area should always be located in close proximity to the pool, and there should be some ability to soak the area with water. This can be done through the use of soaker hoses, sprinklers, and by adjusting the level of a pool or lake to flood the area. Please refer to Chapter 4 - Reproduction for more information.

Containment Barriers

A variety of containment barriers have been used in outdoor exhibits and are outlined below. Depending on the style of the exhibit, any of these barriers will work. Any fences should be constructed with the posts on the outside of the enclosure. Once settled in an enclosure pinioned flamingos will not normally cross fences one meter high although they are quite capable of jumping over such fences. Prevailing winds should be taken into account when designing new enclosures. In strong winds even pinioned flamingos may be able to fly/jump considerable distances. Banks, fences or trees can be used to form wind breaks and enclosures should not be oriented to allow long run ups into the wind.
a) Chain link: This type of barrier is inexpensive and available in a variety of heights and diameters. There is a considerable amount of flexibility with installation, but in all cases, posts should be placed on the outside of the enclosure. However, chain link is not naturalistic and can require a considerable amount of maintenance and upkeep over time. Birds can get feet and wings stuck in this type of fencing during captures.

b) Pipe fence: Although inexpensive and durable, this type of barrier is also not naturalistic and requires considerable upkeep such as yearly painting.

c) Split rail wooden fence: A fence of this nature can often be manufactured and installed in-house which can be inexpensive. It is an attractive alternative but will need periodic maintenance for repair/replacement of damaged rails. Split rail fencing can be an ineffective barrier against predators and the public. It can also pose a safety hazard to zoo visitors due to the fact that it will be used as a bench, and children find it irresistible to play on.

d) Brick: This type of barrier is durable with very little maintenance and is an effective barrier. However, brick can be expensive to install, is prone to graffiti, and can provide reduced visibility for smaller zoo patrons

e) Gunite: An attractive, naturalistic alternative, gunite can be utilized as an effective barrier. It requires expert installation and can be quite expensive. Depending on the surface applied, gunite can also be very abrasive to bird wings. This type of fence is hard to remove once installed.

f) Foliage: Natural planting can be a very attractive and naturalistic barrier for an outdoor exhibit. It is very high maintenance and requires frequent trimming, watering, and replacement of damaged plants. This does not provide an effective barrier against zoo patrons and predators.

g) Water: Some facilities use large bodies of water as a public barrier. This type can occur in the form of a lake or moat. It can effectively deter some predators.

A factor that should be considered when choosing an effective outdoor containment barrier is predator control. Several institutions have experienced losses within their flocks due to predation by feral dogs and, in Europe, foxes. Some alternatives that have been used in some zoos are electric fences, routine trapping of predators, and enclosed areas that have roofs or meshed ceilings that the flamingos are shifted into at night. Typically, flamingos are housed in open-air exhibits, which lend themselves to potential predator problems. Several zoos have minimal public barriers and keep their flocks contained without incident.

**Water Source**

The water source for a flamingo exhibit typically occurs in the form of a pool. The pool is probably the most important feature of the exhibit and should be designed carefully. Construction should allow water to flow freely through every part of the pool with no dead ends where sediments or concentrations of botulism can build up. Flamingos rely heavily on the use of bodies of water for various activities, such as courting, copulating and sleeping. The depth of the pool should be anywhere from 1.5 –2.75 ft (46-70 cm). Some facilities provide deeper pools that allow birds to
swim. Flamingo pools can be a natural stream/lake or a man-made pool. Natural streams or lakes should be tested periodically for contaminants. The pool should allow the birds to easily access the water. Special attention should be paid to the slope, which should be gentle. A steep slope will pose a trip and slip hazard for the birds. A water flow adjustment should be built into a pool whenever possible. The ability to raise and lower the water level around the nest site would assist with the management of a breeding flock and diminish the amount of keeper intrusions.

There are several different types of man-made pools that can be utilized, such as dump and fill and recirculating/skimming. The dump and fill pool is probably the most common and is less expensive to install than recirculating/skimming pools. Dump and fill pools require weekly cleaning and can be a disruption factor with breeding birds.

Regardless of the type of pool installed, a substrate must be adhered to the surface of the pool. Several different types of pool substrates that have been used in zoos are outlined below:

- **Natural bottom:** A pool that contains a natural bottom typically has clay, sand, or mud. Sand is not recommended for lesser flamingos due to risk of ingestion and impaction. Pools with this type of substrate allow natural behaviors and are easy on bird feet. Clay, mud, or sand substrates do, however, pose a potential disease problem, and some species may ingest the substrate. If a natural substrate is installed in a man-made pool, it may need to be changed periodically. Again, testing for contaminants would be advisable with any type of organic substrate. A natural bottom pool is recommended only if there is good water flow.

- **Concrete:** This type of substrate can be inexpensive to install and is easy to clean. It can, however, be abrasive to bird feet and slippery if not textured.

- **Fiberglass**

- **Combination of rock and concrete:** This substrate can be attractive and naturalistic. Depending on the texture, it can be abrasive to bird feet.

- **Gnite formed concrete:** This type of surface can also be made to look naturalistic. It also can be abrasive to bird feet and is expensive to install.

- **Plastic liner:** A substrate of this nature often occurs in recirculating pools and is designed to operate without routine cleaning. It can also be easy on bird feet. The surface can become slick and could pose a potential fall hazard for keepers and birds alike.

Another water source is salt water. This has not been widely used in zoological institutions but is an interesting concept. A source for fresh drinking water should be available for the birds, if a saltwater pool is installed. This type of water source should be checked periodically for contaminants.

Anti-erosion devices are often used around pools. These devices should not be jagged, and the use of netting is not advisable due to the potential for birds to get caught in it. Wooden piling is also advised against, as birds may catch or break their legs in it (Pickering, 2000). Enkamat, which is an anti-erosion product that is currently used by zoos for flooring, can be a safe alternative.
Feeding Areas

It is recommended that when designing a new exhibit separate feeding areas should be set aside within the enclosure. These areas should be separate from the pool or main water source, with their own drainage system and water source. There should be access from all sides of the feeding area or pool to prevent aggression. A round design is recommended for pools and tubs, and all of the birds should appear to be comfortable approaching the feed station. A diameter of 3.8-5.9 ft (1-1.5 m) and a maximum depth of six inches (15.2 cm) work well. Placement at the front of the enclosure will draw the birds closer to the public during feeding. If using a container instead of a feeding pool, the container needs to be thoroughly cleaned on a daily basis with a disinfectant.

Water Quality and Filtration

Water quality and filtration can be important issues when managing a flock of flamingos. There have been reported die-offs due to contaminants in the birds’ water source. Some facilities use water filtration systems and skimmers in artificial pools to maintain water quality. If using a natural lake or stream, the water quality should be tested for coliform levels and contaminants. A separate water source and drain is recommended for feeding areas. There have been cases of birds becoming ill due to contaminants in the pool in exhibits that did not have separate feeding areas. Water for an exhibit can come from a variety of sources, such as: city water, well water, or natural pond or stream.

Substrate/Topography

In an outdoor area the following substrates have been utilized:

a) Grass: This substrate has been used the most in outdoor exhibits and is very good for flamingo feet. It does require frequent maintenance, such as watering and mowing. This substrate is recommended for use in outdoor enclosures.

b) Soil/clay: Although this substrate does not require much maintenance, it has been attributed to numerous foot problems, and lesser flamingos are prone to ingesting it.

c) Mulch: This substrate requires frequent replacement and can be quite expensive. It has also been attributed to numerous foot and leg problems.

d) Sand and decomposed granite: These two substrates are often attractive and easy to maintain but ingestion has caused impaction. Lesser flamingos appear to be especially prone to ingesting sand (see Health and Medicine, Chapter 6). Numerous foot problems have been attributed to sand and decomposed granite substrates.

The topography of the exhibit should be as flat as possible. Steep hills and slopes should be avoided. A greater proportion of water to land should be part of the overall design whenever possible. The variety of different activity areas, such as feeding stations, loafing, and nest sites should be kept separate.

Indoor Facilities

Two factors usually determine when flamingos need to be brought indoors. They are predators and weather. Northern zoos are faced with cold weather during the winter months that necessitate the
birds coming indoors for a portion of the year. These indoor facilities should be built adjacent to the exhibit to allow the birds to move into winter holding without capture. It is not recommended to capture birds and move them to a winter holding area that is away from the exhibit. This building does not need to be as large as the outdoor exhibit space but should be large enough to allow the birds to move freely and separate from aggressive members of the flock. If the birds need to be kept indoors during part of their breeding season, larger quarters should be considered to allow display behavior (Heldstab and Studer-Thiersch, 2001, unpublished paper). A recommended size (land and pool space combined) is 1.4 m² or 15 ft² per bird. The depth of the pool should be at least 30-60 cm or 1-2 ft. with gently sloping sides. It is also recommended that the keeper service area be kept separate from the bird areas and that all floors be sloped to the drains. Built-in footbaths allow easy treatments of foot problems as well. Ideally, a public viewing area should be designed into any new winter holding structure, with viewing limited to one side. This arrangement has been very successful at The Wildfowl & Wetlands Trust in Slimbridge, United Kingdom (Pickering, 2000).

Note: Since most indoor holding facilities’ floors can remain damp for long periods of time and are usually constructed of concrete it is essential that rubber, vinyl, or other easy-to-clean fast-drying matting material be used to separate the birds’ feet from the caustic and abrasive properties of concrete. Long term exposure to damp concrete causes the birds’ feet to become receptive to abrasions thus opening up the opportunities for infection and the debilitating condition known as bumblefoot.

Containment Barriers

Some of the types of barriers that have been used in winter holding facilities are:

a) Chain link/expanded wire: This type of mesh is versatile, easy to install, inexpensive, and provides increased airflow. However, wings and legs can get caught within the mesh, and it can be abrasive to bird wings. Debris and feathers can be difficult to clean off of the surface of the wire.

b) Concrete or CMU block: This material provides a solid barrier, can be glazed to aid in cleaning efforts, provides durability, and requires little maintenance. It can be expensive to install, and if it is painted instead of glazed, it will require periodic repainting.

c) Metal walls: Metal provides a solid barrier and is easy to clean. This material can be expensive to install and does not have any insulation properties.

The placement of barriers within the facility is important. Several institutions have built shift stalls to allow the flock to be shifted during routine cleaning. Shift stalls also provide areas to separate birds if aggression occurs. Typically an indoor facility will house more than just flamingos, and the interior walls should act as a separation between species that cannot be housed together. Solid interior walls up to six feet with mesh extending from the top of the wall to the ceiling are recommended. The mesh will allow for good air circulation within the building.

Sometimes it is necessary to catch up birds while they are in their holding area. If the walls are concrete or metal, the following method, used at the Los Angeles Zoo in California, can help prevent any injuries:

“Metal lag screws/bolts are put into the wall at about two foot intervals around the room, about five feet up from the floor. The bolts stick out from the wall approximately eight to
nine inches. A piece of PVC pipe is put on the bolt as a spacer to keep a curtain out from the wall. The curtain itself can be made of indoor/outdoor carpeting, shade cloth, canvas or anything with enough body to give a little resistance when the birds hit it. This has greatly cut down on the incidence of scraped and bloody wings, hocks, etc.”

Outdoor Access

Access to the outdoors during the winter months is essential for birds that are housed in winter holding facilities. This practice allows the birds to go outside on nice days and keeps the flock acclimated to outdoor temperatures. An acclimated flock will be able to go outside sooner in the spring. Many northern zoos have courtyards that connect to the building to allow the birds limited access to the outside. Snow on the ground can cause foot dryness and cracks. Some institutions shovel the excess snow out of the area and put down a bed of straw to prevent these foot problems. Doors to the outside should be as wide as possible to prevent injuries from crowding. If possible, a built-in footbath should be placed in front of the door. Among other things, this makes it easier to treat foot disorders with saltwater or other solutions.

Predator Control

Predators can be a problem in such a small, enclosed area and it is recommended that this be taken into consideration. Some methods of preventing depredation include the use of electric wire on the top of the fence and a mesh ceiling to prevent predator access to the area.

Air Quality

Air quality within the building is always a concern during long winter months. The building should have adequate ventilation, and there should be at least ten air changes per hour.

Substrate/Topography

The substrate/topography of indoor enclosures should be carefully considered. Flamingos are especially prone to foot problems, and there are some materials that the birds will actually ingest. There are several substrates that have been used in indoor facilities. These substrates are outlined below:

a) Concrete: This substrate can be extremely caustic and abrasive to feet and legs without protective matting between the birds’ feet and the surface. It is the easiest to clean and disinfect on a daily basis. Concrete should be brushed at pouring to give a just a little texture. (This has worked well for Chilean flamingos at the Wildlife Conservation Society/Bronx Zoo; Caribbean flamingos needed mats.) However, a floor covering for all species of flamingos is recommended to prevent foot and leg injuries. Rubber, vinyl, or other soft synthetic matting have been used successfully and are easy to disinfect. Some institutions use wood shavings and straw. Although these two substrates are inexpensive, they must be kept dry at all times and pose an aspergillosis (mold, fungus) risk to the birds. Straw and wood shavings must be cleaned regularly to reduce health risks to the birds. Lincoln Park Zoo uses sphagnum moss over sand. The moss is replaced once a week, and
it is hosed everyday to keep it moist. Rubber flooring can also be affixed permanently to the concrete. This can be very expensive and difficult to repair. Also, several institutions have had difficulty with the slick surfaces that these types of floors often have. A list of flooring vendors can be found at the end of this chapter under product information.

b) Soil/clay: This soft surface can be effective in preventing foot and leg problems. Using this type of substrate poses several problems. A soil floor poses an aspergillosis (mold, fungus) risk to the birds and can be difficult to clean and disinfect. This type of substrate also needs to be removed regularly and replaced which is the most labor intensive of all.

Generally speaking, concrete floors with a washable soft surface to keep the birds’ feet from coming in direct contact with concrete is recommended. Since most indoor holding facilities’ floors can remain damp for long periods of time and are usually constructed of concrete it is essential that rubber, vinyl, or other easy-to-clean fast-drying matting material be used to separate the birds’ feet from the caustic and abrasive properties of concrete. Long term exposure to damp concrete causes the birds’ feet to become receptive to abrasions thus opening up the opportunities for infection and the debilitating condition known as bumblefoot.

Temperature/Humidity

We think of flamingos as tropical birds and sensitive to cold. The three species most often managed in zoo and aquarium collections are surprisingly hardy and can benefit from some limited exposure to mild low temperatures. Temperature and humidity should be taken into consideration when housing flamingos. A suggested general minimum ambient cold temperature for the birds to remain outside is -6°C (24°F). However, wind chill will more often be the determining factor. Once the outside temperature has fallen to this level, the birds should be brought into a heated facility and definitely if snow or ice are present. In some areas summer temperatures can be extremely hot. Misters and sprinklers are used to provide relief for the birds. Shade from natural vegetation can also provide relief from the sun. Flamingos can suffer from dry skin on their feet and legs. Providing at least 40-50% humidity may provide relief for flocks that reside in dry, heated buildings during winter months. A recommended indoor temperature is 10°C (50°F). Appendix 1 lists the results of a survey of winter lock-in parameters and holding shelters of U.S. Zoos that can be used as a guide. Contributions from the European community are invited and will be added to the survey.

Utilities

In areas that have short day lengths, supplemental lighting might be interesting to try and simulate the even day/night hours of the natural range. Supplemental lighting can be provided in a number of ways. Skylights are an option and provide the ability to use natural day length, although it may not correspond to the species’ native photoperiod. This type of lighting is also able to provide a larger quantity of light. The installation of skylights can be expensive, and they have a tendency to leak. Several different types of windows can be installed in a building to provide light. Two types that have been used in various facilities are glass block and regular windows. Artificial lights can be installed in indoor facilities to provide lighting. It is advisable to place the lights on timers to allow for the setting of photoperiods. Two types of artificial lights are that are utilized in zoos are fluorescent and UV spectrum.
Short-term holding

Short-term holding is defined as one week or less. Many southern zoos are faced with severe weather that necessitates bringing the flock inside a shelter. Some of the reasons for bringing a flock of flamingos into a short-term holding are: 1) brief cold snaps 2) severe thunderstorms and hail 3) hurricanes 4) tornadoes, etc. The Fort Worth Zoo has a 12’ x 16’ (3.6m x 4.9 m) shelter for a flock of 20-30 birds. This shelter appears to be adequate to house a flock of this size without problems for approximately one week. Moving a large flock into a shelter can be quite stressful. The stress on the birds should be weighed carefully against the severity of the storm and the potential loss of life. There have been several reports of flamingos surviving hurricanes by immersing themselves in deep water for the duration of the storm. In this circumstance it may be better to leave the birds with access to their pool, if it is deep enough, vs. putting into a shelter that may be blown away by hurricane force winds. These types of decisions must be made on a case-by-case basis, with the needs of the birds kept in mind.

Utilization Of Space / Indoor And Outdoor

There are several considerations for utilization of space that need to be taken into account regarding both outdoor and indoor space. For both outdoor and indoor space, courtship and aggression should be considered. The nest site location in an outdoor area should be located some distance from the public. The keeper activities should be kept in mind when placing a nesting area. Some keeper activities to consider are pool cleaning, feeding, exhibit servicing, and gardening activities (i.e. lawn mowing, pruning etc). An indoor facility puts the birds in close proximity to the keeper staff, and room should be given for the birds to be able to move away from the keeper during stall servicing.

Public viewing can be a factor for both indoor and outdoor facilities. Some institutions have indoor facilities that can be viewed by the public year round. It is ideal to allow only two to three sides of an exhibit for public viewing. There are exhibits that have public viewing from four sides, and they still get breeding. The location of nesting areas should be considered when designing public space. The birds should have some distance between their nesting area and the zoo visitors.

Capture And Handling Facilities

Many exhibits have attached holding areas that the birds can be herded into. This type of area can be very useful when dealing with medical procedures, exhibit maintenance, and flock management activities, such as ringing/banding. The area should be large enough to hold the flock comfortably for an extended period of time and be predator proof. A mesh roof is highly recommended for a capture stall, but not required.

Isolation From Similar Or Same Species

A quarantine area can be a separate facility or a modified stall within an existing hospital/quarantine space. Flamingos are very prone to foot problems, such as bumblefoot. The floor should be covered with some sort of substrate to prevent potential foot problems. Please see the section on substrate/topography for a discussion on floor substrates for an indoor facility. There is also a list of products at the end of this chapter. The same type of caging that is used in a winter holding facility should be utilized here. The air quality should be monitored, and adequate ventilation should be available. The space should allow for more than one bird to be housed at a time, as flamingos
typically do better when housed with one or more birds. A shallow pool should be provided for birds in quarantine. It may be permanent or removable, as space permits.

There should be some plan for medically treating flamingos. The same considerations outlined above for a quarantine facility should be taken into account for medical holding areas. Existing caging can be modified for use as medical holding areas. See Management, Chapter 3 for further details.

**Special Features**

Fountains have been placed in several outdoor exhibits. Although this can be a very attractive addition to an exhibit, it should be designed with the birds in mind. In zoos that have fountains, the birds really enjoy bathing in them, but some designs pose potential trip hazards for the birds.

Enrichment has been provided to several flamingo flocks, mostly to stimulate breeding in small or inactive flocks. Audiotapes of flamingo vocalizations have been used to stimulate breeding as well as to encourage new or sick birds to eat. Mirrors have been used in some institutions to stimulate small flocks to breed. The mirrors are supposed to fool the birds into thinking that the flock is much larger than it actually is.

**Severe Weather**

All zoos that receive severe weather should have an emergency preparedness plan for their flamingos. The potential for severe weather includes hurricanes, tornadoes, severe thunderstorms, hail, flooding, extreme temperatures (hot or cold), ice storms and blizzards. Some southern zoos have used public bathrooms as safe areas for their birds during severe weather. Other zoos have set contingency plans and designated holding areas. Appendix 1 lists the results of a winter holding criteria survey.
Appendix 1

Cold weather lock-in parameters for zoos in North America. All temperatures are in degrees Fahrenheit.

<table>
<thead>
<tr>
<th>Zoo/Institution</th>
<th>Tulsa Zoo</th>
<th>Pittsburgh Zoo</th>
<th>Tracy Aviary</th>
<th>Cleveland Metroparks Zoo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determining Factor for bringing Flamingos Inside</td>
<td>predators, low temps.</td>
<td>in every night, regardless</td>
<td>low temps.</td>
<td>experience</td>
</tr>
<tr>
<td>Determining date or temp.</td>
<td></td>
<td></td>
<td></td>
<td>&lt;20</td>
</tr>
<tr>
<td>Judgment call factors</td>
<td>wind, precip, sun</td>
<td></td>
<td></td>
<td>cold rain</td>
</tr>
<tr>
<td>When outside, is there access to shelter or heat?</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no (lessers only)</td>
</tr>
<tr>
<td>Is the shelter or heat over water or land?</td>
<td>both</td>
<td>both</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do the birds use the shelter by choice?</td>
<td>no, trained to come in</td>
<td>no, door too small</td>
<td>no, walked in</td>
<td></td>
</tr>
<tr>
<td>Factors to keep birds locked in the shelter</td>
<td>ice on ground or pool</td>
<td>temps. below 40°, precip.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temps. when birds are allowed to go outside (degrees F)</td>
<td>over 25 if clear or over 30 if precip.</td>
<td></td>
<td>over 20° heat lamp if &lt;10°</td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoo/Institution</td>
<td>Denver Zoo</td>
<td>Roosevelt Park Zoo</td>
<td>Dallas Zoo</td>
<td>Columbus Zoo and Aquarium</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------</td>
<td>--------------------</td>
<td>------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td><strong>Determining Factor for bringing Flamingos Inside</strong></td>
<td>(into winter holding) – 5-7 days</td>
<td>low temps., violent rains</td>
<td>low temps., precip.</td>
<td>temps. and weather</td>
</tr>
<tr>
<td><strong>Determining date or temp.</strong></td>
<td>consec, of &lt;20 night low temp.</td>
<td>&lt;32 at night</td>
<td>&lt;32 at night</td>
<td>&lt;25</td>
</tr>
<tr>
<td><strong>Judgment call factors</strong></td>
<td>or 3-5 days consec. of &lt;5 real temp/wind chill or 12-18+ inches snow accum. in 24 hrs with no 40+ temps in the next week</td>
<td>wind, precip.</td>
<td>wind chill</td>
<td></td>
</tr>
</tbody>
</table>

| When outside, is there access to shelter or heat? | no | shelter only | yes | yes |
| Is the shelter or heat over water or land? | land | yes | yes | |
| Do the birds use the shelter by choice? | no | yes, on rare occasions | yes | |

| Factors to keep birds locked in the shelter | | ice, wind chill, <40 | low temps. and precip. | |

<p>| Temps. when birds are allowed to go outside (degrees F) | | 32, no wind | mid 20's with no wind | |
| Notes | winter facility separate from exhibit. Birds let out in mid to late April, depending on weather. | winter facility separate from exhibit | often kept themselves in once herded in | |</p>
<table>
<thead>
<tr>
<th>Zoo/Institution</th>
<th>Topeka Zoo</th>
<th>John Ball Zoological Gardens</th>
<th>Detroit Zoo</th>
<th>Akron Zoo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determining Factor for bringing Flamingos Inside</td>
<td>n/a</td>
<td>temps.</td>
<td>low temps.</td>
<td>ice or snow on ground</td>
</tr>
<tr>
<td>Determining date or temp.</td>
<td>&lt;32 for several nights</td>
<td>20's at night</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Judgment call factors</td>
<td>ice on their pond</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When outside, is there access to shelter or heat?</td>
<td>no, vegetation only</td>
<td>yes</td>
<td>no, vegetation only</td>
<td></td>
</tr>
<tr>
<td>Is the shelter or heat over water or land?</td>
<td>yes</td>
<td></td>
<td>both</td>
<td></td>
</tr>
<tr>
<td>Do the birds use the shelter by choice?</td>
<td>no, walked in</td>
<td></td>
<td>no, walked in</td>
<td></td>
</tr>
<tr>
<td>Factors to keep birds locked in the shelter</td>
<td></td>
<td>&lt;10 or snowing heavily</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temps. when birds are allowed to go outside (degrees F)</td>
<td></td>
<td>when stays at 40 at night</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td>only 2 birds, never been outside</td>
<td>birds are put inside for the winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoo/Institution</td>
<td>Tautphaus Park Zoo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>--------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determining Factor for bringing Flamingos Inside</td>
<td>temps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determining date or temp.</td>
<td>&lt;32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Judgment call factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When outside, is there access to shelter or heat?</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the shelter or heat over water or land?</td>
<td>land</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do the birds use the shelter by choice?</td>
<td>no, walked in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factors to keep birds locked in the shelter</td>
<td>temps.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temps. when birds are allowed to go outside (degrees F)</td>
<td>over 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
References


List of Products

Enkamat 7010
American Excelsior Co.
P.O. Box 249
Sheboygan, WI 53082-0249
Phone: (414) 458-4333

Dri-Deck Tiles
R.C. Steele
1989 Transitway
Box 910
Brockport, NY 14420-0910
Phone: 1-800-872-3773

Turtle Tiles
Turtle Plastics, The Recycled Products Co.
7450 A Industrial Park
Lorain, Ohio 44053
Phone: (440) 282-8008    FAX: (440) 282-8822.

Bandettes used by Disney’s Animal Kingdom
Any poultry supply company or

National Band and Tag Company
721 York St. P.O. Box 72430
Newport, Kentucky 41072-0430
tags@nationalband.com

For Europe please contact the EAZA Office
Acknowledgments

The following individuals provided their expertise for this chapter:

Peter Shannon, San Francisco Zoo
Tom Schneider, Detroit Zoo
Linda Henry, Sea World Adventure Park San Diego
Susan Healy, Sacramento Zoo
Jeff Perry, San Antonio Zoo
Lynda Paul and Cathy Christel, Los Angeles Zoo
Nigel Jarrett, Wildfowl & Wetlands Trust, Slimbridge, England
Chris Sheppard, Wildlife Conservation Society/Bronx Zoo
Megan Ross, Lincoln Park Zoo
Identification

It is now vital to ensure all captive flamingos are marked so that they can be individually identified. There are two main types of ring or band available. These are metal rings/bands (either models made from an alloy of nickel and copper or aluminum) or large Darvic plastic rings/bands. Metal rings/bands probably last longer but it is necessary to catch birds to identify individuals. Engraved plastic rings/bands have the advantage that they can be read easily without the need to catch birds to identify them.

Metal rings/bands should only be applied by an experienced ringer/bander using a pair of ringing/banding pliers.

Engraved plastic rings/bands are made out of two or three sheets of different colored plastic laminated together. The letters or numbers are engraved exposing the second color which contrasts against the outer layer. These can be made in various sizes and length to fit each species of flamingo.

Plastic rings/bands can either be bought ready made and engraved or, with the correct equipment rings/bands can be cut, engraved and molded on site. This is only practical if thousands of rings are to be made on site.

All rings/bands need to be fitted properly to avoid any damage to the birds' legs. Because flamingos spend a large proportion of their time standing in water, it is advisable to apply the ring/band on the upper leg above the tarsi-tibia joint.

Ring/band wear and ring/band loss appear to be greater in breeding birds compared to non-breeders (Pickering 1992). This may mean that some birds may require regular re-ringing/banding. Permanent transponder tags may soon be required for C.I.T.E.S. species and may prove valuable in the long term. The bill patterns of flamingos are highly variable and individually distinct. A photographic record of each individual in a flock should ideally be made when they are first ringed.

All flamingos are sexually dimorphic and most individuals can be sexed using one or two standard measurements (Studer-Thiersch 1986, Richter and Bourne 1990). Standard measurements are tarsus, bill length or bill and head, wing length and body weight. This can be checked by laparoscopy.

Rings/Bands

Plastic rings/bands are the recommended form of physical identification. They are easy to order and relatively inexpensive, providing numerous color variations, numbers, lettering and stripes. It is
important to note that the color of the plastic may affect the durability of the band, with different colors having different strength characteristics, i.e., white core appears to last longer (P. Shannon, personal communication). Additionally, color may be important to overall readability of the band, e.g., WWT recommendations state that yellow with black lettering or green with black lettering may be the easiest to read. Conversely, dark backgrounds with white lettering may become difficult to read if mud fills the light lettering. Simplicity of lettering or numbering is recommended, using not more than a two-digit system but with the numbers repeated two to three times around the circumference of the ring/band (vertical versus horizontal orientation). Please consult the Bibliography for detailed articles about ring/band design. Please see Product Information below if you do not have a supplier for plastic rings/bands.

It is recommended that the ring/band be placed above the tarsal joint on the leg. Size of the ring/band should be suited to the species and to size variations within the species. Please consult any of the ring/band suppliers in the Product Information section for appropriate size. Some institutions place ring/bands above the foot, but this may adversely affect readability and increase the risk of injury if the ring/band slips over the toes. The plastic ring/band has the potential to migrate on the leg causing constriction or abrasion. It is recommended to consult your TAG if you have concerns about this. Ring/band suppliers recommended in this publication have experience with the appropriate material to minimize abrasion. Occasionally rings/bands crack, break or fade over time. Therefore, it is recommended to have a secondary or back-up means of identification.

Also, after the band has been placed on the leg, the overlapping edges can be, if desired, bonded with a high-quality adhesive. After application, the surfaces can be held together with clear adhesive tape, which will wear off with time. Band wear and band loss appear to be greater in breeding birds compared to non-breeders (Pickering, 1992).

Secondary Identification

a) Plastic or metal ring/band

b) Transponders: The use of a transponder is optional. Transponder failure and migration have been reported. The bird must be in hand or adjacent to scanner to read the transponder. The IUCN/SSC Captive Breeding Specialist Group’s recommendations (CBSG, 1991) concerning transponder site and use should be followed when using a transponder system. The transponder should be placed dorsally at the juncture of the neck and the body on the left side.

c) Plastic cable ties, such as are used by electricians to bind a group of cables or electric wires together, are not recommended except as a temporary form of identification. The cable tie has a mechanism intended to synch the tie around the object(s) and the only way to loosen the tie is to cut it. The ties can constrict the bird’s leg causing compromised circulation, swelling or abrasion. Instances of birds’ bills becoming entangled in the cable ties have been reported. In addition, birds can manipulate the ties in such a manner as to further tighten them around the leg.

d) Wing Web Clip/Patagial Flags are not recommended.

e) Tattoo/dyes are not recommended.

f) Physical characteristics that are specific to some birds (e.g., old fracture, bill and facial markings, size, eye injuries, etc.) may allow some secondary identification to be
possible, especially in a small flock. This method is not reliable and highly subjective, but it is always useful to note these special individual characteristics.

Record Keeping

It is particularly important to keep accurate records on long lived birds such as flamingos. During a flamingo's life, (50+ years) even if it stays in the same collection, it is likely to be looked after and be the responsibility of a large number of people. It is essential that each flamingo should be individually marked and records kept of any movements between collections, mates, breeding, offspring and health. It is particularly important for the future genetic management of captive flamingos that accurate records of breeding and parentage are kept.

Each season a map of the nest site should be drawn with the location of each nest marked prior to the first egg being laid. If the flock goes on to breed the flock should be checked daily to record the location of each egg, lay date and identity of the parents. Care should be taken to check each nest every day as birds are frequently displaced from their nest by incoming pairs.

The absolute minimum for a system of records should be a card index with one card for each bird. More convenient, but more expensive is a computer data base. The Animal Records Keeping System (ARKS), developed and supported by International Species Information System (ISIS), has now become the world standard. Standard For Data Entry by Joanne Earnhardt (AZA publication) offers guidelines that might be a starting point for standardized record management.

Capture, Handling and Restraint

Flamingos are captured, handled and restrained for a variety of purposes. Some of the more common reasons are for weight measurements, placement of identification, pinioning and seasonal flock movement. On occasion it may be necessary to intervene for a particular event or circumstance such as for shipments, removal of sick or injured birds, individual or flock movements, construction or severe natural events. It is not recommended to handle or move birds often, or during the breeding cycle (see Reproduction, Chapter 4). When considering flamingo colony intervention, it is prudent to weigh the benefits of the procedure against the stress and possible physical harm that may be incurred. Catching and moving flamingos can result in severe injury or death. It is recommended to seek advice from your TAG prior to undertaking a move or capture if not familiar with the process.

There are several basic guidelines that should be observed when working with flamingos. It is important to be aware of the flocks' position at all times, while in or around the exhibit. Awareness will facilitate in responding to the flamingos' behaviors or reactions to external stimuli. Avoid sudden movements and loud unexpected noises that could frighten the flock. Do not leave objects (e.g., hoses, shovels, rakes) unattended in the exhibit. These could be potential sources of injury from tripping. Training should be provided for all bird and non-bird personnel who may have reason to work with or around flamingos.

Methods used for capture and handling are influenced by exhibit design, flock size and birds' behavior. It is important to observe and interpret individual bird or flock behavior to aid in capture. Flamingos can be conditioned over time to recognize particular keeper behaviors or movements eliciting a particular response from the bird (i.e., hands in the air to prevent birds' approach, back
turned to allow birds’ passage). Again, care should be taken to protect birds from potential hazards in the exhibit such as rocks, branches, pipes, slopes, holes, etc. Once captured, extra persons may be required to hold birds. Planning and discussion of capture and handling procedures should be undertaken prior to the event.

**Capture**

In planning a capture sequence, managers should consider the following important factors:

a) Species  
b) Number of birds  
c) Reason for capture  
d) Location of capture - indoor vs. outdoors; water and land details (i.e., topography, depth, etc.)  
e) Acclimation level of the flock  
f) Previous capture experience for both flock and staff  
g) How many staff available/needed for event  
h) Location of release  
i) Procedures planned while birds are in hand - time in hand  
j) Ambient temperature (it is not a good idea to plan a catch in hot weather)

It is imperative to understand that all these factors are co-dependent. Circumstances are variable as are each of these factors. After evaluating the above factors, managers can then decide on the type of corralling necessary and the appropriate barrier materials.

**Corrals**

Flamingos can be herded into primary and even secondary corral systems, when it is necessary to catch them up. In smaller flocks, birds can be conditioned to enter a corral, if used routinely (e.g. winter holding), or a “follow-the-leader” type behavior may be encouraged to move the flock to a desired area. In larger flocks, selectively separating out smaller numbers from the flock into corrals may work as well. By letting a few birds out at a time they can be caught up without causing undue stress to the flock as a whole.

Corrals may be permanent or temporary and the barriers made from a variety of materials. In designing new exhibits, managers should take into consideration the necessity of catch and release for flock management (see Housing, Chapter 2 for further details.)

**Barriers**

Barriers can be modified to fit the corral size needed. Some commonly used barriers include fencing, plywood, burlap, regular or closed-cell foam, and black or clear plastic sheeting. Mesh barriers are not recommended due to the high risk of injury due to entanglement. Care must be taken when using fencing to ensure the holes are small enough so wings or feet do not penetrate. Fencing not greater than 1” X 1” is recommended. Some abrasions have been noted from birds rubbing against wire when closely confined. Burlap and plastic sheeting work best as hand-held
barriers. Given adequate numbers of staff, a line of people arms length apart can function as a barrier.

Barriers can be designed as a corral, as a corridor to direct the route the birds are to follow, or to block visual access to unfamiliar or frightening objects. In other cases, materials can be used to reduce the impact on objects with which birds might collide. Hand-held barriers can be used to separate small groups from the colony or move the entire colony in one direction.

Water versus Land Capture

The advantage of arranging water capture is that the birds’ movements are inhibited, making them easier to catch by hand. In addition, deeper water can reduce the impact if a bird were to trip or fall. Some disadvantages include potential medical complications from birds getting wet, hypothermic or aspirating water. Other hidden dangers might include submerged rocks, wood snags, plants or pipes.

Advantages of land capture are the ability to visually read leg rings/bands for easier identification and targeting of selected birds. The propensity for birds to collide with barriers and fall has greater probability for injury.

Hand Capture

It is recommended that flamingos be caught by hand. It is not recommended to use hand-held or mist nets. Flocks may become sensitized to long-handled tools if hand-held nets are used. One way to catch a bird is to take hold of the upper part of their wing (T. Richardson, pers. comm.)

Escapes

Flamingos can and will escape from outdoor exhibits, even if flight ability has been restricted. Methods for capture are similar to in-exhibit capture with added hazard considerations such as public access, vehicular traffic and buildings.

Handling and Restraint

Techniques

Whenever possible, birds’ legs should remain unfolded. Folding can increase the risk of capture myopathy and leg paralysis or injury. A very large or unruly bird may require folding the legs for ease of handling or safety. Other circumstances might dictate the need for folding. If folding of the legs is to be undertaken, it must be done with caution. To fold, grasp the legs below the ankle joint and apply gentle pressure until the bird relaxes. Legs should never be forced into a folded position. Additional care should be taken to avoid crossing the legs at the ankle.

a) Hand-held restraint:
   i. Body close to holder, head facing backward; legs may be down or folded.
ii. Body close to holder, head facing forward; legs may be down or folded.

iii. Wing hold at shoulders with one hand, grasping neck gently with the other, legs down allowing bird to be guided along in a semi-walking fashion. It is recommended that only handlers with experience use this method.

b) Mechanical restraint:

i. On occasion it may be necessary to restrain a bird in a sling. Slings are made from fabric, foam and/or plastic. Flamingos can be secured in the sling by using cloth, vet wrap, tape or netting. When positioning the bird, one should take into account the bird’s comfort level and the injury necessitating the use of a sling (See Health and Medicine, Chapter 6).

ii. Towels can be used as a temporary form of restraint for weighing. The flamingo is wrapped snugly with legs folded. Another towel can be draped over the head (as it lays on the back) to reduce external stimuli. Some facilities place the bird in a clean trashcan with a lid for weighing. Subtract the weight of the trashcan.

Special Considerations

a) Time in hand: Every effort should be made to reduce the overall time birds are handled from capture to release. Advance preparation can greatly reduce the amount of time birds are in-hand by insuring proper training and adequate supplies.

b) Concerns: Medical problems associated with capture and handling include overheating, myopathy, leg paralysis, and trauma-related injuries such as dislocations, fractures, tendon/ligament damage, eye injuries, broken blood feathers, lacerations and abrasions. A period of flock over-excitability and in appetence is likely to follow any capture event (Ref. Health and Medicine, Chapter 6).

c) Safety: The wearing of goggles and hooded sweatshirts to prevent bite injuries is used by some institutions as a safety precaution. Do not wear jewelry, as birds may bite off or become entangled in the articles. Some facilities have used hoods or socks to quiet the bird by covering the head.

Moving Between Exhibits

When moving birds from summer to winter holding or between exhibits flamingos may be walked, guiding with hand-held barriers, or hand-carried. All the same handling and restraint considerations apply.

Release

When releasing flamingos, managers must take into consideration all the same factors as listed for capture with special attention to the following points:
a) The time from capture to release should be as short as possible. Pre-planning is vital to this aspect of capture, handling and restraint.

b) Release is a critical stage in the capture sequence; it is advised that an experienced person undertake the releasing of birds following capture.

c) Managers must examine exhibits for release locations that have an even topography for a land release or moderately deep water (two to three feet) for a water release.

d) A variety of techniques may be used to release flamingos. Flamingos may be unsteady on their legs by the time of release, especially when folded. Furthermore, they are often panicky and eager to escape being held. If the bird has been folded, it is important to unfold the legs and ensure the legs are steady and the bird is able to stand before release. Blood flow may have been compromised and simple massage of the legs and thighs with fingers can assist with improving the blood flow. Extra caution should be used when dealing with a struggling bird, as these birds may bolt away and fall. Having a quiet area within the exhibit where birds can reside immediately following release without undue disturbance or keeper activity is beneficial.

e) Managers should make provisions for a reduction of disturbance in and around the flock. This should include keeper activities, landscaping or other activities in proximity to the exhibit.

f) Flocks should be monitored closely following release for signs of capture myopathy. Medical problems resulting from a capture event may be seen from the time of release to two weeks thereafter. Common symptoms might include leg shaking, shivering, droopy wings, generalized weakness, lethargy, in appetence, and individual isolating from the main flock.

**Crating and Transport**

Crating and transport are areas of flamingo management that require further examination. Previous transport experience is often vital to a successful shipment. Even experienced managers have had serious adverse consequences resulting from the shipping process. However, successful movement of flamingos is crucial to the future management of self-sustaining captive populations.

It is recommended that flamingos be shipped individually crated and free standing when possible. This method eliminates folding and may reduce the incidence of capture myopathy, leg paralysis and overheating. It is not recommended to ship freestanding birds grouped together due to reported wing and leg injuries. International Air Transportation Association (IATA) regulations require the following container dimensions; 50cm (19.5in) long, 90 cm (35.5in), tall and 35cm (14in) wide per container, or compartment of a container. Padding, made from a soft non-destructible material, is required under the top of the roof. The two cm (3/4 in) wood frame is covered with lightweight plywood or similar. The floor must be covered with a solid non-slip, leak proof absorbent material (non-agricultural) and securely attached to the floor to give bird a solid foothold. The container must have an entry and exit means, the front or rear may slide or be hinged with a secure means of fastening, or the roof can act as a lid. Adequate ventilation must be provided in at least three sides of the container. Flamingos must be packed individually in compartments of a container, or in an individual container. No more than four flamingo compartments must be in a single container. Separate food and water containers must be provided, they must be accessible for refilling, and the sides of the water container must be flanged to prevent spillage. (For additional information and specifications see IATA CONTAINER REQUIREMENT 17).

A note about slinging individual birds inside shipping compartments:
Although IATA includes slings within the shipping specifications as optional, flamingo managers should consider the hazards associated with slinging birds unmonitored during shipping.

The height of the sling must be properly adjusted to fit each individual bird so that it is in contact with the keel, without supporting the bird. That is, each bird’s feet should be allowed to touch the floor of the shipping container compartment. This means each sling must be custom fitted to each individual flamingo. Severe leg and foot injuries have frequently occurred when using slings often leading to death. Flamingos struggle while in transit and a sling makes this worse as the bird can not reason why it is unable to move unrestricted and so it continually fights trying to free itself from the sling. If slings are used they should only be installed by an experienced, proficient handler. In the past, some airlines have refused shipments without slinging birds. If you experience this tell your airline cargo manager that IATA now allows slings to be optional. The AZA Ciconiiformes Taxon Advisory Group does not recommend the use of slings during shipping.

Preparations

Key considerations in preparing for crating and transportation are:

a) Species, age and physical condition
   i. It is not recommended to transfer flamingos two years of age or younger.
   ii. Do not ship during wing molt due to increased risk of blood feathers breaking.
   iii. Caribbeans may be more high-strung than other species.

b) Time of day and year
   i. breeding cycles
   ii. air temperatures

c) Total flight/confinement time
   i. from capture to release
   ii. folded no longer than eight hours

d) Temperature
   i. above 0° C (32ºF) but below 21° C (70º F)

e) Conditions under which birds are caught and crated

Methods of Shipment

A variety of methods have been used to ship flamingos. Among them are the following:

a) Freestanding, individually crated. Construct a crate large enough to allow the bird to stand at normal height but narrow enough to prevent extension of the wings. Be sure the dimensions of the box are long enough to accommodate the legs of a bird if it were to sit down. The best substrate is indoor/outdoor carpet secured to the floor. One disadvantage of this method is that the crate may be difficult to maneuver within the air cargo hold during loading and unloading. In addition, the size of the crate may preclude airline shipments.

b) Standing, crate height to back (keeps bird’s head down). Construct a crate of a height no higher than the back of the bird. This allows the bird to stand but unable to raise the
head above shoulder level. The bird is then in position to steady itself with its bill, if necessary, for balance. Again, the crate must be of a dimension to accommodate the legs should the bird sit down and/or flex its wings. The advantage of this method over the full freestanding method is that the crate is smaller and the bird may have better balance inside the crate.

c) Folded, wrapped, and crated. Crates are constructed individually or larger with individual compartments. Again, size will depend on the mode of transportation; airlines have size restrictions. Each bird is wrapped and secured from rolling after placement in its crate or compartment. The disadvantage of this method is that birds are folded. However, if the crate meets airline specifications, birds can be shipped over longer distances than by truck. The risk of myopathy is greater.

d) Folded, wrapped, in back of truck. Flamingos have been transported as a group in the back of a truck lined with clean hay. Each bird is individually wrapped in a pillowcase then nestled in the hay, which prevents the birds from rolling around. An alternative method to prevent rolling would be to use pipe insulation tubes, cut to length, on each side of each bird. Since the birds’ heads are free, it is advised to alternate the position of each bird, i.e., head, tail, head, tail, to prevent aggression. A refrigerated truck is recommended to help regulate temperature. The disadvantage of this method is that birds are folded, and it is only recommended for shipping distances of less than eight hours.

e) Freestanding in back of truck/van. This method involves putting freestanding birds together in the back of a truck, commercial van or trailer. The vehicle should be padded and air ventilation assured. The substrate should be non-slip and securely affixed to the floor. Birds are then added one-by-one to the holding space until all birds are loaded. The disadvantages of this method include the high propensity for a bird to be injured from falling and being trampled. Driving must be slow with careful starts, stops and turns.

Shipment Procedures

Preparing the Flock for Shipment

Refer to Health and Medicine (Chapter 6) of this manual (Noninfectious Diseases – Capture or External Myopathy) for recommendations on the supplementation of Vitamin E/selenium prior to and at transport.

Crating

Flamingos have been transported in sky kennels, cardboard boxes and wooden crates. A crate can be designed to hold more than one bird and compartmentalized to eliminate direct physical contact between birds. Crate dimensions vary depending on the species to be shipped. The bird’s position in the crate (standing or folded) will determine the length, width and height. It may be necessary to have several crate sizes available. There should be one bird to each compartment, although they may be built in blocks of up to five compartments. Internal walls may be made of a thick sacking material (T. Richardson, pers. comm.)

Crates can be constructed using plastic, wood, cardboard or pegboard. Metal containers are not recommended. Evaluate the interior for potential scrape hazards and cushion as necessary. Proper air ventilation and circulation is imperative, and ventilation holes are suggested on at least
three sides. A secured indoor/outdoor carpeting or a similar non-slip surface is recommended for the bottom of the container. Other substrates that have been used are shavings and clean hay.

Wrapping

A pillowcase of 100% cotton or gauze-like material is used to enclose and immobilize folded birds for transport. Nylon or body stockings are not recommended. The pillowcase is affixed with masking or duct tape to secure the legs and body. Caution must be taken to ensure the legs are not crossed inside the case. It is critical that this material allow heat exchange to prevent overheating. It has been reported that a cotton tubular fabric (similar to material used to cover casts in hospitals) has been used with some success.

Transport

Airplanes have the advantage of covering a greater distance in a shorter period of time. Advance communication with the airline is necessary to ensure the crate size will fit in the cargo hold. It is recommended that an attendant accompany the shipment to facilitate in container placement, monitoring and later release.

Release following shipment

Birds should be removed from the container as soon as possible. It may be necessary to assist the bird in standing. This may simply involve supporting the bird until it can stand, massaging the legs or walking the bird to increase circulation. Weaker birds may need to be slung for a few hours prior to release. Some birds may get too wet when released in water, exacerbating weakness. It is recommended that birds be monitored closely up to 24 hours after release. Managers should be aware that problems associated with transport may occur up to one week following release.

Shipping and Transport - Examples of What Has Worked

Modified Sling For Shipping Flamingos
Steffan Patzwahl, Parc Paradisio (Belgium)

This shipping crate design was used by Ralph Boussfield of “Birds and Game” in Botswana. Mr. Boussfield shipped 70 adult-sized Greater flamingos (Phoenicopterus ruber roseus), rehabilitated birds found as chicks in an abandoned colony, from Botswana to Belgium. The duration of the trip was more than 24 hours, and only one of the 70 birds was lost in transit.

Each crate contained four adjacent compartments. Cotton cloth walls divided the compartments. Cotton cloth wrapped around the body of each flamingo (with wings closed) was stitched closed down the middle of the flamingo’s back. Openings were made for the neck, cloaca and legs. A piece of cotton attached (sewn) along both sides of the top of the compartment was slung under the flamingo. Food containers were attached along the front wall of the crate.
Shipment of 20 Greater Flamingos from Slimbridge Wildfowl & Wetlands Centre to the Auckland Zoo
Nigel Jarrett, Avicultural Manager, The Wildfowl and Wetlands Trust (England)

Sixty-day-old Greater flamingo chicks (Phoenicopterus ruber roseus), hand-reared in isolation under strict quarantine conditions, were flown in special crates over 11,000 miles to New Zealand. They were reared and attended by Michael Batty, a senior keeper at the Auckland Zoo. They went first to quarantine and then on to a purpose-built African Exhibit at the Auckland Zoo.

Shipping Chilean and Caribbean Flamingos from Discovery Island to San Francisco
Scott Barton, Disney’s Animal Kingdom (U.S.)

In the fall of 1999, Discovery Island (Orlando, Florida) shipped 32 Chilean flamingos (Phoenicopterus chilensis) and 65 Caribbean flamingos (Phoenicopterus ruber ruber) in three separate shipments. Two shipments were by ground vehicle, and one shipment of 32 Chileans flamingos was shipped by air to San Francisco (California). For these shipments, birds were in the crates from eight to 14 hours.

All flamingos were shipped in crates that allowed the birds to stand but did not have any sling device. Each crate had four compartments. The overall crate dimensions were: 56 inches long x 30 inches wide x 32 inches high. When putting the birds into the crates, we make sure that the birds are standing comfortably in the crate before securing the compartment. With this method, we had 100% success with each of our flamingo shipments. In one shipment, a single bird was sitting down on arrival and had difficulty standing after being released. With assistance and veterinary care, this individual recovered completely. The only other injuries were slight abrasions to the wings in the alula region on some birds. For future shipments I would consider adding padding to help with this. Narrowing the crate to 12 inches might also reduce the movement of the flamingo in the compartment and reduce these abrasions. Shade cloth denser than 0% should also be used. In all cases, these were minor injuries and resulted in no more serious complications.

Disney’s Animal Kingdom also received 10 Greater flamingos (Phoenicopterus ruber roseus) from Pretoria, South Africa. They were shipped in a crate measuring approximately 1.1 meters tall, two meters wide and 2.5 meters long. This crate was divided into two sections, with five birds in each section. The flight from Pretoria to New York was over 16 hours. All the birds arrived well. The zoo in Pretoria reported that they have used this technique for other flamingo shipments as well.

In conversations on this subject with Dr. Mark Penning, a veterinarian and Director of Umgeni River Bird Park in Durban, South Africa, he related that they have shipped over 100 birds using the IATA designed crates with slings, and they see between four to six percent of the birds develop injuries or myopathy, often associated with the slings. He said that he has seen birds get their heads stuck in the leg holes in the slings, leading to serious injury or death.
Dimensions of Crates used by the Caldwell Zoo (Texas)
A shipment of Chilean flamingos (Phoenicopterus chilensis) was sent to the Wildlife Conservation Society, Bronx Zoo by the Caldwell Zoo in Tyler, Texas. The crates were 10 inches wide by 28 inches long by 29 inches tall.

Notes on American Flamingo Transport from Discovery Island to Audubon Park
Published in The Quill in 2000

Crate Details

Two types of crates were utilized for transporting flamingos. Thirty crates originally designed for Mississippi sandhill cranes measured 21 inches wide X 20 inches deep X 33 inches in height. Full-length slide doors were located in the front of each crate. An additional 15 crates were constructed specifically for this transfer and measured 18 inches wide X 24 inches deep X 36 inches in height. Full-length, side-hinged doors were located on the front of each crate. See Figure 1 for diagrams of crates.

All of the crates were padded in some manner. Pieces of carpet remnants were stapled on the ceiling and upper half of the sides in 39 crates. The inside of the doors of the larger crates were padded; the slide doors of the smaller crates could not be padded. Four of the larger crates were padded with two layers of burlap, which were stapled to the ceiling, sides and door. All crates were bedded down with one to two inches of shredded paper.

During the crating process, it was decided that larger, taller birds would be placed in the taller crates whenever possible.

Vehicle>Loading Details

Two trucks with 8'X16” refrigerated cargo holds were rented for the transfer. Temperature was controlled by digital thermostats, adjustable up to 80 degrees. As per discussion with Mary Healy, it was agreed that maintaining a temperature of 60 degrees would be desirable. In actuality, the thermostats cycled between 59 and 66 degrees with a 60-degree setting. Since the birds were enclosed in padded crates and under stressful conditions (i.e. generating more heat), a lower temp setting probably could have been used. There were no examples of extremely overheated birds when they were uncrated.

Crates were loaded in the cargo areas from front to back. Spacing between crates averaged approximately four inches on the sides, and between approximately two to three inches on the front and backs. All crates were distributed more or less equally between the two trucks. After loading the full complement of crates in each truck, they were tied together as a unit to prevent sliding or tipping. No tie-downs were available within the cargo area.

The trucks departed Discovery Island at 1300 EST (1200 CST) on 10 November and arrived in New Orleans at approximately 0200 CST on 11 November. Travel time including several refueling/rest stops totaled 14 hours. Birds spent between 15 and 18 hours crated during the trip.
Quarantine Facility

For the first 24 hours, birds were allowed access to only the indoor portion of the quarantine area. This consisted of three indoor holding rooms measuring 12 foot square, with two similarly sized adjoining outdoor areas (see Figure 2 for schematics). The concrete floors of the inner rooms were bedded down with straw, while several rubber mats padded the floor of the outer areas. Two wading pools were placed in the outdoor area along with feeding tubs. Inner rooms were artificially lighted.

On Friday, 12 November, the group was allowed access to the large, outdoor courtyard measuring 48 feet X 40 feet with grass substrate. A small portion of the yard was partially flooded to allow the birds to dabble in mud pools. Four wading pools were placed throughout the yard in addition to four feeding tubs. One pool has a continuously running hose to provide a source of fresh water, however, the birds preferred pools that became muddy. Once the birds had been given access to the outdoor courtyard, they would not utilize indoor holding areas.

Unloading Details

Upon their early morning arrival in New Orleans, the decision was made to uncrate the birds. Since some birds had been crated for over 15 hours, it was felt that it would not be in the birds’ best interest to keep them crated until first light. Within 20 minutes of arriving, staff began unloading birds one at a time. A veterinarian was present with one additional staff member when unloading birds. As each crate was opened, birds were carefully assisted in exiting the crate and were then examined by the vet. Heads, wings and legs were examined for abrasions or other injuries. Each bird was physically supported until it was confirmed that it was coordinated and capable of walking, after which it was released. Only three to four birds were found in the sitting position as the crates were opened. Only one of these birds was one from a large crate.

Virtually all of the birds were a bit shaky after uncrating, but all but one bird was able to quickly walk away with minimal assistance. The one exception was a large bird (yellow #52 R) that had been crated in a small crate. The bird was found in a sitting position, and upon its removal from the crate was alert but very uncoordinated with poor balance and leg extension. The bird’s hocks were slightly abraded due to contact with the unpadded portion of the crate’s sides. After physically supporting the bird for up to five minutes, it was able to stand and, with difficulty, take short steps. Its condition continued to improve over the next 20 minutes, and the decision was made to let it remain with the group without further intervention.

Post Arrival Details

Throughout their day of arrival, the flock was very nervous and flighty. Food was offered in the morning. However, there was no evidence that the group ate (most likely stress-induced loss of appetite), but introduction of a new diet was probably also a factor. By Friday, 12 November, the group was allowed access to the outdoor courtyard. Food was offered in both dry form and with water mixed in to form a slurry. By Saturday, the group’s appetite began to improve, and by Sunday, 14 November, it had recovered completely. By this time, the group was displaying normal behaviors and showed little to no sign of stress. Windows overlooking the courtyard proved to be the most effective way to observe the group at close quarters.
Weighing

It is recommended to weigh birds opportunistically, if circumstances allow, when birds are in-hand. Several techniques have been used to weigh flamingos as follows

a) Folded and restrained (towel) without a container.
b) Restrained in a container (e.g., trash can)
c) Keeper holding bird with a walk-on scale.

Other measurements, such as bill and tarsus length, can also be taken at this time. The addendum at the end of this chapter outlines the various measurements that can be taken and the methods and materials to accomplish the task.

Flight Options

It is recommend that flamingos be full-winged in appropriate exhibits (ref. Housing, Chapter 2). It is currently hypothesized that full-wing flamingos have better balance for copulation than their flightless counterparts, which may improve overall fertility. However, many exhibits are not designed to house full-wing birds. The three most common ways to render a bird flightless are pinioning, feather clipping and tendonectomy.

a) Pinioning is the surgical removal of the metacarpals, which permanently inhibits flight. Some managers prefer a long pinion, where four to five primaries are left intact. It is believed that fertility may be enhanced in long-pinioned birds. It is still unclear if a long pinion adequately inhibits or prevents flight.
b) Feather clipping involves cutting the primaries along the wing coverts on one wing. This method is not recommended due to the irregularity and frequency of wing molt in flamingos. It is temporary and may need to be repeated every six to eight months.
c) A tendonectomy is a surgical procedure that abrades the carpo-metacarpal joint to ankylose or freeze the joint. This procedure is not recommended. There has been low success in preventing flight, and it is highly invasive with a long post-operative recovery period. Tendonectomies can only be done on adults; birds under two years of age are at increased surgical risk and, therefore, poor candidates for this method.

Sex Determination

It is recommended that all birds be sexed. The most commonly used sexing techniques are DNA analysis (blood, feather pulp), surgical laparoscopy, body measurements and behavioral observations.

a) DNA analysis and laparoscopy are the most reliable methods but may not be practicable. (Reference Health and Medicine, Chapter 6)
b) The tarsus, bill length or bill and head, wing length and body weight are anatomical features used for measurement (Studer-Thiersch 1986, Richter and Bourne 1990). Caribbean flamingo juveniles can have measurements taken as early as 2-2.5 months of age. Kevin Drees of Blank Park Zoo in Des Moines, Iowa reported that the tarsal lengths of 12.12 Chilean flamingos were measured. Male tarsal lengths were between 28.57 and 29.53 cm. Female tarsal lengths were between 25.01 and 26.07 cm (95%
confidence intervals). For more information on measuring flamingos, see the addendum to this chapter, Measuring Flamingos, by Nigel Jarrett.
c) Behavioral observations, such as pairing or copulations, as a sole source for gender determination are not recommended. However, behavior can be used as a temporary method for sexing until other procedures can be performed.

Pests/Predators

Predators and pests can be a problem for any flamingo exhibit. Depending on geographical location, predators may include foxes, raccoons, dogs, coyotes, bobcats, rats, humans, owls, eagles, hawks, herons, white ibis, gulls and snakes. Pest species include Canada geese, flies, mosquitoes, fire ants and lice. Managers should be aware of standing water as an environment for vector species (e.g., mosquitoes), which carry avian malaria, the West Nile Virus, and pox. New World flamingo species are especially vulnerable to West Nile Virus.

Protection from predators might include aviary housing, electrical fencing, Havaheart® traps, motion sensor lighting or barriers (above and below ground). Some managers have had to move their flocks on and off exhibit nightly. Alternating feeding stations and times might break up the routine, reducing gull/heron/white ibis numbers in the exhibit.

For mixed species exhibits see Housing, Chapter 2 for incompatible species.

Product Information

Havahart Traps- Valentine Inc. 4259 S. Western Blvd. Chicago, IL. 60609
phone: 1-800-438-7883 and fax (312) 650-9099

Sources for plastic rings/bands:
    Catherine King – EAZA Ciconiiformes/Phoenicopteriformes EEP Chair
    European Association of Zoos and Aquariums
    Peter Shannon- (phoenicops@aol.com)
    Haggie Engraving –Avian Color Bands for Marking and Research (haggie@intercom.net)

Transponder- See your professional organizations recommendations

Tubular fabric - 50% cotton and 50% polyester –
    Kimberly Clark, O.R. Specialty Products, phone: 1-800-524-3577
Acknowledgments

The following individuals contributed their expertise to this chapter:

Linda Henry, Sea World Adventure Park San Diego
Peter Shannon, San Francisco Zoo
Stacey Johnson, Dreher Park Zoo
Laura Wittish, Sea World Adventure Park San Antonio
Susan Healy, Sacramento Zoo
Veronica Hawk, Yerkes Regional Primate Research Center
Sara Hallager, National Zoo
Tony Richardson, Wildfowl and Wetlands Trust

Other contributors include:
Wendy Turner, Sea World Adventure Park San Diego
Sherry Branch, Sea World Adventure Park Orlando
Michael Mace, San Diego Wild Animal Park
Peter Andrews, Zoological Society of San Diego
Laurie Burch (Conrad), Sea World Adventure Park San Diego
Lauren DuBois, Sea World Adventure Park San Diego
Nigel Jarrett, Wildfowl and Wetlands Trust, U.K.
Adelheid Studer-Thiersch, Basel Zoo
Steffan Patzwahl, Parc Paradiso (Belgium)

References

Addendum to Chapter 3

Measuring Flamingos
Compiled by Nigel Jarrett, The Wildfowl and Wetlands Trust (WWT)

Introduction

Morphological measurements of flamingos are used by WWT to ascertain differences in body size that can be related to differences in mating and reproductive success, and in condition and survival.

WWT has developed a guide to describe and standardize the terminology and methodology for various external linear measurements that may be taken from live flamingos under field conditions. The guide seeks to reduce the variation and the detail with which measurements are reported.

The WWT guide defines and illustrates those measurements, which have proven useful and practical for flamingos in captivity. With practice, all of the measurements can be taken from live birds quickly and humanely. The guide is largely based on that for measuring geese, developed by Duzbin and Cooch (1992).

What Measurements to Take?

The measurements that are useful for a study aimed at differentiating populations may be different from those needed to characterize the individual birds. Therefore, a researcher must decide how the morphometric data is to be used before deciding which measurements to record. In general, the researcher should aim to take a sufficient number of different measurements from each individual bird to characterize its overall structural size.

As a minimum, three hard measurements (see below) should be taken, since three dimensions are the minimum needed to define a ‘geometric space’. Hard measurements are those of variables/characters, which do not change in magnitude within individuals as a function of age, length of time a bird is held, or when during the annual cycle the bird is measured. Typically, skeletal bones, such as tarsus are hard characters. In contrast, soft variables/characters can change significantly due to a variety of factors. For example, the body mass of the bird is significantly affected by the stage in the annual cycle at which it is measured: a bird weighed immediately after breeding may be significantly lighter than one caught immediately prior to spring migration.

Nevertheless, body mass is a soft character that is regularly recorded since it is easily measured and provides useful information on the condition of a bird. However, body mass alone cannot not be used as a measure of body size, as body mass will, in part, be a function of structural size. Additionally, body mass is more susceptible to short-term variations than other soft or hard characters, with, for example, variation attributable to handling time before weighing or time of last feeding.

For birds measured during their first year, all characters are soft because in flamingos there is significant growth of all characters during this time. Thus, comparisons of measurements are meaningful only if the age of the bird is known.
The WWT guide recommends that researchers attempt to measure at least the following characters:

**Hard measurements**
- head length
- total tarsus length
- sternum length

**Soft measurements**
- flat wing (a.k.a. wing chord) length
- ninth primary length
- body mass

This set of measurements can be taken from a bird in under three minutes.

This minimum set of measurements should be supplemented with as many other measurements as possible. The minimum set contains both hard and soft measurements. If time does not allow for the minimum set of measurements to be recorded, then only the hard characters should be taken. In general, the hard characters are more repeatable than the soft characters (with the exception of body mass, which is highly repeatable). This is because not only are soft characters more variable over time, but they are also more 'malleable' in hand - subtle variations in caliper pressure may cause considerable variation in the measurement. Despite the problems associated with measuring soft characters, there is considerable value in taking such measurements. Soft characters are often the most sensitive indicators of variation in the condition of a bird.

**Basic equipment**

Equipment needs include a set of digital or Vernier calipers, a steel rule for the linear measurements (long enough to at least measure the length of the ninth primary), and a scale (Pesola™, Salter™ or electronic) for body mass. The measurement board is useful for measurement of total length and flat wing (see the wing chord photographs for an example of an easily constructed measurement board). All equipment should be checked and calibrated against known standards prior to use in the field.

**Definitions and Techniques**

- **culmen**: The chord of the upper mandible length, measured medially from the lowest point of the forehead at the midpoint of the upper bill, where the integument meets the horny portion of the mandible, to the distal tip of the bill.
- **bill-nares 1**: Diagonal length of the upper bill measured from the anterior edge of the nostrils to the distal tip of the upper mandible.
- **bill-nares 2**: Diagonal length of the upper bill measured from the posterior edge of the nostrils to the distal tip of the upper mandible.
- **bill depth**: Diagonal depth of the mandibles from the lowest point of the forehead at the midpoint of the upper bill, where the integument meets the horny portion of the upper mandible, to the lower edge of the bottom mandible.
- **gape**: The length of the upper mandible from the posterior end of the gape to the distal tip of the nail along the mouth line.
**Total tarsus:** The diagonal distance from the posterior junction of the tibiotarsus and tarsometatarsus to the distal junction of the tarsometatarsus at the base of the middle toe.

**Tarsus bone:** The diagonal length of the tarsometatarsus bone only, along the outside edge.

**Mid-toe:** The length of the middle phalanx along its dorsal surface from the proximal articular surface at the juncture of the tarsometatarsus to the distal end of the toe at the base of the claw.

**Nail:** Also known as claw. The length of the chord of the claw from its base to its tip. Fig. 11.

**Wing chord:** The maximum measurement from the bend of the closed wing to the end of the longest primary, with the wing flattened and the longest primary straightened against a vertical border attached to the edge of the measuring surface. Fig. 12.

**Ninth primary:** The total length of the outermost primary feather from the insertion of the remige calamus at the skin surface to the distal end of the feather (with the ruler placed between the 8th and 9th primaries). Fig. 13.

**Sternum:** The length of the sternal ridge nearest the skin, including the skin and feather from the distal to proximal end of the sternum. Fig. 14.

**Tail length:** The maximum length of the entire tail fan from the point of insertion of the calamus on the skin of the center rectrix to the tip of the longest rectrix (usually the third or fourth inward from the most lateral rectrix). Fig. 15.

**Head length:** The length of the skull from the external occipital ridge (at the back of the head) to the distal tip of the bill nail (including skin and feathers). Fig. 16.

**Total length:** The length of the bird from the tip of the bill to the distal end of the longest tail feather - usually the 3rd or 4th from the most lateral feather. This is measured with bird laid on its back on a flat surface. Fig. 17.

**Body mass:** Mass in grams of the entire bird measured with spring balance or electronic scales. Figs. 18 and 19.

**References**

Chapter 4

Reproduction
Facilitator: Jeff Perry, San Antonio Zoo

Introduction

Flamingos are exhibited in nearly all zoos, generally as one of the first or featured exhibits. However, the captive populations are aging, and reproductive levels are insufficient and not reliable enough to support the movement of genetic material from zoo to zoo or maintain population levels and achieve captive self-sustaining populations (Shannon, 1996a, 1996b; Hawk, 1999a, 1999b). The development of successful reproductive programs in captive populations of flamingos is possible for all taxa, and important. Due to the uniqueness of the reproductive biology of flamingo species in the wild, all the species are vulnerable to the disturbance and encroachment by man's activities. Two species, Andean and James’, are now found in only low numbers and in extremely remote areas, a fraction of their historical range. Already efforts are under way to re-introduce them to lakes and areas that have been abandoned, using techniques that have much to gain from captive reproductive programs. Zoos can no longer freely remove flamingos from the wild to provide interesting exhibits. Zoo and aquarium bird collection managers need to seriously concentrate our efforts toward learning more about flamingo biology, in particular reproductive biology. Current collection populations are not self sustaining and so we must work in collaboration with each other, field naturalists, researchers and conservationists sharing our knowledge.

The following chapter is intended to provide information on the little we know about captive breeding biology of flamingos and help flamingo managers develop protocols conducive to successful breeding programs.

Breeding Season

Why flamingos nest in colonies of many thousands of pairs is not known. There are probably significant selective advantages in nesting in large colonies in terms of avoiding avian predation, although limited suitable nesting habitats may also encourage large concentrations of breeding birds particularly in unpredictable environments. It has been suggested that a minimum flock size is required to achieve the level of display activity needed to stimulate breeding behavior. There is some evidence that larger flocks display more frequently (Brown & Root 1958, Studer-Thiersch, 1974; Stevens, 1991; Pickering & Duverge, 1992). In captivity flock size seems to be an important factor in ensuring a group of flamingos will breed. Pickering et al (in press) showed that in Britain and Northern Ireland breeding Caribbean and Chilean flamingo flocks are significantly larger than non-breeding flocks. Also larger flocks breed more frequently than smaller flocks (Pickering et al, 1992). All Chilean flocks containing more than 40 birds have bred successfully at least once, but one flock of only 4 Chilean Flamingos has reared a chick. In contrast all Caribbean flocks in Britain and Northern Ireland with more than 20 birds have successfully reared chicks yet the smallest Caribbean flock to rear a chick was one of 14 birds, although one flock with only four birds has laid eggs.
Flamingos in the wild are opportunistic breeders, taking advantage of conditions that are favorable for building nests and raising chicks. Whenever weather conditions (generally rainfall) are correct, large numbers of colonial flamingos can quickly bring themselves into reproductive condition.

Colonial flamingos achieve synchronous breeding through the use of ritualized displays: head-flagging, wing salute, twist-preen, inverted wing-salute, wing-leg stretch, marching, false feeding, broken-neck, marching (Kahl, 1975; Studer-Thiersch, 1975; Ogilvie, 1986). These displays precede breeding by months. They can also occur during breeding and may occur when no breeding takes place. However, the displays are good indices of impending breeding. The San Antonio Zoo’s Caribbean flamingos begin displaying in October and peak in display intensity and duration in February. Copulations begin in March, early April (Perry, unpublished data). Observing copulations indicates the birds are ready to begin nest building.

In the temperate parts of their range, the seasonal window of opportunity is restricted compared to the tropical areas. Flamingos can be easily put off breeding by changes in weather conditions, loss of food supply, or disturbance by man or storms. In captivity, this can make flamingos fickle breeders. Changes in weather, hotter or colder than normal, too wet or too dry, can result in an earlier or later than normal season, or preclude it altogether. When flamingos are housed indoors, permanently or temporarily for the cold months of the year, breeding can occur at unusual times, even during the winter months. However, because more control over these variables can be achieved in captivity, relatively predictable breeding seasons can be established (Tables 1 and 2).

Mating

Flocks should ideally have equal sex ratios although female-female pairs appear to be able to rear chicks. Unpaired male greater flamingos may cause considerable disturbance to a breeding flock by persistently attempting to rape incubating birds. Unpaired male and female Chilean flamingos have been observed smashing and eating unguarded eggs at The Wildfowl & Wetlands Trust, Slimbridge.

Unlike wild greater flamingos (1995), captive flamingos tend to breed with the same partner each season (Studer Thiersch 1975, Shannon 1985, Wilkinson 1989, Pickering 1992) although the degree of fidelity appears to decrease as flock size increases (Pickering 1992). While paired birds are often seen associating in the non-breeding season (Studer-Thiersch 1975) pairs can form very rapidly during the breeding season (Wilkinson 1985) and birds losing their first egg may re-pair with a different bird in the same season (Pickering 1989).

Factors regarded as important in breeding flamingos in captivity are flock size, sex ratio and age structure, the design of the enclosure and nest site, manipulations of water levels and diet (Duplaix-Hall and Kear 1975).

The first documented breeding of a flamingo in captivity was when the semi-feral flock of Caribbean flamingos at Hialeah racetrack, Florida USA laid eggs in 1937. The first chick was successfully reared there in 1942. The first zoo bred flamingo was reared at San Antonio Zoo in 1952. Since then the number of collections breeding flamingos has increased (Kear & Duplaix-Hall 1975); in Britain there are at least 30 flocks of flamingos that have bred once or more in the last five years (Creighton and Stevens-Wood 1990).
### TABLE 1

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Table 1. Mean date of first egg laid in a season and duration of laying season in flamingos at Slimbridge. (Pickering, 1992).

### TABLE 2

**CARIBBEAN FLAMINGOS**

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National Zoo, Washington D.C.

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*Last hatch dates for 2000 and 2001 were of eggs kept at the National Zoo. Some of the last eggs laid for those two years were sent to the Baltimore Zoo.
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San Antonio Zoo, Texas

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### Zoological Garden Dvur Kralove nad Labem, Czech Republic

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### GREATER FLAMINGOS

**Disney's Animal Kingdom (Tree of Life) Orlando, Florida**

<table>
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<th>First Hatch</th>
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Los Angeles Zoo, California

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Note - These are the eggs we can account for. The nesting areas do not allow us to see all parts of the enclosure without disturbing the birds, therefore it is possible that some eggs may be broken without the keepers seeing and recording them.

*There was not a good record taken that year.

Rotterdam Zoo, The Netherlands

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<th>SEASON</th>
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<th>LAST EGG</th>
<th>FIRST HATCH</th>
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Sea World San Diego, California

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Zoological Garden Dvur Kralove nad Labem, Czech Republic

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CHILEAN FLAMINGOS

Caldwell Zoo Tyler, Texas

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Los Angeles Zoo, California

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<th>FIRST HATCH</th>
<th>LAST HATCH</th>
<th>TOTAL # OF EGGS</th>
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<td>15 Aug*</td>
<td>15 Aug*</td>
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<td>14-Aug</td>
<td>19-Aug</td>
<td>14-Aug</td>
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*The chick that hatched this year is of unknown species. The Chilean and American flocks had not been separated when this egg was found and put into the incubator. It may be a hybrid. There is a DNA test pending to try to determine his species. At this time the chick has the appearance of a Chilean.
Re´Serve Africaine de Sigean, France

<table>
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<tr>
<th>SEASON</th>
<th>FIRST EGG</th>
<th>LAST EGG</th>
<th>FIRST HATCH</th>
<th>LAST HATCH</th>
<th>TOTAL # OF EGGS</th>
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<td>1992</td>
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<td>28 Jun</td>
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<td>24-Sep</td>
<td>13 Jul</td>
<td>26-Sep</td>
<td>24 (chicks)</td>
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<td>--------</td>
<td>10-Jun</td>
<td>3-Sep</td>
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<td>16 Jun</td>
<td>22-Aug</td>
<td>27 (chicks)</td>
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Note: The nesting area is an island on a 10 hectare lake. Observations are difficult, even with binoculars.

Rheine Zoo, Germany

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<th>LAST EGG</th>
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San Antonio Zoo, Texas

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### Sea World Orlando, Florida

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### Zoological Garden Dvur Kralove nad Labem, Czech Republic

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LESSEER FLAMINGOS

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HYBRID - AMERICAN X GREATER FLAMINGO

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Table 2. Laying and hatching data from American, greater, Chilean, lesser and hybrid flamingos from several zoos
Egg Laying and Incubation

Timing of egg laying appears to be dependent on latitude and local weather conditions (Duplaix-Hall & Kear 1975). Onset of egg laying is approximately a month later for every 10 degrees north; the egg laying season extends for approximately half a year at any latitude. It has been suggested that flamingos are inhibited from breeding when there is less than 12 hours daylight (Duplaix-Hall & Kear 1975). At any given latitude each species tends to lay at different times during the summer. Clutch size of one is normal but birds will re-lay after losing an egg. A maximum of five eggs laid by one female Chilean flamingo has been recorded (Liggett 1989). The period between egg loss and relaying is highly variable, 6-90 days, but is typically between 10 and 15 days (Pickering 1992).

At the beginning of the egg laying period, particularly in large flocks, there is often considerable fighting over nest sites even when there is an excess of nesting space and nest bases. Egg loss due to fighting can be very high (Pickering 1990). Vulnerable eggs can be removed to an incubator (see 2.4.3) and replaced with dummy wooden or clay eggs. Flamingos appear to be unable to recognize their own egg and will incubate any object roughly the correct size and shape.

Although they have relatively thick shells and often become covered in mud, eggs can be easily candled at approximately 10 days. Infertile eggs (or the dummy eggs on the parents' nest) can then be removed to encourage birds to relay. Pairs producing infertile first eggs will often produce fertile second eggs (Pickering 1992). An alternative strategy is to give fertile eggs to infertile pairs and encourage proven fertile pairs to relay.

Fertility of captive flamingos varies between different flocks, species and seasons (Duplaix-Hall & Kear 1975, Yoshitake, M. Suuki, T., Yasufuku, M. & Murata, K. 1988, Pickering 1992). It has suggested that pinioned males may find difficulty balancing when mating. Captive pinioned male greater flamingos certainly fall off when mating more frequently than full winged wild greater flamingos (Pickering 1992), although there is considerable variation between individual males (Pickering 1990). Also there was an increase in hatching success in greater, Chilean and Caribbean flamingos at Kobe Oji Zoo after the practice of feather cutting stopped when the birds were placed in an aviary.

The share of incubation is almost equal between male and female parents. In trios one bird often takes a greater share of incubation than the other two. Incubation period is 28-30 days. Incubating Flamingos stand and turn eggs 3-8 times during daylight hours.

Nests

Nesting Area Sites

It is essential that all routine maintenance work is carried out to a regular pattern in tune with the flock's breeding cycle. All concrete edges to ponds and nest islands should be checked and repaired annually to avoid sharp edges where birds may damage their legs. Silting up of ponds is an inevitable problem with large numbers of birds in large enclosures and sludge should be pumped out when necessary. Generally horticultural work is disruptive but with care and consideration disturbance can be minimized and flocks can become accustomed to regular work programs.

Greater flamingos seem to prefer open, sunny areas for nesting and resting (Studer-Thiersch, 2000). Caribbean and Chilean flamingos seem to prefer shaded areas. The nest site should also
be separated from the resting and feeding areas. The same should apply to separation from the public, either by space or visual barriers. Ideally, the nest site should have minimal disturbance from the keeper while performing daily routines. Many times this can be accomplished by having the nest site on an island, surrounded by water. This would also serve as a protection from predators. It can also be accomplished by using vegetation as a visual barrier, exhibit design or distance.

Flocks of flamingos will sometimes select their own nest site. It is important to observe the flock during the spring and summer and if birds are seen attempting to nest build in an area other than the carefully designed nest site it is probably wise to let them get on with it and only provide extra mud if necessary. Careful observations may help to decide how best to develop this area for the following season. Small modifications rather than wholesale redesigning of enclosures tend to bring the best results; however, it has proved possible to persuade colonies to breed on the keeper's preferred site by denying access to the site they had chosen the previous season.

Once an established flock has begun breeding, indicating their choice of nest site, they will remain faithful to that site from season to season. A new flock, or one that hasn't nested yet, may choose sites that are inappropriate or difficult to manage. However, they may need to be encouraged at those sites to get them started. Careful observations may indicate the reasons for choosing those sites, such as the need for privacy and lack of disturbance (very important for novice flocks and/or new imports), and the suitability of the nesting substrate (its moisture level and manipulative qualities). As an example, when the San Antonio Zoo's flock of breeding American flamingos was moved to their new exhibit in 1988, they made initial attempts at nest building on the pool edges and along the rear walls where the pool and watering of the plants kept the substrate wet. Next season they moved over to a more suitable and manageable nest area set up for them.

**Nest Site Preparations**

The important criteria for flamingos to build nests are a suitable substrate and an appropriate moisture level. Where there are no suitable natural nesting sites concrete lined pits filled with mud and clay can be created as nest islands. The concrete lip of each nest site should be lower than the edges of ponds. This allows the nest sites to be regularly flooded by raising and lowering the water level in the pond; however, this may also bring risks in sites susceptible to Botulism. An alternative method is to have a separate clean water supply to the nest so it can be flooded without the need to change the level of the water in the pond. Experiments have shown that rising water levels result in greater nest building activity than simple wetting of the nest site (Pickering 1989).

The best substrate should be easily manipulated by the flamingos to build and maintain a nest mound. The flamingos will stand or sit and pull nesting material to their feet and body using the bill like a backhoe. Eventually a mound is built, surrounded by a trench. At the San Antonio Zoo a sand/clay mix is used. This is the material used for baseball/softball diamonds, a 50% sand 50% clay mix. When this material is brought into the nest area, it is worked into the existing soil and any old, remaining nest material along with some timothy hay, by digging and turning over with shovels. Then it is thoroughly wetted with water. We find this mix, when formed into mounds, holds its structure well, even with heavy rains. Other institutions use the existing soils, adding potting soils or fine bark mulch as necessary but also turning over the soil, mixing in the mulch and wetting the area.
The nature of the substrate and the moisture level go hand in hand. The nesting material must be kept wet enough to enable the flamingos to dig with their bills. This can be accomplished in several ways. One is to raise the water level and flood the area. If one has a nesting island, especially one designed for this purpose, this can be very effective. Secondly, one can have a hose(s) set up to allow the area to be flooded on a controlled basis. The control (on/off and volume) of the hose needs to be somewhat remote from the nest area to prevent disturbance. A disadvantage of this method is that once the flamingos start digging and mound building, dams, dikes and low spots may be created generating problems in getting even coverage of water. Thirdly, sprinklers can be used. With proper placement on the ground or overhead, the coverage can be effective, even and controllable. At the San Antonio Zoo, two flamingo exhibits use the flooding technique, and the main flock uses a combination of a hose and sprinklers.

Providing Nest Starts

Most managers will provide “starter” nest mounds to help stimulate the birds. Providing a nest start may be more important for young or newly formed flocks. It appears to act as a stimulus to entice first-time breeders into nest building. This has also been tried with free-ranging birds in the Camargue, increasing numbers of breeding pairs and establishing a regular nest site (A. Johnson, pers. comm.) In captivity, established breeding flocks may not require “starter” nests. At the San Antonio Zoo in 1995, no nest starts were given to the well-established breeding flock of Caribbean flamingos. The birds built good nest mounds entirely on their own and had an excellent breeding year. However, providing nest starts is an effective stimulatory tool and ideally providing nest material to the nest site should be done just prior to the nesting period or even the week the first sign of nest building activity is observed. Using about a half or more of a wheelbarrow load of material, suitably wetted, one can form a mound measuring about 0.6 meters (2’) in diameter at the base, 0.45 meters (1 ½’) in diameter at the top, and 0.38 meters (1 ½’) tall. The mound should be packed together to insure its survival, even during rains. A shallow depression should be formed on the top. A 18.9 liter (5-gallon) bucket can be packed with the nest material and inverted over to aid in the formation of a nest start. Flamingos tend to build their nest mounds as close together as possible. Therefore, the bases of any nest starts can be as close as 0.45 meters (1 ½’) to each other. An excess of nest starts should be provided to allow the flamingos to select their own nests. Spare nest sites are often occupied by young birds practicing nest building. The nest site should be kept damp. If the flock does not lay within three to four weeks of the extra mud being added the nest site should be reworked to ensure there is sufficient freshly turned mud for nest building. This practice should be continued at intervals throughout the summer until the flock breeds or autumn arrives.

Permanent nests built out of fiberglass or concrete are not recommended. The hard surface can result in broken eggs and broken legs. Nests left intact throughout the year lose their stimulatory effect. If any birds are reproductively active, and they like the location, they may choose to adopt a pre-made mound or nest start, add to it and finish it off.

Nest Building Behavior

Paired flamingos start nest building by standing at the site and begin pulling material to that site using their bills and reaching out with their long necks to extend the range of nest material gathering. The mated pairs work together. As the materials start to accumulate and pile up, the birds will alternately adopt a standing and a sternal-recumbancy position on top of the pile and
continue pulling materials to them. With their breasts on the middle of the top, a shallow depression is formed with a lip. The mound will grow in diameter and height until the egg is laid. Nest building will continue after the egg is laid. The mound is constantly maintained by pulling wet material to it and dribbling it down the sides. Sometimes the nest mounds can reach a remarkable height of 2 3/4 feet (0.76 meter) tall.

Space Requirements for Nest Area

The recommended space for each individual nest site is 12.25 square feet, or 3.5 x 3.5 feet (1.15 square meter, or 1.07 x 1.07 meter). The size of the nesting area will be determined by the size of your flock. The main breeding flock of Caribbean flamingos at the San Antonio Zoo numbers approximately 60 birds. In our experience, about one-half of the flock will be taking part in nesting activity at any one time. This gives us 15 pairs, or 183 square feet (16.8 square meters) of nest area used. Approximately 500 square feet (46 square meters) is set-aside as a nesting area. This seems to adequately accommodate the amount of area used by the nesting birds. This also seems to correlate with other institutions published figures (Johann 1998; Studer-Thiersch 2000).

Post Hatching Nest Maintenance

Once chicks start hatching and leaving the nests, the hazards they may encounter if there is too much standing water around the nests becomes a concern. Most institutions cease or reduce the watering necessary for nest maintenance, in order to insure the survival of the chicks. However, the disadvantage is impairment to nest maintenance and any further nest building and egg laying. Does this reduction or lack of watering curtail some of the potential breeding that could occur? In small flocks (20-40) this may not be a major concern, but in larger flocks (50+) it probably is. Larger flocks do seem to have a more extended breeding season. This requires extra duties to enhance chick survival, continued breeding and nest building. Careful water management is necessary to keep the substrate suitable for nest building without endangering chicks leaving the nests. Adding nest material if necessary, egg manipulation and management, chick management, and pinioning of chicks all require considerable skill and experience to perform without undue disturbance of the colony. This disruption can cause egg breakage, injury to chicks, and potential abandonment of nests. Inexperienced flamingo managers are urged to contact institutions with the necessary experience and knowledge. See also the Egg and Chick Management sections.

Pinioning and Fertility

Pinioning flamingos definitely impacts fertility of eggs (King, 1994). The degree of reduction in the percentage of fertility in eggs can be quite variable, ranging from only 25% fertility in San Antonio Zoo's pinioned male Caribbean flamingos (Perry & Atkins 1997) to higher percentages, like 100% fertility in the 14 eggs produced by the pinioned male Chilean flamingos at the San Antonio Zoo in 1997. The impact of pinioning is also variable amongst the other species of flamingos (Pickering 1992, King 1994, King 1997). Even amongst individuals of the same species, the effect of pinioning is variable. Some individuals have "the knack" to achieve proper copulation and produce fertile eggs, while others never seem to get it. The exact reason for this reduction of fertility is not clear. Probably the mechanical act of copulation is impaired, as all the long-legged birds seem susceptible to it (Pickering, 1992). The impact on reproduction in captive pinioned flamingo flocks is considerable. Large flocks can make up for it in sheer number of eggs and still achieve
considerable hatching success. However, in smaller flocks, where the number of birds coming into breeding condition is low and egg production is low, considerable time is wasted brooding infertile eggs. Careful egg management, such as egg pulling, dummies, recycling, egg substitution, candling and artificial incubation, can help but won't solve the ultimate problem of low fertility.

One solution is the "long pinion" proposed by Peter Shannon in 1991. This pinioning method leaves a greater portion of the flight surface. It is hoped this will increase balance during copulation and increase fertility. The Audubon Zoo in New Orleans has been "long pinioning" since 1991 and the San Antonio Zoo since 1997. However, the data to support this is still pending. (Figure 5) The other solution is to leave your flamingos full-winged. In enclosed exhibits, indoors or outdoors, this can be done without fears of the flamingos flying away. The full-winged breeding flamingos at the San Antonio Zoo were housed in an enclosed exhibit from before 1950 to 1988. Since 1988, the San Antonio Zoo's newer Caribbean flamingo exhibit is enclosed but has an open front with curtains that can be lowered at night or whenever work has to be done in the exhibit. The birds, in general, have shown no inclination to fly out. Only five birds have flown out of the exhibit. All of these were one or two-year-olds and were recovered. The pay-off is nearly 100% fertility in the eggs.

At the Basel Zoo in Switzerland, no chicks have been pinioned in many years so now the majority of the flock is full-winged. The exhibit is outdoors and not enclosed. While an occasional flamingo has left, the losses have been very acceptable (Studer-Thiersch, personal communication). There are also a number of examples of flocks that have or had a full-winged bird or two in them that don't fly off. The San Antonio Zoo has a smaller, outdoor, open exhibit where a full-winged bird has shown no inclination to fly off for two years. Another male has been left full-winged for six months without flying off. The San Antonio Zoo's goal is to have a few full-winged males amongst the flock of 20-25 birds to up the percentage of fertility.

It should be pointed out that leaving flamingos full-winged is not a guarantee of 100% fertility. Nomadic flamingos depend on synchronous breeding in their reproductive cycle. Any asynchrony that exists between males and females, whether it be from weather variations such as sudden drop in temperature or other reasons, could result in infertile eggs, even though the copulations may be technically perfect (Studer-Thiersch, personal communication).

With newer sexing techniques, it should be possible to sex chicks quickly, before they need to be pinioned. Females could be pinioned and males left full-winged. Newer ideas, management techniques, exhibit designs, and exhibit construction materials may allow for more full-winged birds to maximize egg fertility.

**Egg Production and Incubation**

**Record Keeping and Observations**

Good record keeping and observations, combined with colored, numbered plastic banding can help with reproductive management, including egg management and chick management. Knowing the reproductive history of your individual flamingos allows you to anticipate fertility/infertility in eggs and make informed decisions as to whether to pull, allow recycling, substitute a dummy, or allow continued incubation. Good records will also alert one to adept parents, ones with a history of chicks with problems, and any of the anomalous social units (trios, quartets, same-sex pairings).
Figure 6 is an example record sheet used at the San Antonio Zoo to keep track of eggs, chicks and parents during nesting season.

Clutch Size

All of the six flamingo species lay single-egg clutches. Multiple-egg clutches are rare and are discussed under Anomalies.

Incubation Period

Table 3 lists incubation periods for all the species, compiled from various sources.

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Table 3. Incubation Periods of Flamingos

Anomalies

Multiple-Egg Nests

Multiple-egg nests have been reported but are rare (King, 1994, Shannon, 2000, Studer-Thiersch, personal communication). The San Antonio Zoo has had only four cases of multiple-egg nests during the years 1984-2000. Shannon (2000) reports one female regularly laying two eggs in one nest at 5-9 days apart at the Audubon Park Zoo. Multiple-egg nests can also result from some of the trios, quartets and same-sex pairings, which occur amongst flamingo colonies (Shannon, 2000). In multiple-egg nests, the survival of the eggs is reduced. When the same female lays a second egg, the first egg will probably be buried with continued nest building prior to the laying of the second egg. With the social dynamics of the various trios, quartets and same-sex pairings, the first egg is generally lost, and the chances of the second egg surviving are also reduced. In other words, the chances of both eggs surviving in a multiple-egg clutch are nil, and the chances of the remaining egg are also reduced. Due to the unlikely success of multiple-egg clutches, consideration should be given to managing the eggs by pulling one or both, and/or using dummies (see also the Trios, Quartets and Same-sex Pairings section).

Uneven Sex Ratio

When there is a significant variance from an even sex ratio, observers find there are problems with nesting and egg breakage. This is probably a result of unpaired birds trying to pair up with or take
part in the breeding activities of paired birds. The most easily observed is a flock of Caribbean or greater flamingos skewed towards males. The larger males can be seen trying to pair and copulate with the shorter females of a bonded pair. This interrupts the normal activities and can result in nest abandonment and egg breakage. If a manager has the facilities, the troublesome birds can be removed from the flock for the duration of the breeding season. This would be more difficult to observe in the less sexually dimorphic flamingo species.

Even though a more or less-balanced sex ratio is desirable, it still does not prevent the formation of trios, quartets and same-sex pairings, which can cause more disturbances than heterosexual pairs (Studer-Thiersch, personal communication).

Egg Breakage

It seems to be a normal phenomenon for some egg breakage to occur in the gregarious, colonial nesting flamingo. The normal acceptable level needs to be defined. At the San Antonio Zoo, the successful Caribbean flamingo flock has suffered from 10 to 50% egg breakage each year. King (1994) reports egg losses of 28% in 1992 and 48% in 1993 for the Caribbean and greater flamingo flock at the Rotterdam Zoo. Pickering (1992) reports egg losses ranging from 13 to 37% for Slimbridge’s greater, Caribbean and Chilean flamingos. Is this normal? How does it compare to colonies in the wild? Can some of it be prevented or managed?

Adelheid Studer-Thiersch’s paper, “Behavioral Demands on a New Exhibit for greater flamingos at the Basel Zoo, Switzerland (2000)”, offered some well-studied answers and solutions to egg breakage. The increased size of the new Basel Zoo exhibit allowed for greater separation of various activities, such as feeding, resting, exploring, and displaying. The higher vegetation barriers allowed for visual separation. The new wintering quarters resulted in fewer disturbances to preparations for breeding. This made for calmer flamingos, higher breeding motivation and increased synchronization of egg laying, thus reducing egg breakage. Fewer females had to recycle and lay additional eggs. The number of eggs laid by the females was reduced from 2.5/female per season to 1.6/female to achieve the same degree of breeding success.

Trios, Quartets and Same-Sex Pairings

Even though heterosexual pairings and fidelity are more common in flamingo social relationships, other relationships do exist. In captive populations, homosexual pairs may comprise five to six percent of the couples (Bagemihl, 1999). Same-sex pairs will feed, call, sleep and deal with aggression by other birds together. Mountings and copulations may also take place. When nesting, these couples act the same as heterosexual pairs and have been known to successfully hatch and raise foster chicks (King, 1994). Peter Shannon’s paper, “Social and Reproductive Relationships of Captive Caribbean Flamingos” (2000), details homosexuality and multiple-partner relationships and their impact on reproductive activities. Table 6 from that paper summarizes these relationships (see also King, 1993b, 1994). These other relationships can impact egg laying and chick rearing, not only in that particular relationship, but on those nesting around them. This can impact egg management. For example, in relationships involving two females, two eggs and the possibility of the eggs being fertile, one or both of the eggs are more vulnerable to being lost. If a manager is aware of the situation, those eggs could be saved through careful egg management (see also Multiple Egg Nests and Egg Management sections). To detect and monitor for these trios, quartets and same-sex pairings requires an investment of observation time. Beginners may
require considerable time to gain these observations, but experienced observers and careful record keeping can reduce, significantly, the time necessary to gain this knowledge and insight.

Extended Monogamy
* A single male and a single female
* Multi-year monogamous relationship
* Little or no promiscuous behavior by either bird
* Relationship usually ended only with the death of one partner or if the female chose a new, exclusive partner

Serial Monogamy
* A single male and a single female
* Typically one or two-year monogamous relationship, lasting throughout the nesting season
* Either bird more likely to have been promiscuous than birds in extended monogamous relationships

Trios (one male and two females)
* Formed when a second female joined an established pair (usually the new female remained subordinate to the original female), or a female attracted a male from a established pair, and his previous mate remained attached to the male (the new female became the dominant female)
* Typically did not last longer than one season
* Associative – all three birds maintained the same nest
* Disassociative – the second female maintained a separate nest without assistance from the male or the other female

Trios (two males and one female)
* Usually formed when a female changed mates and the former mate remained attached to her, or the second male had a relationship with her sometime in the past and had no current mate, or the two males were paired with each other in previous years, and one of them then accepted a female mate
* Once established, typically lasted for several seasons
* Usually associative – all three birds maintained the nest, although depending on the group’s history, sometimes the second male merely stayed close and helped defend the nest

Trios (other)
* In two cases, the chick from the previous year participated in the parent’s nesting activity, never incubating but sometimes feeding the current chick

Quartets (two male and two females)
* Usually developed when a trio was formed from partners of two previously established pairs and the fourth bird remained attached to the group of four, or the birds routinely switched partners among the group of four
* Typically a long-term relationship among the group
Other birds outside the group could be seasonal partners of one member of the quartet, but they did not remain a long-term member of the group.

**Same-sex pairs**

- Often seen among juvenile birds
- Sometimes occurred when the female of a two male:one female trio died or chose a new partner
- Adult female seemed more prone to same-sex pairings than adult males, although female:female pairings generally lasted only one season, whereas male:male pairings could continue over several seasons.

Table 4. Characteristics of typical breeding relationships among captive Caribbean Flamingos at the Audubon Park Zoo, 1981-83. Used with permission of The Waterbird Society

**Egg Size**

Table 5 lists egg dimensions for all flamingo species. Table 6 focuses on egg dimensions of Caribbean and Chilean flamingos from two zoos.

### Table 5

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>MEAN (mm)</th>
<th>n</th>
<th>RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caribbean</td>
<td>90.7 x 55.0</td>
<td>115</td>
<td>82.6-104.0 x 49.0-59.4</td>
</tr>
<tr>
<td>Greater</td>
<td>89.1 x 54.6</td>
<td>402</td>
<td>77.0-103.5 x 47.7-61.6</td>
</tr>
<tr>
<td>Chilean</td>
<td>92.0 x 53.1</td>
<td>51</td>
<td>82.7-106.0 x 49.8-59.7</td>
</tr>
<tr>
<td>Andean</td>
<td>86.6 x 55.0</td>
<td>27</td>
<td>80.9-94.0 x 52.0-60.0</td>
</tr>
<tr>
<td>James’</td>
<td>82.8 x 51.0</td>
<td>19</td>
<td>78.1-87.8 x 48.4-55.2</td>
</tr>
<tr>
<td>Lesser</td>
<td>82.3 x 49.9</td>
<td>124</td>
<td>52.0-94.0 x 38.0-56.0</td>
</tr>
</tbody>
</table>

Table 5. Egg dimensions for all species of flamingos. Data from a variety of wild and captive sources, adapted from Kear & Duplaix-Hall (1975, Appendix 5).

### Table 6

<table>
<thead>
<tr>
<th>CARIBBEAN FLAMINGO EGG MEASUREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoo</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>San Antonio</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Audubon Park</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Hatching & Development

Parental Care

During the hatching process, the brooding parent will fidget and may rise (weather dependent) more often to check on the hatching chick, especially as the chick vocalizes. Here is where the chick-parental bond is cemented. While eggs may be freely substituted, chicks cannot, nor can pipping eggs be switched. Once vocalizations have started, whether from the internally piped egg, the externally piped egg or the newly hatched chick, no exchanges can be made. Eggs need to be switched or substituted before vocalizations have started. In Caribbean, greater, Chilean and lesser flamingos, the internal pip will be around day 26 or slightly before.

During the hatching process and once a chick hatches, good parents will sit tight to the nest, never leaving it unattended. They will be very solicitous of the chick, even when standing up. As the parent moves around on top of the nest, they step “gingerly” to avoid undue pressure on the hatching egg or chick. When standing, a good parent will be frequently and “solicitously” touching the bill to the hatching egg or chick. Observations have shown that a parent may actually help the hatching process. Parents can help the chick emerge from the egg by gently pulling on shell fragments or membranes with their bills. A parent may ingest some of the hatched shell fragments and materials.

An inexperienced parent may lack in some of these “solicitous” behaviors, actually appearing “alarmed” at the hatching events and easily displaced by curious or other aggressive flamingos. If an aggressive non-parent gets on the nest with the hatching egg or newly hatched chick, the response is usually immediate and fatal. They may attack the egg or chick by hitting it aggressively with their bill. In some of the rare anomalous social groupings (triads, quartets, same-sex pairs), the non-parent can be solicitous and exhibit good parental behaviors. However, the potential for competition and/or friction between that group’s members could lead to inappropriate results, such as the chick or egg being crushed or displaced out of the nest.

Immediately after hatching, an exhausted chick will look wet, very “flattened” and immobile. Inexperienced observers can be alarmed and think the chick is dead or crushed. However, the chick should begin trying to lift its head and vocalize within an hour.

The chick will fluff out and begin sticking its head up between the parent’s body and wrist joint of the wing. This is usually how the chick will receive its first food, as the parent drools the red crop milk from its beak tip into the upraised bill of the chick. Both parents will normally feed, however, occasionally only one parent will do the feeding of the chick. A single parent is capable of rearing a chick if it is in good condition. Sometimes over zealous feeding will result in the red crop milk

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CHILEAN FLAMINGO EGG MEASUREMENTS

<table>
<thead>
<tr>
<th>Zoo</th>
<th>Seasons</th>
<th># of eggs</th>
<th>Measurements (Mean)</th>
<th>Measurements (Range)</th>
<th>Weights (Mean)</th>
<th>Weights (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>in millimeters</td>
<td>in millimeters</td>
<td>in grams</td>
<td>in grams</td>
</tr>
<tr>
<td>San Antonio</td>
<td>90-97</td>
<td>10</td>
<td>91.1 x 56.1</td>
<td>85.3-95.2 x 53.0-58.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Caribbean and Chilean Flamingo Egg Dimensions and Weights from the San Antonio and Audubon Park Zoos
getting all over the grayish chick’s down. This blood-like crop milk may alarm zoo visitors (and staff also), who are convinced that there is blood everywhere.

While the chick is on the nest, one or both of the parents will always be in attendance, whether brooding, standing on the nest over the chick, or standing at the side of the nest when the parents are relieving one another.

Leaving the Nest

Chicks will leave the nest as early as three days and as late as eleven, with five to seven days old the most common. When the chick is ready to leave the nest, there will be a few days when the chick will leave or fall off the nest and clamber back up. The chick’s ability to do this is amazing, even when they leave as early as three days, or when it involves a nest as high as 2.8 feet (0.76 meter) tall. The parents and chick will use a nest other than their own, if one is available. A chick trying to climb back up an occupied nest will be re-buffed by the adults. Considerable bickering and fighting can occur between the parents trying to defend their chick and the nest occupants defending their nest site.

When the chick leaves the nest, the parents will stand over it, or just to the side of it, and guard it from all other flamingos. They will brood and feed the chick off the nest just like they did on it. At this point, it is important to discontinue the water that has been supplied for nest building. A chick that leaves early is less able to walk to drier ground and may be vulnerable to drowning or being trampled. Aggression from other flamingos is another obstacle. A parent that is brooding its chick off the nest may even engage in nest building while brooding.

This is a vulnerable time for the chick and where parental experience plays a big factor. Veteran or adept parents that have a record of success will ably brood, feed, lead and protect the chick. First-time or novice parents may not be as adept or confident in caring for their chick and may suffer losses. Good record keeping, banding, and observations are valuable assets in monitoring a chick’s progress. Once leaving the nest, over the next few days, a chick will expand its boundaries by exploring the water area around the nest, all under the watchful eyes of the parents. The chick and parents may temporarily adopt a different, abandoned nest mound. The parents will gradually become more tolerant of the distance they allow the chick to wander away from the nest but will always be nearby and responsive to the chick’s vocalizations. These wandering chicks may approach other adult flamingos and even beg to be fed. However, only the chick’s parents will feed it; it will be rebuffed by other adults.

Weaning

It has been demonstrated that hand-reared flamingos can be weaned in as few as 23 days, but 30 days or longer is more typical (Perry & Atkins, 1997). When being parentally reared in captivity, this process can take much longer, in fact, almost a year. In other words, some parents can still be feeding their young as the next breeding season approaches. Some parents and juveniles break off the feeding in about four months while others do not. This prolonged feeding may relate to captivity, where the parents and juveniles are always in close proximity to each other. In the wild, the parents can fly off and, therefore, encourage weaning in the non-flighted juveniles. At the San Antonio Zoo, concerns have grown that this prolonged feeding of the juveniles may have negative effects on the health of the parent(s). The San Antonio Zoo’s exhibit is a small one, 40 x 170 feet
(12.23 x 52 meters). This may contribute to this phenomenon more so than a larger, more spacious exhibit. The Basel Zoo reports that they regularly separate their greater flamingo parents and juveniles in the autumn. It is felt that when the juvenile stays too long with the parents (especially the male), it may adversely effect breeding in the following season (Studer-Thiersch, pers. comm.).

Adult Caribbean flamingos will lose their color while feeding their chick. One can detect the parents who are still feeding and the ones who are not, by the color in their plumage. The feeding parents will be pale, while the non-feeders will have more normal coloration. This is a gradual process as the rearing process progresses. This loss of color in the feeding parents is probably the result of a depleted blood supply of the pigment necessary for feather coloration. As the properly pigmented feathers are molted, they are replaced by feathers that lack the pigment. It gives the feeding parents a "mottled" appearance.

At the San Antonio Zoo, some three-month-old parentally reared young were pulled from the flock to keep some hand-reared flamingos company and aid in their socialization and weaning. They were separated from their parents for 1.5 months. Within a day of their return to the flock, the juveniles were being fed by their respective parents.

Fledging

When the feathers harden and the birds have the ability to fly, flamingo chicks are considered fledged. (They attain flight stage in 90 to 120 days (Allen, 1956)). For Caribbean flamingos, fledging is 70 to 75 days (Shannon, pers. comm.). In the Camargue, greater flamingo chicks have been known to fledge as early as 62 days. If pressed, wild lesser flamingo chicks can fly at 65 days (Brown, et al, 1982). In areas where adult lessers have to travel long distances to feed, the chicks develop slower and flight can be delayed as long as 90 days.

Sexual Maturity

Greater, Caribbean and Chilean flamingos are capable of breeding in their second year. In other words, a 1996 hatch bird can breed in 1998. However, the majority of those birds wait until later. Young, juvenile flamingos will participate in ritual displays and nest building. This practice probably "hones" these skills and prepares them for the future.

Bonding and Pair Formation

Observations and records with the San Antonio Zoo's Caribbean flamingo flock show that the initial pair bond of young flamingos is almost always with a peer, when peers are available. In other words, a 1996 hatch bird will pair with a 1996 bird. After the initial bonding, if a mate dies or if a new mate is acquired, then the age of a new mate is much more variable.
Reproductive/Egg Management

General Record Keeping

Egg and chick management depends on good record keeping and observations, as well as banding the birds with colored, numbered plastic bands. Knowing the reproductive history of your individual flamingos allows anticipating fertility in the eggs and making informed decisions as to whether to pull, recycle, substitute a dummy egg or allow continued incubation. Good records also help alert one to non-adept parents or parents with a history of chicks with medical problems.

Removing Eggs From the Colony

If one must remove eggs, for whatever reason, to minimize disturbance to the flock and other incubating birds, it helps to take the shortest route to the particular egg. Allow time, by moving slowly, for the flamingos to know you are entering and to get off their nests with the least amount of panic. In other words, allow enough time to allow the birds to rise up slowly, in a controlled way from their eggs and walk away from the nest(s). This will hopefully prevent any egg breakage or eggs falling out of the nests. If the birds won't walk away when given the opportunity, get low by going on your hands and knees, or duck walk for the final approach to the nest. If the birds stubbornly refuse to vacate the nest for the final grab, extend your hand, palm down over the egg as quickly as you can without totally spooking the bird. That way, if the parents strike out with their bill, it will hit your hand and not the egg. Most normal flamingos should leave the nest, but long-term captives, and especially hand-reared birds may be inclined to defend the nest from a human intruder to the end. It also pays to watch, or have an assistant to watch the return of the flamingos to the nests and make sure all returns to normal. The brooding parents should be highly motivated to return first and are easily identifiable by their bands and solicitous behavior to the egg. Non-parent birds returning to the nest will be aggressive to the egg.

Sometimes problems, such as egg breakage, disease, or predation, will require the removal of eggs. Eggs should be removed as soon after laying to ensure their safety and the pair given a dummy egg as a replacement. The handler should wear disposable gloves to reduce the transmission of germs to the egg, and the egg should be placed in a bowl lined with a paper towel and immediately transported to the incubator room where any excess dirt on the egg can be gently wiped off with a paper towel. To denote parentage, the egg is marked with a number or letter using a pencil or felt tip pen. The egg should be weighed and measured and all information entered into a data book. The egg should then be immediately placed in an incubator (37.5 C, 55% relative humidity). The entire process of egg removal and data collection should take no more than five minutes.

A cautionary note on removing eggs when dealing with small flocks with only a few pairs nesting: more care is necessary. Keep your visits as brief as possible and do not make wholesale changes, only small limited changes. At the San Antonio Zoo our small auxiliary group of 20 Caribbean flamingos had three nests with eggs. It was determined all three eggs were infertile. All eggs were pulled at one time with intentions of getting the birds to recycle. However, doing it all at once caused abandonment of the nest site. The infertile eggs should have been removed one at a time (see other note under recycling pairs).
Candling

If the egg is clean and free of dirt, determination of fertility may be made as early as four days following laying. At this stage, fertile eggs have a uniform "rosy glow" about them. After seven days of incubation, eggs free of dirt may be discarded if they are candled infertile, as by this time fertility, or lack thereof, is quite evident. Eggs that are particularly dirty may not be easy to candle and, therefore, should not be discarded. (These eggs should be routinely smelled to ensure they are not becoming rotten. It is advisable to move these undetermined eggs to a second incubator if one is available). Candling should preferably be done by personnel familiar with the composition of flamingo eggs, as the strikingly orange yolk could be mistaken as a sign of fertility. The candling process should be done as quickly as possible so the egg does not cool off too much. The candler should ensure that the egg is not jarred during the process or does not become too hot from the light source. Eggs are candled once a week to monitor development. Any fertile eggs that die during incubation can be necropsied to determine cause of death.

Returning Eggs to the Colony

As the time of hatching approaches, eggs should be carefully monitored. If the egg is to be returned to the parents (and not hand-reared from day one), the optimal time is when the chick is just beginning to internally pip or just before. By returning the egg to its parents at this time, the egg is maintained in the safe environment of the incubator that much longer. However, circumstances may dictate that the egg may need to be returned when the chick is in the air cell. This method is used when hatch dates for several chicks are one to two days apart. This will help reduce the amount of stress placed on the nesting birds by minimizing the times one has to venture into the nesting colony.

When returning eggs to parents for hatching, it is important to remember the pipping egg does not need to be returned to its biological parents. To increase the odds of survival for the chick, the egg should be placed under a pair that has demonstrated good parental skills in the past. In the case of new breeding flocks, eggs are best placed under parents that have demonstrated good incubation techniques with their dummy egg. After the egg is placed back under the parent, it is critical that the pair be monitored to ensure that the egg remains on the nest and is not kicked off in the uproar and scuttle that occurs during the switching period. The same techniques used in returning eggs should be used in removing eggs.

Also, see the Parental Care section of this chapter.

Recycling Pairs

To increase the number of fertile eggs produced in one season, females can be encouraged to lay again. This is accomplished either by removing a dummy egg from the pair any time during the incubation period or by removing the nesting pair’s egg for artificial incubation and not replacing it with a dummy egg. Although the production of a second egg will not always occur, if it is early enough in the nesting season, most pairs will lay a second egg, and even a third egg is possible. When using this technique to increase the number of eggs laid, it is important to remember to keep an appropriate number of pairs sitting on dummy eggs so that there are enough parents to raise all the chicks. Otherwise, one will be forced into hand-rearing a chick. If an institution has the skill and means to hand-rear chicks, this can be an effective way to maximize production. Properly hand-
raised flamingo chicks are fully capable of integrating into the flock and are reproductively viable (Perry and Atkins, 1997). The San Antonio Zoo has had a hand-reared pair successfully rear chicks.

This can be an effective tool in a pinioned flock with a history of producing more infertile eggs than fertile ones. An egg can be pulled and replaced with a dummy while the egg is artificially incubated. If after seven days an egg is determined to be infertile, the dummy egg can be pulled and the nesting pair will hopefully recycle and possibly lay a fertile egg. This can significantly reduce the time wasted on incubating infertile eggs. If the egg proves to be fertile, it can be returned to the parents at the appropriate time or be a potential candidate for hand rearing.

At the San Antonio Zoo the small flock of 11 Chilean flamingos were breeding, with three pairs nesting. The conditions they were nesting in required hand rearing of any chicks produced. They were able to keep those three pairs nesting and recycling from July 1st until the end of November. The three pairs of flamingos produced a total of 13 eggs. They were able to do that by pulling one egg at a time, thereby leaving two pairs to continue brooding until the third pair recycled and laid their next egg. Then one of the eggs was pulled from the next longest sitting pair, allowing them to recycle, and so on. By keeping at least two pairs brooding, they were able to maintain nesting and recycling. Of the 13 eggs, 11 hatched, and nine were successfully reared.

Dummy Eggs

Flamingos will readily accept a substitute or "dummy" egg as a replacement for their real egg. The egg should be white and approximately the same shape, size and weight of a real flamingo egg (see Egg Size section). A chalky surface is not necessary. Dummy eggs made of plaster or wood will work well. Another way of creating dummy eggs is to save infertile eggs. The infertile egg can be blown out and refilled with sand or other suitable material. Also, if an infertile egg is not compromised with a crack or torn membrane, it will not become rotten too early, and may last long enough to function as a dummy. Infertile eggs can be refrigerated until needed.

End of Season Management

When the breeding season is near the end, there may still be one or more pairs still incubating eggs. However, the colonial nature of flamingos and the desire to join the flock may be strong enough to cause abandonment of the remaining egg(s). At this time, dummy substitution or just plain removal of the egg(s) for evaluation and potential hand rearing may be in order to prevent their loss.

Parent/Chick Management

Chicks may also require hand rearing when the chick itself is sick and needs veterinary attention or when the parents are neglectful or inept/inexperienced.

With an inexperienced pair, the chick will not be defended, brooded or fed like normal. One will see the chick more than momentarily alone and being abused by other flamingos. Long term, even a healthy chick will weaken, chill, and appear dirty from lack of parental preening and protection. If the chick lacks a feeding response and interest in attentive, solicitous parents, it may necessitate
removal from the colony for veterinary attention and potential hand rearing. Please refer to the Chick Management section for further details.

Summary

Since zoos can no longer freely remove flamingos from the wild, captive propagation has become a high priority. Zoos should be able to achieve captive, self-sustaining populations for all flamingo species. Hopefully, the information provided in this chapter, and the entire Flamingo Husbandry Manual, will help the zoos not currently breeding their flamingos to do so and enhance the success of the zoos that are already breeding flamingos.

If your flock is not breeding, try something different. Separating a portion of the flock and re-introducing them later is being investigated as a stimulus for breeding. Introduction of nests and eggs can be tried. Use of mirrors to fool flamingos into thinking the flock is bigger has been used in the past. Moving the flock to a new location or setting up a new flock in a new exhibit can also be an effective stimulus. Introducing new birds to the flock can trigger reproduction. Never assume breeding cannot occur! For flamingos, change itself can be a stimulus.

Acknowledgements

I would like to thank all who have so freely shared information with me: Catherine King, Adelheid Studer-Thiersch, Peter Shannon, Sara Hallager, Susie Kasielke, Sherry Branch, Stephanie Costelow, Linda Henry, Sue Maher, Kim Smith and all I fail to mention. I especially have to thank Chris Brown and Sherry Mossbarger for their patience and guidance. Thanks to all the flamingo observers at the San Antonio Zoo, especially Clarita Johnson. Your work and insights are a part of this chapter.
Bibliography


Chick Management
Facilitators: Sherry Branch, Sea World Orlando; Susie Kasielke, Los Angeles Zoo; Catherine King, Rotterdam Zoo

Introduction

This chapter covers the special aspects of chick management. There are some general management guidelines that have been covered earlier in the Management Chapter. Please also see the chapters on Reproduction, Health and Housing for more information.

Chick management can be broken down into two main types: management of chicks being parent-reared or as part of a colony or flock, and management of chicks being hand-reared.

Colony Management

Managing flamingo chicks that are part of a colony presents unique challenges. Generally, chicks should only need to be manipulated if they are ill, abandoned, or regularly being picked on by other birds. In the event that it becomes necessary to manipulate a chick, the keeper should know that any intrusion will affect the dynamics of the entire colony and may increase the opportunity for injuries to occur.

In large colonies (50+ individuals) catching and restraining chicks is more risky than with smaller colonies. Flamingos panic easily, and it is wise to move slowly around them to avoid startling them, letting them move out of the way on their own. It is also important to use your most experienced staff when manipulating chicks within a colony. If the chick needs daily attention, it is recommended that it be removed until it is back to normal, rather than to attempt entering the colony and restraining the chick frequently.

Primary Concerns

Parental acceptance of the chicks is a primary concern (see Chick Abandonment). From hatching you should see both parents (in some cases you may only have one parent) feeding, brooding and protecting the chick. Most adults will vigorously defend the chick from other adults and other chicks. Some adults defend better than others, and you will need to make sure other adults aren’t constantly harassing the chick. You may even see aggression between the pair who are feeding and brooding the chick. The chick should be very vocal from day one, and parents usually respond only to their own chick’s vocalizations. Chicks can swim from the first day, although they can’t swim for long periods. A general visual assessment of the chick should show you an active, vocal, healthy-looking chick that is being brooded, fed and defended by at least one parent.

Secondary Concerns

Other things to watch for with a newly hatched chick would be nest conditions and weather conditions. Nest conditions may include the level of the water around the nest and the height of the
nest itself. If the nest is too high and the chick falls out, it may not be able to get back up into the
nest. Sometimes a chick will use a nearby nest if it is unable to get back up into its own. Weather
can be a problem too. If it rains continuously chicks can get wet and be unable to thermoregulate.
Too much rain can also contribute to high water levels around the nest. Water that is deep around
the nests may cause nest erosion, loss of eggs and even loss of chicks if they are unable to get out
of the water.

Chicks may also eat dirt substrate from around the nest, which can lead to impaction.

You should step-up your predator control during this time, as gulls, herons, and other animals will
predate the youngsters.

Pinioning

If your management program calls for pinioning, this is something you can do during a catch-up to
assess the chicks. (See the Health and Medicine Chapter for pinioning techniques). One thing to
consider when pinioning chicks is that it is better to do it when the chicks are younger (two to ten
days old). You may need a general anesthesia if you do it when the birds are older. If you pinion at
less than five days of age, the chick is usually still in the nest. You want to be very careful if there
are other birds on eggs, as eggs may be smashed when catching up the chicks. Even young
chicks can be very mobile and may prove difficult to catch. Novices may want to contact people
from other zoos who have experience in doing this. (For restraint techniques see the Capture,
Handling and Restraint section in the Flamingo Management Chapter or the Physical Restraint
section in the Health and Medicine Chapter.)

During this catch-up you may also want to conduct other procedures such as weighing, taking blood
for genetic sexing, tarsus measurement, banding, adding a transponder chip, egg candling of other
eggs and nest management. Be aware of how long you are in the colony and try to keep all
handling and disturbance to a minimum. This is a judgment call that should only be made by
experienced staff.

If done properly, flamingos quickly adapt to the regular handling of young chicks and other nest
management activities. A brooding parent may not even stand up when an egg or chick is removed
from under him or her.

Banding and Chick Identification

You can permanently band a chick at 60 days, but some people prefer to use temporary bands
before that. Plastic poultry bands work well temporarily. These must be checked for tightness often
as the chick grows. A color dye works well if you have only a few chicks. Keep in mind that dyes
may fade and wash off so frequent reapplication may be necessary.

Various flamingo holders solve their identification problems in different ways (input from the Web).
San Diego Zoo, as well as Rotterdam Zoo staff place transponders in the chicks when they are
pinioned. The birds are recaptured at a later date for final banding. Disney’s Animal Kingdom
places plastic bandettes on their Greater flamingo chicks when they do the neonatal exam.
Pinioning and drawing blood for sexing are done at the same time. The bandettes have to be
changed to a larger size at about one month of age. At two months old the chicks receive their
adult bands. Past experience has shown the bandettes fall off before they become too tight. Many
years ago, Audubon Park Zoo would alternate a chick’s pinion site, depending on the order of hatching. Height and other definitive physical characteristics, such as color, were noted for each chick as it developed. This enabled the staff to definitively identify the chick when it was finally banded. This method has also worked well for older, parent-raised chicks, which can be further identified when their parent(s) feed(s) them. At the Wetlands and Wildfowl Trust in Slimbridge, England, they fit their five-day-old chicks with web tags until it is time to band and/or microchip them (see Marking Flamingos in the Management Chapter).

When permanently banding a bird at 60 days, if this is your first hands-on, you can sometimes do a physical exam at the same time. This can be used as a training opportunity for vets and keepers (see the Health and Medicine Chapter for sample collection information). Since there is some correlation between tarsus measurement and sex (see the Addendum to the Flamingo Management Chapter), you can also do a tarsus measurement (i.e. a larger tarsus = a male). If you have a lot of chicks, you may want to do just a brief visual check, weigh, pinion and return the birds.

**Chick Issues**

**Chick Abandonment**

The decision to pull a chick that has been abandoned is a difficult one. Sometimes chicks can be left alone for several hours but may not be abandoned. It depends on a lot of variables and should not be done without a great deal of consideration. It may also depend on your institution’s policy on hand rearing. The decision to pull a chick should only be made by an experienced person who has spent a lot of time observing the situation. Things to look for include: chick is isolated, getting dirty, not being fed by either parent, shivering, lethargic, unable to stand, lack of good vocalizations and no contact with either parent. Other considerations may be approaching darkness, threat of predation, and continuous aggression from other flamingos. No other flamingo will accept any chick but its own so fostering to another pair is not possible.

If you must pull a chick you should immediately provide supportive care, i.e. heat, food, and/or fluids. Do this until you can stabilize the chick and then return it to its parents as soon as possible. Try to return it in the early a.m. so you have all day to watch. Chicks have been pulled for as long as two weeks and returned to the flock, and the parents have accepted them back. Your first choice should always be to return the chick to its parents.

Another option, if you are able to, may be to offer supplemental feedings to the chick while it is still in the colony (see the hand-rearing section of this chapter for diet). This option will work in some cases, but it requires thought on how to get the chick alone without too much disturbance to the rest of the flock.

As the chick gets older and starts eating food on its own, you should add extra pans of food so the chicks don’t have to compete with the adults. Also, if the adults are fed a dry pelleted food, providing pans of food with water in them can help encourage feeding.
Hand-rearing

Sometimes it becomes necessary to hand-rear a chick for medical reasons or for reasons mentioned under chick abandonment. The concerns of hand-reared chicks becoming imprinted on humans have been raised, however, it has been proven that they slowly lose this dependence after being assimilated into the flock. San Antonio Zoo personnel were instrumental in formulating the early guidelines for hand-rearing flamingo chicks, and more recently the National Zoo staff has redefined the protocols for a more expedient, less labor-intensive process.

Care and Feeding

Early Chick Handling and Brooder Requirements

Once a chick has hatched and dried, the umbilicus is swabbed with a dilute betadine solution, and it is placed in a brooder with a clean towel substrate, with an initial temperature setting of 99˚F (37.22˚C). During the first two weeks after hatching, the brooder temperature is critical for a chick. If a chick is too cool or too warm, this in turn will affect proper food passage and, thus, the well-being of the bird. Temperature guidelines must be utilized as just that, guidelines, as each bird is slightly different. The temperature is gradually lowered over an approximate two-week period until it is at room temperature. Heat can be provided by a forced-air brooder or a brooder with a 100-watt flood lamp that warms the surrounding air. If a chick is shivering, the temperature should be slightly increased. If a chick is panting or is lethargic, perhaps the temperature is too high. Also critical during the first two weeks after hatching is the chick’s hydration. This can be controlled by dilution of the formula. If the chick’s feces are thick and pasty or it seems to have trouble defecating, adding more water to the formula when feeding can increase the hydration, which in turn allows for better food passage. However, you don’t want the formula to be so diluted that the chick is not receiving enough calories to gain weight. [Note: During the first couple of days it is not unusual for a chick to lose weight and then begin gaining weight under the formula dilution guideline.] Strengthening the formula too soon will lead to impaction and dehydration. Weighing the chick after hatching or retrieval from the colony gives you an important benchmark to work from. Thereafter, a morning weight, prior to the first feeding of the day, allows you to follow the developmental progress of the chick.

Feeding the Chick

1. Feed under a heat lamp on a clean towel to keep the chick warm. After warming the formula, stir well to avoid hotspots, then test it on your wrist. Keep the formula container in a bowl of warm water to prevent cooling off during feeding. The chick may refuse formula that has cooled.

2. Place index finger under lower mandible to cradle head and encircle the neck with the thumb to control head movement (forming a semi-circle). Once the chick is conditioned to feeding, it may sway its head side to side slightly. Cradling the head will offer better control (see photo).

3. When the chick elicits a feeding response, dribble formula slowly into the tip of the lower mandible with a syringe, either with a catheter tip syringe (diagram A) or with a luer lock
syringe with the lock cut off (diagram B). It is very important to feed slowly, making sure the chick is swallowing while you slowly push the plunger on the syringe. It is easy to aspirate a flamingo chick if you feed too fast. The chick will stop when full.

4. Wait approximately 8-10 hours after hatching before offering the first feeding. Thereafter, feedings should be 2-3 hours apart, between the hours of 6:00 AM and 10:00 PM. The amount given is gradually increased at each feeding, if the chick will take it. Start with an initial amount of 3-4 cc of lactated ringers or unflavored children’s electrolyte-type product for a newly hatched chick. At the second feeding, formula is introduced at a 75% water/25% formula dilution initially. The formula is gradually strengthened over the next week or two (depending on the chick’s hydration and feces consistency) to 100% formula (see Figure 1). IMPORTANT: Most problems observed with hand-rearing flamingos are seen in the first two weeks and are caused by feeding formula that is too thick, thus impacting the chick.

5. As the chick grows, the frequency at which the chick is fed decreases to three times per day (at approximately 30-40 days of age, depending on the bird), while the amount at each feeding is increased to a maximum of 60 cc. Larger syringes can be used as the amount fed increases.

Under the traditional hand-feeding method, as formulated by the San Antonio Zoo (Kunneman and Perry, 1992), amounts fed were gradually increased as the chicks were fed ad lib prior to weaning, up to as much as 180-200 cc each feeding, with the frequency fed reduced to three times per day (see Figures 2 and 3). This was continued until the chicks were 1 1/2 - 3 months of age, then the middle feeding was dropped. After a few days the morning feeding was dropped, then finally the evening feeding was dropped, as the chick increased foraging on its own to maintain its weight. This method kept the chicks full of formula but decreased self-feeding from the food pan, hence delaying the weaning process.

The accelerated method protocol defined by the National Zoo (Hallager, 1996; Bishop, 1998) limited the amount of formula fed to a maximum of 60 cc at each feeding. Formula was offered only three times per day by around day 12-15 (depending on the bird).

The five stages of this accelerated method are:

1. Stage One: The first feeding consists of lactated ringers or water. At the second feeding the birds are fed a diluted formula consisting of 75% water and 25% formula. The first 2-3 days they are fed every 2-3 hours, between 6:00 AM and 10:00 PM. The first stage is to gradually strengthen the formula to 100% over the next week, though this stage has ranged from 2-15 days, depending on the chick.

2. Stage Two: Gradually increase the volume to 60 cc, while decreasing the feeding frequency to three times per day. At the same time, gradually lower the temperature so that by around day 12 the chick is maintained at room temperature. A 100-watt amber flood lamp hung at one end of an open-air brooder provides a heat source. Solid food, a complete flamingo pelleted diet, broken into small pieces, is offered on day seven, served both dry and soaked in water. The chicks will instinctively begin picking at the pieces, however, initially, they will not be ingesting too much.

3. Stage Three: Maintain feeding the volume of 60 cc of formula three times per day until the chick is over 400 grams. This averages about 24 days old.
4. Stage Four: The weaning process involves reducing the volume of formula to 30 cc at one feeding and then discontinuing it. First, reduce the noon feeding and then discontinue it, then repeat the procedure with the afternoon and morning feedings. The reduction of formula in the weaning process is in direct proportion to the chick’s ability to maintain or gain weight by self-feeding. Weaning should take an average of 10 days.

5. Stage Five: Post weaning, chicks are maintained in a back area away from flock competition until they are approximately 30 days old. Body weight is monitored daily until the chicks are introduced to the colony. After that, the chick’s interactions with the flock should be watched as well as continuing to monitor its weight. The chick should be removed from the group in the evenings until you are certain it has adjusted well to the colony.

Chicks have been weaned between 29-42 days under this 30-day wean objective. Flexibility of process and individual evaluation of each chick, with changes based on differences in development, make this accelerated method successful, saving both time and labor.

Notes:
* Until the chick demonstrates a strong swallowing response the formula should be fed much diluted. The chick should be encouraged to stand while feeding. The continuous vocalizations during feeding are a good indication that all is proceeding well. All hand reared chicks should be weighed regularly. To ensure proper growth a weight gain in the region of 8% per day (Chilean Flamingo; Liggett 1989) to 10% per day (Caribbean; Kunneman & Perry 1990) should be expected. If weight gains exceed this the amount of food should be reduced. Chicks are normally fed five times a day, every two hours for the first ten days, four times per day up to ten weeks of age and twice a day from ten weeks until weaning. Unless the chick is showing a particularly slow growth rate, night feeds are not necessary. Hand reared chicks wean between 80 and 130 days.

* Flamingos chicks which have been abandoned by their parents may refuse to accept food from a syringe and may have to be fed via a catheter tube. When tube fed the formula must be liquidated to prevent clogging. All feeding equipment must be scrupulously cleaned and disinfected after each feed. Exercise is very important for young flamingos to reduce the risk of abnormal leg or wing development. Imprinting does not always occur in hand reared flamingo chicks but to reduce the risk of imprinting contact between human attendant and chicks should be minimized. Rearing chicks of a similar age together also avoids imprinting.

* Some chicks raised under the accelerated weaning process have experienced leg problems at fledging age. Captive hatched and reared flamingos are prone to developing "bow legged syndrome" found in other long legged birds (see the Metabolic Bone Disease section in the Health and Medicine, Chapter 6). This condition has been associated with nutritional factors in conjunction with growth rate (Brunning 1973, Humphreys 1985, Fowler et al 1987). Exercise and supplements of calcium and vitamins have shown some success in preventing these problems in other long legged birds (Brunning & Dolensek 1986, Duignan 1987).
Exercising the Chick

In a colony environment, the chicks would naturally exercise as they follow their parents around. In a brooder environment, chicks should be taken out on warm days for short walks to strengthen their legs after two weeks of age. A natural substrate is preferred. It is best not to walk the chick immediately after feeding. The chick will follow you closely, listening to your voice, so care should be taken not to accidentally trample it. A behavior that has been noted is that chicks will excitedly walk up to your feet and sit down suddenly.

Multiple Chicks

If it is necessary to rear multiple chicks, they may be introduced to one another as early as two weeks of age. Earlier introduction will not allow you to monitor the feces of the chick during that critical first two weeks when hydration is so important. Multiple chicks may reduce imprinting somewhat as the chicks have one another to focus on. Prior to introduction, the birds need to be identified in some manner. Various methods have proved useful and are listed near the start of this chapter (Banding and Chick Identification). Care must be taken upon introduction, as even a small chick can be aggressive to another. If aggression does occur, wait and try introducing at a later date. Placing the birds next to one another so they can see, or at least hear each other should ease the transition. Having a brooder mate will often times encourage picking at the solid food as they follow the leader.

Introduction of Chicks to the Flock

Once the chicks are weaned and have fledged, weigh more than two kilograms, are more than 100 days old, and are self-feeding well (as determined by maintaining or gaining weight), they may be introduced to the flock. This is best accomplished on a day when the chicks can be put out in the morning (in good weather) so observations can be made all day and when staffing allows for intermittent observations. Prior to introduction, using the same or similar food pans in the back area as the colony feeds from will benefit the chicks, as they may be hesitant about eating from an unfamiliar food pan. There may be some initial aggression by the flock, and the chicks may remain on the outside fringe until the group accepts them. If more than one chick has been hand-reared, waiting to put them out in small groups is preferred and beneficial over single introductions, as the chicks will have familiar “buddies” to mingle with until they acclimate to the flock. Minimal interaction with the chicks by aviculturists servicing the area will help as well. The chicks will gravitate towards the aviculturists when they enter the area, but this should not be reinforced through interaction. This gradual transition could take as long as a year. Monitoring the weight one week after introduction will indicate if the birds are utilizing the food pans and acclimating well.
References


## Figures

Figure 1 – Examples of hand raised flaming feeding records.

**SPECIES:** Chilean flamingo feeding record  
**D.O.H.** 11/2/93  
**WEIGHT:** 80 grams  
**TIME**

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
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<th>Wt.</th>
<th>Time</th>
<th>Amount</th>
<th>Diet</th>
<th>Remarks</th>
<th>Morbidity</th>
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<td>1</td>
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<td>1000a</td>
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<td>Lactated ringers only</td>
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<td></td>
<td>300p</td>
<td>3.5 cc</td>
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<td>730p</td>
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<td>60%H2O/40% Formula</td>
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<td>530a</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>600p</td>
<td>35 cc</td>
<td>25% H2O/75% Formula</td>
<td>Fecals look good.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>930p</td>
<td>35 cc</td>
<td>25% H2O/75% Formula</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>530a</td>
<td>35 cc</td>
<td>100% Formula</td>
<td>Started on 100% Formula.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>845a</td>
<td>35 cc</td>
<td>100% Formula</td>
<td>Fecals look good on full strength formula.</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Day</td>
<td>Temp</td>
<td>Wt.</td>
<td>Time</td>
<td>Amount</td>
<td>Diet</td>
<td>Remarks</td>
<td>Morbidity</td>
</tr>
<tr>
<td>---------</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1130a</td>
<td>35 cc</td>
<td>100% Formula</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300p</td>
<td>35 cc</td>
<td>100% Formula</td>
<td>Very vocal &amp; active.</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>715p</td>
<td>35 cc</td>
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<td></td>
<td></td>
<td></td>
<td>1030p</td>
<td>35 cc</td>
<td>100% Formula</td>
<td>11/11/93</td>
<td></td>
</tr>
<tr>
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<td>90°F</td>
<td>137 g.</td>
<td>600a</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>915a</td>
<td>35 cc</td>
<td>100% Formula</td>
<td></td>
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</tr>
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<td></td>
<td></td>
<td>1230p</td>
<td>35 cc</td>
<td>100% Formula</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>345p</td>
<td>40 cc</td>
<td>100% Formula</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>630p</td>
<td>45 cc</td>
<td>100% Formula</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>11/12/93</td>
<td>11</td>
<td>88°F</td>
<td>162 g.</td>
<td>615a</td>
<td>50 cc</td>
<td>100% Formula</td>
<td>Lowered temp. to 88°F.</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>1030a</td>
<td>40 cc</td>
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<td>100% Formula</td>
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<td></td>
<td>630p</td>
<td>45 cc</td>
<td>100% Formula</td>
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<td></td>
<td></td>
<td>1030p</td>
<td>40 cc</td>
<td>100% Formula</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/13/93</td>
<td>12</td>
<td>86°F</td>
<td>181 g.</td>
<td>600a</td>
<td>35 cc</td>
<td>100% Formula</td>
<td>Lowered temp. to 86°F.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000a</td>
<td>40 cc</td>
<td>100% Formula</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>230p</td>
<td>40 cc</td>
<td>100% Formula</td>
<td>Eating well. Vocal &amp; active.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>630p</td>
<td>40 cc</td>
<td>100% Formula</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>11/14/93</td>
<td>13</td>
<td>86°F</td>
<td>206 g.</td>
<td>545a</td>
<td>45 cc</td>
<td>100% Formula</td>
<td>Very vocal. Good F.R.</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Day</td>
<td>Temp</td>
<td>Wt.</td>
<td>Time</td>
<td>Amount</td>
<td>Diet</td>
<td>Remarks</td>
<td>Morbidity</td>
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</tr>
<tr>
<td>11/15/93</td>
<td>14</td>
<td>86°F</td>
<td>235 g.</td>
<td>930a</td>
<td>50 cc</td>
<td>100% Formula</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>120p</td>
<td>50 cc</td>
<td>100% Formula</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>530p</td>
<td>50 cc</td>
<td>100% Formula</td>
<td>Good F.R.</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>1000p</td>
<td>50 cc</td>
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<td>235 g.</td>
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<td>100% Formula</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1030a</td>
<td>55 cc</td>
<td>100% Formula</td>
<td>Eating well</td>
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<td></td>
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<td></td>
<td></td>
<td>230p</td>
<td>55 cc</td>
<td>100% Formula</td>
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<td>630p</td>
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<td></td>
<td></td>
<td>1030</td>
<td>60 cc</td>
<td>100% Formula</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Example of a typical chick feeding data sheet.
75 grams krill
75 grams capelin (heads, tails, & fins removed)
75 grams hard-boiled egg yolk
2 cups Gerber Oatmeal Baby Cereal (dry)
1 teaspoon Vionate
1/2 teaspoon calcium carbonate
1200 cc water

Blend well

Figure 2. Flamingo hand-rearing formula for chicks ranging from 1-30 days of age (Kunneman and Perry, 1992).

75 grams krill
75 grams capelin (heads, tails & fins removed)
75 grams hard-boiled egg yolk
1 cup Gerber Oatmeal Baby Cereal (dry)
1 cup Mazuri Flamingo Complete Maintenance pellets (soaked)
1 teaspoon Vionate
1/2 teaspoon calcium carbonate
1200 cc water

Blend well

Figure 3. Flamingo hand-rearing formula for chicks over 30 days of Age (Bishop, 1998).
Chapter 5

Nutrition
Facilitators: Ellen S. Dierenfeld, Saint Louis Zoo; Christine D. Sheppard, WCS/Bronx Zoo; Debra L. McDonald, Healesville Sanctuary, Victoria, Australia

Executive Summary

Flamingos have highly specialized feeding mechanisms, primarily the bill, which can sieve small food particles from water. However, they appear highly adaptable to the availability of different types of food in the environment. The diet of a single individual of some species could vary from almost totally herbivorous (Spirulina sp. cultures) to essentially carnivorous (Artemia salina). Most flamingos consume a diversity of foods. A wide range of feeding behaviors has been described for flamingos, used to obtain food from parts of the environment as different as the surface of mud flats and the bottom of bodies of water.

A variety of commercially available, grain-based diets containing 20 to 40% protein, developed using the nutrient requirements of poultry and duck species, have proven successful for maintenance, growth, and reproduction of flamingos in captivity and should be provided as the staple diet. There is no evidence that different flamingo species have different nutrient requirements; most important is providing a particle size (for food as well as grit) optimized for the filtration mechanisms of any particular species (1-4 mm for the larger species; < 1 mm for the smaller species). Reflecting the size range of the flamingos (1.8 kg Phoeniconaias minor to 3.5 kg for Phoenicopterus ruber, energy estimates range from 160 to 200 kcal (660 to 830 kjoule) daily per individual to between 230 and 290 kcal (960 to 1200 kjoule), respectively, depending also on activity level. Energy needs would be supplied by 2-4% of body mass in dry food containing 3 to 3.5 kcal/g daily. If diets are presented as slurry (up to 75% water) this may represent 10% of body mass.

Little formal investigation has addressed the issue of management/enrichment foods for flamingos. The majority of captive flocks are maintained in outside ponds during much of the year, and birds can usually be seen feeding on naturally occurring foods. The importance of appropriate exhibit pools is essential for flamingo enrichment. In the absence of naturally occurring organisms, possible enrichment items could include a range of small whole prey such as krill, copepods, and aquatic insect larvae to duckweed (Lemna sp.), chopped greens, and algae species. At the Bronx Zoo, bird staff working with a group of young American flamingos determined that frozen krill could function as a food reward for operant conditioning.

Introduction (CDS)

Flamingos are best known for their vivid coloration and for the shape of their bills, both characteristics strongly related to feeding and nutrition. While we don’t know, ultimately, why flamingos are pink instead of green or black or blue, we do know that their pink coloration depends on the ingestion of carotenoid pigments, which are chemically altered before deposition in the feathers. The shape of the beak is one of a complex of modifications that specialize various species for straining small food items from water – although the bill tip can still be used to ‘grasp and throw’ larger morsels (Zweers et al., 1995). The ability to filter small particles, coupled with the
ability to tolerate water of high salinity, allows flamingos to exploit some food sources that are unavailable to other species.

The captive nutrition of specialized feeders like the hoatzin or koala is constrained by physiological and anatomical specializations that restrict the types of food the animals can process. While flamingos have specialized mechanisms for feeding, that specialization affects the size of items ingested, not the type. The diet of wild flamingos can actually be quite varied. Basic guidelines for the nutrition of ducks and poultry appear to adequately predict the nutritional requirements of flamingos, and a variety of commercial products are available to fulfill these requirements.

**Feeding Behavior (CDS)**

Flamingos have a repertoire of feeding behaviors, which allow them to feed on land, on water surfaces, on mud flats, at the water’s edge, in the water column, or from benthic mud or sand (Allen, 1956; Jenkin, 1957). Rooth (1965, 1976) illustrated seven different feeding behaviors for the Caribbean flamingo. These behaviors generally target different types of organisms, found in different parts of the aquatic environment. Arengo and Baldassare (1999) report that in low-salinity ponds in Mexico, 99% of potential food was found in substrate samples. In high salinity ponds, only 13% of potential food items were found in the substrate, with 87% occurring in the water column. Arengo and Baldassarre (1998) also note that pond substrates changed, with increasing salinity, from mud and sand to algal mats to precipitates, which form a hard crust at very high salinity. Britton and Johnson (1987) noted hard, gypsum precipitates in high saline lakes in France and indicated that these crusts might preclude feeding from the lake bottoms.

As feeding behaviors have not been reported in equal detail for all species, it is not known to what extent the repertoire of feeding behaviors is shared. It is probable that all *Phoenicopterus* species exhibit the range of feeding behaviors illustrated below, corresponding to the variety of foods used by these birds. The lesser, James’, and Andean flamingos are less well studied and are more specialized feeders (Jenkin, 1957, Vareschi, 1978; Caziani and Derlindati, 2000). It is not known whether these species use all the methods of feeding described for *Phoenicopterus*, especially ‘stomping’ and ‘grab and throw’. The following descriptions are based on Allen, (1956), Jenkin (1957) and Rooth (1965,1976).

(Illustrations from Rooth, 1976, used with permission from Dr. A. O. Debrot, Subdirector, Carmabi Foundation, STINPA, Netherlands Antilles)

**Grab and Throw**: the bill tip is used to pick up large food items -- small fish, mollusks, gastropods -- in very shallow water, on the water’s surface, pond bottom or on shore. This occurs while stationary, walking or running. Rooth calls this ‘running’ and other authors ‘pecking’.
**Grubbing**: birds are floating in water, with the beak in substrate -- birds can reach the bottom at a depth equal to the length of their neck, which in *P. ruber*, is about 30 cm deeper than the length of their legs.

**Skimming**: the point of the bill skims through the upper layer of water as the bird walks or swims.

**Stamping 1: marking time** -- the heel joint is continually extended and retracted, alternating both legs; the head, inverted, is moved back and forth a short distance above the bottom. This can occur while the bird is stationary or moving slowly backwards. Food items from the substrate are filtered or pecked.
Stamping 2: circling around the bill -- the inverted bill is held at a center point, near the substrate, while the bird’s feet stamp in a circle around it. A circle takes about a minute, and the bird's head is lifted and lowered several times. The action of the feet deposits a small mound at the center of the circle, containing mollusks, gastropods, and other invertebrates on a bed of sand. Lighter organic debris collects in the groove around the mound but is apparently not consumed.

Trailing: inverted bill is dragged lightly along the surface of mud or water, leaving a meandering track 1-2 cm deep. ‘Organic ooze', algae, diatoms are ingested in this way. Tests showed organic content of mud near tracks to be 5-95% (Allen, 1956; Rooth, 1965, 1976). Rooth calls this behavior ‘walking’.

Walking, while filtering in water column (no illustration)
Jenkin (1957) produced a monograph on flamingo feeding that is still the best single reference on the subject. She synthesized sources on flamingo diets going back to the 18th century. The specialization and proposed function of the structures comprising the flamingo bill are also described in detail. Jenkin's information has been widely used and cited by other authors. Mascitti and Kravetz (2002) provide additional detail on the bills of the three South American flamingo species.

In a 'typical' bird, when the beak is open, the gape has a 'V' shape, the width of the gape increasing with distance from the head. The characteristic 'bent' shape of the flamingo bill serves to keep the edges of the upper and lower mandible more or less parallel when the beak is opened, and especially when the beak is not fully opened. This facilitates the use of the lamellae on the bill surfaces as a filtration system or sieve by keeping the space between the mandibles constant. Where in most bird species the lower mandible moves against the upper, in flamingos the upper mandible moves to produce the gape. When filtering, the neck is curved down so that the upper mandible is in the water. This allows the birds to feed with their heads closer to their bodies than would be possible if feeding took place with the lower mandible in the water. This is especially important for feeding behaviors that involve stirring up food with the feet.

The flamingos can be divided into two groups based on the shape up the upper jaw. Birds in the genus *Phoenicopterus* have 'shallow-keeled' bills, while the other three species have 'deep-keeled' bills (Jenkin, 1957, Mascitti and Kravetz, 2002). In 'deep keeled' species, the upper bill is very narrow and fits into the lower so that it is not visible in profile (Jenkin, 1957). In all flamingo species, the upper and lower mandibles support a complex and diverse array of lamellae, which vary within and among species in their size, shape, spacing, placement and flexibility (see Figures 1 and 2). These lamellae function as sieves during feeding and, in some cases, also as devices that exclude large items. Mesh size can be adjusted by 'tuning the gape' (Zweers et al., 1995). Filtering can take place with the bill closed, as well as open.
The flamingo tongue is substantial in all species, filling the mouth when the beak is closed. Withdrawal of the tongue produces a vacuum, drawing liquid into the mouth. The tongue then moves forward, forcing the liquid through the sieves formed by the bill (Zweers et al., 1995). Size and shape of the tongue vary, but in all species the tongue carries an array of spines, presumed to move food particles from the bill back into the throat (Jenkin, 1957). Taste buds are not found in the beak or tongue (Jenkin, 1957), but a group of taste buds has been described in mucosa of the ventral esophagus, which is behind the tongue (Bath, 1906). According to Jenkin (1957), two other types of sense organs are present in both jaw and tongue, especially near the bill tip and the edges of the mandibles. These organs, Herbst corpuscles and Grandry bodies, are found in the tongue and bill of waterfowl (Zweers et al., 1995) and may function primarily as pressure sensors.

The process of feeding is an extremely dynamic and complicated coordination of different bill surfaces, tongue, throat and head (Jenkin, 1957; Allen, 1956; Rooth, 1965). Zweers et al. (1995) has developed a detailed description, building on the earlier work, from video recordings of feeding by a trained, captive flamingo (P. ruber). The tongue is used to bring water into the mouth, then to force it out through the sieve formed by the lamellae on the bill. Jenkin (1957) reports that fresh stomach contents are nearly dry and concludes that little water is swallowed during the feeding process. Differences in bill structures among the flamingo species make it likely that details of the feeding process differ as well. A given species may also use different methods to filter different types of food (Jenkin, 1957).

Zweers et al. (1995) confirmed the observation (Mascitti, 1998) that filtering by flamingos does not depend only on the size of particles. An individual greater flamingo (other birds were present in the facility) was offered monotypic suspensions of measured amounts of seeds of different sizes, ranging from millet and poppy seed to pea-sized pieces of bread. These corresponded to maximum measured diameters of 0.25 -12.0 mm. The optimal size for filtering was 2-4mm, based on the number of seeds filtered in 60 seconds. While most of the seeds tested were accepted, the smallest seeds were too small to filter, and the bird eventually refused to feed on them. The largest seeds (peas and marrowfats) eventually discouraged the bird from feeding, as they were too large to filter. Interestingly, while the bird picked up pea-sized pieces of bread, it did not peck at the larger seeds. The video showed that the smallest seeds were filtered with the bill closed.

Offered mixtures of different seeds within the optimal size range, the bird was able to select grass seed (preferred) from barley, milos, or mung beans. In a test of discrimination among seeds of larger sizes, milos were ingested but not mung beans. Several mechanisms come into play here,
including manipulation of the gape to create filters of different sizes, for both inflow and outflow, and using the tongue to direct water outflow to different places along the bill, corresponding to different filter sizes. Sympatric flamingo species, *P. ruber roseus* / *Phoeniconaias minor* in Africa and *P. chilensis*/*Phoenicoparrus andinus* and *jamesi* in South America, have different optimal particle sizes and, therefore, may not compete directly for food (however, see Caziani and Derlindati, 2000). Table 4 (copied below) shows different sizes of particles found in the gizzards of the South American flamingo species.

<table>
<thead>
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<th>Availability in lake</th>
<th>Chilean Flamingo Gizzard</th>
<th>Andean Flamingo Gizzard</th>
<th>James’ Flamingo Gizzard</th>
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<tr>
<td>Diatom size (μm)</td>
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<tr>
<td>0-20</td>
<td>39.7 ± 9.6</td>
<td>0</td>
<td>11.6 ± 3.0</td>
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<td>21-40</td>
<td>39.2 ± 8.8</td>
<td>0</td>
<td>0.5 ± 0.2</td>
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<td>41-60</td>
<td>16.8 ± 7.8</td>
<td>3.1 ± 0.3</td>
<td>5.0 ± 4.4</td>
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<tr>
<td>61-80</td>
<td>2.1 ± 1.9</td>
<td>33.0 ± 8.0</td>
<td>8.8 ± 1.8</td>
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<td>81-100</td>
<td>0.0 ± 0.2</td>
<td>51.2 ± 10.1</td>
<td>0.6 ± 0.8</td>
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<td>101-120</td>
<td>9.8 ± 12.0</td>
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<td>0.2 ± 0.2</td>
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<td>&gt;120</td>
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<td>0.0 ± 0.1</td>
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<td>Seed size (μm)</td>
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<tr>
<td>700-1200</td>
<td>0.0 ± 0.0</td>
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<td>0.0 ± 0.0</td>
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<td>Grit size (μm)</td>
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<td>&lt;60</td>
<td>1.6</td>
<td>2.0 ± 1.3</td>
<td>0.5 ± 0.3</td>
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<td>0.5</td>
<td>1.2 ± 0.3</td>
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<td>3.2 ± 2.4</td>
<td>16.2 ± 20.9</td>
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<td>501-1000</td>
<td>92.0</td>
<td>90.7 ± 4.5</td>
<td>0.0 ± 0.0</td>
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</table>

From Mascitti and Kravitz, 2002, p. 82, with express permission of the copyright holder, the Cooper Ornithological Society.

Comprehensive Digestive Anatomy (ESD)

Length of intestinal tract (gizzard to caeca) ranged from 1.7 to 2.9 m in *Phoenicopteridae* sp., and 2.3 to 4.4 m in the smaller species (*Phoeniconaias minor* and *Phoenicoparrus* sp.) (n=29; Kear and Duplaix-Hall, 1975). In the same birds, caeca length ranged from 2.9 to 4.6% of total intestinal length (*Phoenicopteridae* sp.) but only 0.9 to 1.3% of total intestinal length in the latter group. These differences suggest that fermentation processes (to break down complex carbohydrates such as those of chitinous exoskeletons?) may play a larger role in digestive physiology of the more omnivorous species compared with enhanced digestive surface area of the more herbivorous species.

The Food of Wild Flamingos

Information on the food of wild flamingos derives from analyses of crop, gizzard and stomach contents (for example Allen, 1956; Jenkin, 1957; Mascitti and Kravetz, 2002; Tourenq et al., 2001), from sampling environments where flamingos feed (for example, Arenhe and Baldassare, 1995, 1998, 1999, 2002; Mascitti, 1998; Soto, 1988; Casler and Este, 2000; Caziani and Derlindati, 2000) and comparing areas where flamingos feed to areas where they have been excluded (Hurlbert and Chang, 1983). Because flamingos can use different feeding methods and can filter selectively, and
because some food items (algae, slime) are processed faster than others (seeds, mollusks), in most cases, the relative proportions of items consumed are not known. Flamingos of the same species, in nearby bodies of water, can be consuming very different diets (Jenkin, 1957; Hurlbert, 1982; Hurlbert et al., 1986; Vareschi, 1978; Arengo and Baldessari, 1999; Baldassare and Arengo, 2000). Feeding by large flamingo flocks has significant impact on the relative abundance of available food items in a given body of water (Tuite, 2000; Hurlburt et al., 1986). However, because in some areas flamingos feed on ‘monocultures’, we know that diets for individuals of some species can vary from 100% herbivorous (Spirulina) to 100% carnivorous (Artemia).

Foods reported for species of flamingos

*Phoenicopterus ruber ruber*

*Phoenicopterus ruber roseus*

*Phoenicopterus chilensis*

*Phoeniconaias minor*

*Phoenicoparrus andinus*
Surirella sp. and other diatoms >80 microns, algae; protozoa, nematodes, organic mud; immature sand crabs; insect and crustacean larvae, grit References: Jenkin, 1957; Hurlbert, 1982; Hurlbert and Chang,1983; Caziani and Derlindati, 2000.

*Phoenicoparrus jamesi*
Organic mud, algae, diatom frustules (25 species), vegetable residues (scant), preferring to forage in shallow (2 cm) water, consuming diatoms <60 microns; grit. References: Jenkin, 1957; Hurlbert, 1982; Mascitti, 1998

*Phoenicoparrus andinus*
**Surirella sp.** and other diatoms >80 microns, algae; protozoa, nematodes, organic mud; immature sand crabs; insect and crustacean larvae, grit References: Jenkin, 1957; Hurlbert, 1982; Hurlbert and Chang, 1983; Caziani and Derlindati, 2000.

**Phoenciparrus jamesi**

Organic mud, algae, diatom frustules (25 species), vegetable residues (scant), preferring to forage in shallow (2 cm) water, consuming diatoms <60 microns; grit References: Jenkin, 1957; Hurlbert, 1982; Mascitti, 1998

**Composition of Native Foods (ESD)**

No published reports of the specific chemical composition of native foods eaten by flamingos were found. A generic summary of nutrient composition of types of foods that may be consumed by free-ranging flamingos is found in Table 1. These data were extracted from the literature and do not

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Dried Spirulina sp.</th>
<th>Artemia salina</th>
<th>Copepods</th>
<th>Diatoms Mixed spp</th>
<th>Shrimp-Penaeidae &amp; Panulidae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water, %</td>
<td>4.68</td>
<td>89.09</td>
<td>76.00</td>
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<tr>
<td>Protein, %</td>
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<td>57.20</td>
<td>50.00</td>
<td>17.14</td>
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<tr>
<td>Crude Fat, %</td>
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<td>12.85</td>
<td>35.00</td>
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<td>7.17</td>
</tr>
<tr>
<td>Vitamins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin A, IU/g</td>
<td>5.98</td>
<td>454.50</td>
<td>14.07</td>
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</tr>
<tr>
<td>Vitamin E, IU/kg</td>
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<td>1.41</td>
<td>7.17</td>
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<tr>
<td>Vitamin B₁, Thiamin, mg/kg</td>
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<td></td>
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<tr>
<td>Vitamin B₂, Riboflavin, mg/kg</td>
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<tr>
<td>Vitamin B₃, Niacin, mg/kg</td>
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<tr>
<td>Vitamin B₆, Pyridoxine, mg/kg</td>
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<td>Vitamin B₁₂, Cobalamin, IU/kg</td>
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<td>Folic Acid, mg/kg</td>
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<td>Pantothenic Acid, mg/kg</td>
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<tr>
<td>Vitamin C, mg/kg</td>
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<tr>
<td>Minerals, %</td>
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<tr>
<td>Calcium</td>
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<tr>
<td>Concentration, mg/kg</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Copper</td>
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<td>8.98</td>
<td>10.00</td>
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</tr>
<tr>
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<td>90.00</td>
<td>45.98</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Nutritional content of some foods utilized by flamingos in the wild. Samples were commercially obtained and do not necessarily reflect wild dietary ingredients. All data (except water) is presented on a dry matter basis. Data extracted from aZootrition software (Wildlife Conservation Society, 1999) and bWCS Wildlife Nutrition Laboratory, unpublished.
represent actual dietary samples; nonetheless, some general statements can be inferred from this information. On a dry basis, these types of foodstuffs contain a variable protein content (invertebrates ranging from 16 to about 66% on a dry basis; widgeongrass seeds, 6 to 17%), and moderate to high fat and carbohydrate concentrations (7% to >30%; 5 to >50%, respectively), as well as quite high concentrations of vitamin E, vitamin C (both antioxidant vitamins), and B vitamins. With natural foods providing good sources of vitamin C, it is conceivable that the flamingo has a dietary requirement for this nutrient, but the ascorbic acid synthetic ability of the flamingo has not been established. Vitamin A concentration, on the other hand, is relatively low in natural foodstuffs, while carotenoid pigments may be quite high; presumably the flamingo meets its vitamin A requirements through enzymatic conversion of dietary carotenes. Mineral concentrations vary; sodium and chloride concentrations reported are, in general, high whereas calcium (Ca) content is quite low. Only in algal species (and diatoms) are Ca:P ratios >1.

Carotenoids and Feather Pigmentation (DLM)

While we still do not understand the ecological significance of the pink color of flamingos, clearly, color-feeding is a significant aspect of flamingo feeding husbandry. Proper coloration from dietary carotenoids is important, not only aesthetically from an exhibition perspective, but may be a component of behavioral recognition, reproductive success, and impact other physiological and health processes. Between 500 and 600 carotenoid pigments have been identified in vertebrates, some specifically responsible for coloration of feathers, skin, eyes, scales, beaks, and egg yolks. Pigmentation of feathers and exposed tarsal and facial skin of flamingos is derived from yellow, orange and red molecular components found in the natural diet (Fox and Lint 1975). Only plants synthesize carotenoid pigments; however, many animals (including insects, mollusks, crustaceans and fish) concentrate and further metabolize them to provide a rich dietary food source for birds.

The deposition of pigment into specific tissues is dependent upon three primary factors:
1. The quantity of the appropriate carotenoid in the diet.
2. The bird's capacity to digest and absorb specific carotenoids and metabolize them to the correct chemical form (factors that improve fat digestion can improve carotenoid incorporation).
3. The capacities of specific tissues to take up carotenoids and insert them into the structure of growing tissue.

Dietary carotenoids may be used directly to pigment tissues or metabolized to other carotenoids prior to incorporation; as a consequence, tissue carotenoids may differ from those consumed. It is not known if the feather follicles can further metabolize carotenoids in order to change feather color, or if color discrimination only occurs at the level of carotenoid uptake from the blood. Each carotenoid appears to have its own individual pattern of absorption, plasma transport and metabolism, and there are considerable species differences in the types of carotenoids that are preferentially absorbed and metabolized (Stradi, 1998).

Pigmentation in the Flamingo

The pigments mainly responsible for the plumage color of flamingos are the red carotenoids canthaxanthin, phoenicoxanthin and astaxanthin (Comben, 1976), and metabolism has been studied in detail (Fox, 1975; Fox and Lint, 1975). Flamingos effectively absorb and utilize β-carotene as a precursor for skin and feather pigments (e.g. astaxanthin), but they do not readily
utilize many dietary xanthophylls, including astaxanthin. Instead, astaxanthin is converted from canthaxanthin and deposited in feathers (Klasing, 1998). They demonstrate a selective metabolic preference for ingested carotenes over xanthophyllic fractions, and oxidize carotenes in a stepwise manner (first to ketones, such as echinenone and then to the chief derivatives, canthaxanthin from β-carotene and phoenicopterone from β-carotene) (Fox and Lint, 1975). The hydroxylation of canthaxanthin to phoenicoxanthin and astaxanthin occurs at the site of epidermal and feather growth (Fox, 1975). Trials with β-carotene, lycopene, and zeaxanthin failed to produce any detectable metabolic results (Fox, 1975).

Captive birds can live, reproduce, and appear healthy when consuming a diet devoid of carotenoids as long as vitamin A is provided. However, due to the highly developed social behavior of many species of free-living birds, carotenoids may be required for breeding success. There is some debate as to whether poorly colored birds are less likely to breed. Only sexually mature adult flamingos are fully colored, and it is possible that individuals ‘recognize’ potential breeding partners by the depth of their red coloration. According to early anecdotal literature and speculation (Kear, 1974), more consistent breeding results were achieved when zoos recognized the importance of the bright color in flamingos and added carotenoids to the diet. However, no significant correlation between coloration and reproductive fitness has been demonstrated experimentally in captive flamingos, information is clearly equivocal, and other factors apart from coloration appear more important in breeding success (AZA & EAZA Ciconiiformes Advisory Groups, CICAG, pers. comm.) On the other hand, captive flamingo diets are much less variable than wild diets, so variation in coloration may be less than in the wild.

Pigmentation Loss in the Flamingo

Although pigments are deposited in the liver, blood, fatty tissue, exposed tarsal and facial skin, feathers and yolk (Fox and Lint, 1975), if deprived of their natural food and carotenoid supplementation, flamingos become pale in color. Birds lose blood carotenoids on a carotene-deficient diet considerably faster than they restore canthaxanthin to the blood on a carotene supplement. This may be because the anabolic accumulation of canthaxanthin requires expenditure of chemical energy for oxidation of the hydrocarbon carotene (Fox and Lint, 1975).

The red leg color of the James’ flamingo tends to fade in captivity, and the violet chest of the Andean flamingo may also be lost (Kear and Palmes, 1980). Apart from diet, environmental conditions may also impact the ability of flamingos to express normal coloration. “Stress” can modify hormones such as thyroxine and corticosterone to negatively impact xanthophyll metabolism; direct effects of stress on flamingo pigmentation have not been examined.

Canthaxanthin, the primary feather pigment, is a rather unstable compound and warrants a continuous dietary supply as long as the birds are molting. At other times of the year, limited body stores in adipose and liver tissues can be utilized to maintain color. Canthaxanthin pigment is generally considered to be nontoxic, with an LD50 determined at about 25 mg/kg (in experiments conducted with laboratory model species). However, high levels of dietary carotenoids fed to flamingos have resulted in dull plumage, with the skin of the head developing a purplish tinge (Comben, 1976). Excesses in other species have resulted in mineral deposition in the retina. In addition, high levels of carotenoids can compete with fat-soluble vitamins (A, D, E, and K) for absorption, transport and deposition pathways within the body, and excessive levels can indirectly lead to deficiencies of these vitamins (Comben, 1976).
Pigmentation of Crop Milk

Once flamingos have laid and hatched their eggs, both adults feed the young by crop secretion for up to three months in the wild and up to one year, or even into the next breeding season, in captivity. This secretion (for nutrient composition see Handrearing Section) is formed by glands that lie close together in the upper digestive tract (Studer-Thiersch, 1975). Crop milk secretions fed to chicks are bright red in color for the first few weeks of the chick’s life and gradually fade. While the red color was once accredited to blood in the secretion, it has been clarified that the coloration results from canthaxanthin carotenoids at a concentration of 0.4 mg/100mL (van Bocxstaele, 1974; Fox, 1975). Adults tend to lose plumage color during feeding of chicks. It has been surmised that they are meeting specialized needs of the chick for vitamin derivatives (Kear, 1974) through pigment mobilization. Despite carotenoids being made available to the developing chick in the egg yolk and crop milk, chicks fail to assimilate any pigments into tissues (Fox, 1975).

Health Issues Linked to Captive Diets (ESD, DLM)

Leg problems (see Health and Medicine, Chapter 6) and obesity in captive flocks may be associated with diets high in energy content that result in too rapid growth, but nutritional diseases/imbalances have rarely been reported in flamingos. An imbalance of Ca and P due to high Ca relative to P more likely underlies this observation -- levels of Ca above 1% have been shown to result in bone deformations in poultry. Early diets designed for captive flamingos, comprising dried shrimp and cereal grains, resulted in mineral imbalances and vitamin deficiencies (Wackernagel, 1975) – in particular, vitamin A due to oxidative deterioration. The appearance of rachitic bones together with a hyperplastic parathyroid gland can result from vitamin A antagonism known to exist with vitamin D (Mertz et al., 1985). Chilean flamingos have exhibited a condition superficially similar to rickets, involving bending of the tibio-tarsus and thickening of the head of the bone (refer to Health and Medicine, Chapter 6 for further details). The condition has not been found in young under about four weeks old, but birds at all later stages of plumage have been affected (Humphreys, 1975), suggesting that yolk storage reserves and/or crop secretions may be better balanced with regard to fat-soluble vitamins compared to diets consumed by older birds. Vitamin A toxicosis has not been reported in flamingos; nonetheless, interactions among the fat-soluble vitamins (A, D, and E) probably warrant further investigation in/of this group. Vitamin E deficiency has been reported but not experimentally induced in captive flamingos (Fowler, 1986; Dierenfeld and Traber, 1992). Circulating concentrations of vitamins A and E in flamingos may be useful in evaluating health status (see below). High levels of vitamin E measured in wild foods (Table 1), along with elevated concentrations of polyunsaturated fatty acids (which oxidize readily) in both wild and captive diets suggest a possible increased dietary requirement for this nutrient in its role as an antioxidant. Hemosiderosis (iron accumulation in extraneous tissues) in flamingos has been reported anecdotally as a health issue (although not a primary pathology) and may be linked to excess dietary iron and/or antioxidant status in association with vitamins C and vitamin E; this condition is currently under investigation (Marques, pers. comm.)
Feeding Requirements of Captive Flamingos (ESD)

Placement of Feeders and Diet Form

Historically, it was recommended that flamingos be fed in bowls, troughs, or pools away from main water bodies to minimize fouling of exhibit water (Testa and Johnson, 1992; Kear, 1974). However, behaviorally as well as physiologically, feed or feeder placement directly in or on the water can provide an optimal feeding environment and this is recommended when possible. Bildstein et al. (1991) demonstrated that the food intake of juvenile Chilean flamingos was at most 82% that of adults due to aggressive displacement, hence, appropriately spaced and adequate numbers of feeding stations should be available to minimize aggression between birds. Feeding stations should have access from all sides to permit less dominant birds an easy escape if they are displaced.

Nutritionally complete diets ground to a fine particle size (fed either dry or mixed with water to provide a slurry), small-dimension (1-5 mm) dry crumbled diets, and larger (1 cm diameter) extruded floating diets have all been successfully fed to captive flamingos. This reflects their adaptability to different sizes and shapes of dietary ingredients. Feeding stations should be available for free-choice feeding throughout the day. The significance of filtration of nutrients directly from exhibit ponds should not be overlooked in the feeding of flamingos, although its contribution has not been quantified in captive birds.

Grit has been reported in digestive tract contents of all species. Unless it is available as part of the exhibit substrate, grit should be provided separately in the size range of 500 to 1000µm for the larger flamingo species, and 90-250µm for the smaller species.

Nutritional Requirements of the Flamingo

**Water** - Flamingos can survive by drinking ocean-strength seawater through efficient filtration mechanisms and secretion of hyperosmotic solutions of sodium chloride (Bildstein et al., 1995). Many free-ranging flamingos occasionally travel long distances to drink and bathe at freshwater sites; captive flamingos, however, showed no preference for feeding in fresh, saline, or hypersaline solutions during one short-term study (Bildstein et al., 1995). Fresh, potable water should be constantly available to flamingos in captivity.

**Energy** - Despite the variety of feeding habits among species, there are no data to surmise that nutritional requirements of flamingos differ substantially from those established for domestic ducks or geese, and biliary bile acid composition suggests that flamingos are more closely related to Anseriformes compared to other Ciconiiformes (Hagey et al., 1990). Seeds of grasses and tubers have been found in crops and stomachs of free-feeding flamingos, hence, plant-based diets (see also Table 1) appear entirely suitable for these species, and few nutritional problems have been reported for this group. Energetics calculations based on dry commercial feeds containing between 3 and 3.5 kcal/g (12.5 to 14.6 kjoule/g) suggest that a 3 kg *Phoenicopterus ruber* requires between 230 and 290 kcal per day (960 to 1200 kjoules per day) depending on activity level (Aschoff and Pohl, 1970). This level would be supplied by consumption of 65 to 100 g of dry food per individual (2-3% of body mass). If diets are presented as a slurry (up to 75% water), this may represent 260 to 400 g of food offered daily, or up to 10% of body mass. Similar calculations for a 1.8 kg *Phoeniconaias minor* result in energetics requirements of 160 to 200 kcal (660 to 830 kjoule), which
would also be met by feeding a slightly higher percentage of body mass at 2.5 to 3.5%, or 45 to 65g of dry food (180 to 250g of slurry). Kear (1974) fed 364g (slurry) per bird to a flock of 275 in a mixed exhibit; other zoos feed between 200 – 300 g per bird daily (wet slurry).

**Protein** - Based on poultry nutrient requirements, Wackernagel (1975) recommended that diets for captive flamingos contain not less than 13% protein. The inclusion of a large proportion of animal ingredients and algae in the diet of free-ranging flamingos, however, might suggest a higher protein intake in nature (see Table 1 for nutrient composition of some native foods). Diets, however, are invariably diluted with plant materials, mud, and other filtrates to provide a lower overall protein content, and commercially available diets or mixes used in zoos containing between 20 and 45% protein (see Table A1) have been shown to support reproduction. Respondents from an earlier captive diet survey (Roberts and Hesch, 1992) reported that a majority of US zoos (83%) incorporated green produce, shrimpsmeal and trout or even cat extrusions to commercial diets fed the lesser flamingo in an effort to meet presumed higher protein (or other nutrient) requirements of this species, but current data do not support this assumption. Species differences in protein requirements, variation due to physiological stage, and/or the importance of seasonality in dietary protein content or availability have not been examined in flamingos.

**Vitamins and Carotenoids** - Native foods eaten by flamingos appear to contain less vitamin A, and more vitamin E, than typical diets formulated for domestic poultry. Additionally, if high carotenoid supplementation is required for proper coloration, this may decrease absorption of vitamin E from the diet, thus increasing dietary vitamin E requirement. In general, domestic avian vitamin E requirements appear to underestimate dietary needs of this nutrient for flamingos in captivity. The ratio of A:D:E may be more important than any one fat-soluble constituent, with dietary concentrations of 20,000 IU vitamin A, 2000 IU vitamin D3, and 200 IU vitamin E per kg dry matter suggested as reasonable for captive flamingos. Due to potential toxicity problems with canthaxanthin reported in other species at levels >25 mg/kg, future inclusion of this pigment in animal diets may be limited or discontinued in Europe (EAZA Flamingo Husbandry Manual, 2002). Other pigments and/or mixed carotenoid products may prove effective in feeding and coloration of flamingos. Pigmentation is required in the diet for coloration only during feather formation; however, its inclusion year-round has not been shown to be detrimental to health (when levels are not excessive).

**Minerals** - Requirements do not appear to differ from those of domestic poultry species. Adult flamingos are unlikely to require more than about 1% calcium (dry basis). Accordingly, the dietary P content should be approximately 0.5%. The wild environment of the flamingo is highly saline, resulting in expectations of a captive diet high in salt. However, the flamingo excretes salt via supra-orbital glands and does not require a high salt intake in captivity; they also ingest very little water with their food. High concentrations of salt can lead to excessive consumption of water and attendant problems with ventilation control (NRC, 1994). Diets recommended for the domestic fowl, containing 0.5 % NaCl, have proven to be adequate (Wackernagel, 1975).

**Composition of Captive Diets (ESD)**

The chemical composition of a number of diets fed to flamingos in North American zoos is summarized in Appendix Table 1A, along with suggested recommendations for nutrient ranges. Diets included in the table represent commercially available products fed as sole items, as well as mixed practical rations utilized by two zoological institutions with proven reproductive success. Chemical analyses of commercial diets do not indicate any significant differences between breeding
and maintenance diets, and zoos generally do not vary diets seasonally. Faced with a lack of published data from controlled, comparative studies, it is not possible to say whether these diets based on poultry requirements are adequate to support optimal reproduction or growth (NRC 1985; 1994). Based on available data, all formulated diets reported herein appear to be capable of maintaining captive flamingos, and at least minimally meet requirements for growth and reproduction. Hand-rearing information is presented in a separate chapter; no provision for geriatric animals has been identified.

Recommendations for standardized flamingo nutrient ranges are based on these practical diets in combination with information from native foods and domestic poultry requirements. Currently, vitamin A is being offered to captive flamingos in significantly higher concentration than those recommended by the NRC (1994) for laying poultry, with at least one commercial diet exceeding maximum tolerance levels suggested for poultry. While vitamin A toxicosis has not been reported in flamingos, imbalances of fat-soluble vitamins can result in antagonisms and overt deficiencies of other nutrients. With pigmentation of flamingos dependent on uptake of other fat-soluble constituents, further nutrient interactions must also be considered. Given that the presentation of flamingo diets is often in a liquid form, allowances have been made for potential oxidative deterioration of specific nutrients.

The majority of North American zoos use canthaxanthin as a pigment added to the diet: Roxanthin Red (10% dry canthaxanthin beadlets manufactured by Roche) or Carophyll Red (10% pure canthaxanthin) have been added in the range of 25mg/kg food (Wildlife Conservation Society) to 1g/kg food at Slimbridge (Griswold, 1975). Approximately 10 g of canthaxanthin has historically been fed on a daily basis to 275 birds at Slimbridge (Kear, 1974). Comben (1976) believes that delivery of the carotenoid through a ‘soup’ mixture is wasteful and that a pelleted mixture is more economical. Some zoos now use mixed carotenoid products, with some commercial feeds incorporating mixed carotenoids at manufacture. A suggested dose of pigmentation in flamingo diets, which has resulted in feather coloration equivalent to free-ranging birds when scored using a standardized color index (Wildlife Conservation Society, in preparation) is 23 mg canthaxanthin per kg dietary dry matter; 50 mg/kg mixed carotenoids (Betatene 7.5%) also provides suitable coloration.

Physiological Assessment of Nutritional Status (ESD)

It may be valuable to develop a standardized feather color scoring system for use in flamingo management to establish quantitative links between dietary constituents and bird appearance, as well as to compare geographic differences among flocks both in situ and ex situ. These data can then be correlated with reproductive and health parameters. Prototypes of such a system exist; conversion to an Internet-based system has been proposed, with funding, implementation, and dissemination pending (Dierenfeld and Sheppard, unpublished data). Color will be scored against fine-grade international color standards used in the graphics industry.

Fat-Soluble Vitamins A and E

Table 2 summarizes values of vitamin A (measured as retinol) and vitamin E (measured as tocopherol) in the blood of provisioned free-ranging Caribbean flamingos and captive Caribbean, Chilean and lesser flamingos. While vitamin E levels are not significantly different among flamingo species, the vitamin A levels in the free-ranging Caribbean flamingos are significantly lower than
any of the species maintained in captivity. The detection of the retinyl palmitate ester (A-palmitate, Table 2) often indicates the presence of a synthetic source of vitamin A from the diet or can be an indication of high dietary levels of vitamin A. Retinyl esters were not measured in the zoo-held flamingos but were seen in the provisioned free-ranging birds with access to a commercial diet. Presumably these semi free-ranging flamingos were meeting vitamin A needs through conversion of dietary carotenoid pigments; the presence of the retinyl esters, then, may have been an indication of dietary excess.

There were no significant differences in circulating concentrations of vitamin E among flamingo species measured. Overall, the flamingo values reported here are more similar to ranges seen in carnivorous birds (10-40 µg/mL) rather than herbivorous/granivorous species (2-10 µg/ml; (Dierenfeld and Traber, 1992). The Lesser Flamingo, which feeds predominantly on algae, tended towards the values for herbivorous species. Gamma-tocopherol, the predominant form found in seeds, although measured in all plasma samples, was only detected in blood samples from the provisioned free-ranging flamingos.

<table>
<thead>
<tr>
<th>Species</th>
<th>Retinol (µg/ml)</th>
<th>A-palmitate (µg/ml)</th>
<th>a-Tocopherol (µg/ml)</th>
<th>g-Tocopherol (µg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi Free-rangiing Caribbean (n=53)</td>
<td>0.046 ± 0.22 (0.00312-1.443)</td>
<td>0.014 ± 0.072 (0.0005 - 0.4630)</td>
<td>19.04 ± 10.08 (4.3-38.9)</td>
<td>2.15 a + 0.91 (1.0-4.0)</td>
</tr>
<tr>
<td>Caribbean (n=15)</td>
<td>0.44 b ± 0.33 (0.12 - 0.77)</td>
<td>NA</td>
<td>15.41 ± 6.49 (0.26 - 25)</td>
<td>ND</td>
</tr>
<tr>
<td>Chilean (n=55)</td>
<td>1.23 c ± 0.56 (0.16 - 2.29)</td>
<td>NA</td>
<td>21.20 ± 8.9 (0.54 - 34.28)</td>
<td>ND</td>
</tr>
<tr>
<td>Lesser (n=6)</td>
<td>0.73 ± 0.16 (0.45 - 0.92)</td>
<td>NA</td>
<td>13.20 ± 2.11 (9.95 - 15.39)</td>
<td>ND</td>
</tr>
</tbody>
</table>

Table 2. Plasma or serum retinol, A-palmitate (retinyl palmitate), a-tocopherol and g-tocopherol levels (mean ± SD and range) measured in provisioned free-ranging Caribbean (*Phoenicopterus ruber ruber*) flamingos and captive Caribbean (2 facilities), Chilean (*P. chilensis*; 2 facilities) and lesser (*Phoeniconaias minor*) flamingos (Wildlife Conservation Society Nutrition Laboratory and Norkus, unpublished data). NA = not analyzed, ND = not detected.

**Carotenoids**

In flamingos, total blood carotenoid have been measured comprising 96% canthaxanthin at a total concentration of 2.64 mg/100 mg blood, with only 4% being β-carotene (Fox and Lint, 1975). A more recent assessment of circulating carotenoid concentrations in provisioned semi free-ranging Caribbean flamingos (Table 3) demonstrated a considerably different distribution, with almost 80% of total carotenoids (0.02/0.03) remaining as β-carotene. This might suggest that this compound was not needed for vitamin A synthesis in the provisioned birds.
## Conclusion

In summary, there is very little published data pertaining to the nutrition of captive or wild flamingos, probably because nutritional problems are rare in flamingos. Aside from issues of feather pigmentation loss, there are few published references documenting nutritional deficiencies or toxicities in flamingos maintained in captivity. Diets currently being employed by zoological institutions vary substantially, and recommendations have been made for a uniform flamingo diet in Table A1, CicAG (Ciconiiformes Advisory Group) Diet. These recommendations are based on a combination of published requirements for the laying hen, inferential evidence from natural foods, and practical husbandry experience with flamingos and other avians. Given that the presentation of flamingo diets is often in a liquid form, allowances have been made for potential deterioration of specific nutrients.

In addition, there are several areas of flamingo nutrition suggested for further detailed research:

- Assessment of nutritional composition of wild diets
- Extent of conversion of carotenoids to vitamin A
- Interactions of fat-soluble vitamins and carotenoid supplementation
- Interactions among vitamin D, calcium and phosphorus
- Assessment of calcium status in adults and chicks throughout the breeding season
- Intake and digestion by different species, and responses to various commercial products
- Effects of temperature on intake and protein nutrition
- Vitamin E requirements
- Significance of vitamin E/Se in the prevention of capture myopathy
- Effect of fatty acid complex on oxidation and antioxidant nutrition
- Vitamin C metabolism.

### Table 3.

Carotenoid values from provisioned free-ranging Caribbean flamingos (n=41). Values for total carotenoids are based on a β-carotene standard (Norkus, unpublished data 1999).

<table>
<thead>
<tr>
<th></th>
<th>Lutein</th>
<th>Cryptoxanthin</th>
<th>β-Carotene</th>
<th>Total Carotenoids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ug/mL</td>
<td>± SD</td>
<td>± SD</td>
<td>± SD</td>
<td>± SD</td>
</tr>
<tr>
<td>1.20</td>
<td>0.72</td>
<td>0.46</td>
<td>0.024</td>
<td>0.0304</td>
</tr>
<tr>
<td>Range ug/mL</td>
<td>0.20 - 2.89</td>
<td>0.04 - 2.26</td>
<td>0.001 - 0.207</td>
<td>0.004 - 0.092</td>
</tr>
</tbody>
</table>
References


Products Mentioned in the Text:

Betatene 7.5%, Cognis Corporation, Nutrition & Health, 5325 South Ninth Avenue, LaGrange, IL 60525

Carophyll and Roxanthin Red, Hoffmann-LaRoche, Inc., 45 Waterview Boulevard, Parsippany, NJ 07054

Flamingo Complete, Mazuri, P.O. Box 66812, St. Louis, MO 63166-6812

Flamingo Fancier, Zeigler Bros, Inc., 400 Gardners Station Rd., P.O. Box 95, Gardners, PA 17324

Flamingo Fare, Reliable Protein Products, Inc., 70-105 Frank Sinatra Drive, Rancho Mirage, CA 92270

Flamingo AP, HMS Zoo Diets, Inc., Bluffton, IN 46714

Table A1. Summary of nutrients (dry matter basis, except water) contained in diets utilized for flamingos maintained in captivity in North American zoological facilities. Data represent four major commercial formulations utilized, and 2 “in-house” mixtures.

*Maximum values are outlined for vitamins A, D, and E in the CICAG recommendations while all other values are minimum requirements or ranges. Wackernagel (1975) provides recommended values for the flamingo based on nutritional requirements of the laying hen.
Chapter 6

Health and Medicine
Facilitators: Terry M. Norton, DVM, Diplomate ACZM; James Raymond, DVM, Diplomate ACVP; Susan Clubb, DVM, Diplomate ABVP-Avian; Nandine Lamberski, DVM, Diplomate ACZM; Murray Fowler, DVM, Diplomate ACZM; Thomas H. Reidarson, DVM, Diplomate ACZM; Beth Chitick, DVM, Diplomate ACZM; Linda Henry

Husbandry Issues That Affect the Health of Flamingos

Flight restraint methods

It is encouraged to keep flamingos full-winged when the appropriate facilities are available and, hopefully, more zoos will account for this when designing facilities for flamingos in the future. Pinioning is the most common de-flighting method performed on flamingos maintained in outdoor enclosures. Successful pinioning has been performed on chicks from 2-10 days of age. Refer to Reproduction, Chapter 4 for further details on animal husbandry issues related to pinioning. The procedure may be performed with simple crushing of the tissue with a hemostat and cutting with a scissors or scalpel. The incision may be closed with tissue glue. General anesthesia is needed if the procedure is performed on adult-sized flamingos. For traditional pinioning, the site of amputation is determined by finding the alula and cutting the bone just distal to the base of this structure. Remove the flight feathers at the amputation site. Other feathers should be plucked and the skin surgically prepared. A circumferential skin incision is made, leaving enough skin to close the wound. The major vessels in this area are between the metacarpal bones, which are fused at either end. A figure eight transfixation ligature is placed loosely around the proximal ends of the bone. The bones are amputated with a sharp chisel, a bone-cutting forceps or a giggly wire. Once the distal end of the metacarpal bones is freed, the ligature is tightened. The skin is pulled into place to cover the end of the bones and sutured closed. A light pressure bandage is applied to assist in controlling hemorrhage. The bird usually removes the bandage in a day or two. Amputating less bone (i.e. “long pinioning”) may improve reproductive success, but it is still unclear if some birds are completely inhibited from flight. Tendonectomy is not recommended because it is more invasive and in some countries is forbidden. Birds often develop droopy wings, and the procedure frequently does not prevent the flamingo from flying.

When designing a new facility, efforts should be made to allow chicks to be retrieved for pinioning and other procedures with minimal disturbance to the flock. Refer to the Management and Housing Chapters for details.

Sexing Methods

Males and females are sexually monomorphic, although males are usually larger than females.

A non-blood feather technique utilizing PCR technology is currently available in the US (Avian Biotech, 1-800-514-9672, Fax: 850-386-1146, e-mail: agt@nettally.com,
This technique is the least invasive, easiest to perform, and the preferred method to be used for sexing flamingos by some institutions. A small amount of DNA is extracted from the shaft of a freshly plucked feather. It is then purified, and special primers are used to amplify a sex-specific DNA fragment. This technique still needs to be validated in flamingos.

European Laboratories that are able to sex flamingos by this methodology are as follows:

**Austria**
1) Pluma Osterreich  
Lochauestrasse 2  
6912 Hobranz  
T: +43(0) 55 73 8 54 03  
F: +43(0) 55 73 8 54 03  

**Czech Republic**
1) Genservice, s. r. o.  
Laborator molekulami genetiky  
Palackeho 1-3  
612 42 Brno  
T: +420 5 41321229  
F: +420 5 41562648  
Email: genservice@volny.cz  

2) Statni veterinarni ustav Brno  
Palackeho 174  
612 38 Brno  
T: +420 5 41321229  
F: +420 5 41221050, 41217383  
Email: svubrno@login.cz  

**Germany**
1) Pluma GbR-Molekularbiologische Analytik  
Postfach 70 03 59  
70573 Stuttgart  
T: +49(0) 711 990 59 23  
F: +49(0) 711 990 59 24  

2) Genedia GmbH  
Burgstrasse 12  
D-80331 Muenchen  
T: +49 (0) 89 64289624  
F: +49 (0) 89 64249666  
Email: info@genedia.de  

3) Loboklin  
Prinzregentenstr. 3  
D- 97688 Bad Kissingen  
T: +49 (0) 971 72020  
F: +49 (0) 971 68546  
Email: laboklin@t-online.de
DNA testing from a blood sample for gender determination is a commonly used technique and is relatively non-invasive. Zoogen (PE AgGen, Inc) has validated the technique for most flamingo species. For ease of sampling from a chick, blood can be taken from the pinion site.

Surgical sexing via laparoscopy may be performed. The advantages of this method are that the gonad can be visualized directly (e.g. assessment of sexual maturity and activity can be made) and other body organs can be evaluated. The disadvantages are that the bird must be restrained,
preferably with anesthesia, and the procedure is somewhat invasive. It is recommended to perform
this technique on birds two years of age or older so that the bird is sexually mature and out of the
age range where traumatic injury is most common.

Proper Environment to Prevent Bumblefoot

The most satisfactory enclosures for flamingos have a substrate of grass and several shallow pools
for feeding and bathing. Refer to Housing, Chapter 2 for details. Hospitalized flamingos should be
housed on soft, thick rubberized or meshed mats (again, refer to the Housing Chapter for details).

Housing

Avoid isolating flamingos by themselves. Sick flamingos should be housed with at least one other
bird. If this is inappropriate for the specific medical problem (e.g. infectious disease issues), then
mirrors or a tape recording of vocalizations can be used as alternatives. Another flamingo should
be placed with the ill flamingo as soon as is appropriate, e.g. no infectious disease issues. Refer to
Housing, Chapter 2 for specifics on enclosure design and size.

Life Span

Flamingos are long-lived, some reaching over 50 years (Fowler and Cubas, 2001). They are
capable of reproducing at this age as well (Shannon, pers. comm., 1999). Geriatric medical
problems start at approximately 35 years of age (Shannon, pers. comm., 1999).

Physical Restraint

Flamingos may be slowly herded into a corner, allowing handlers to capture them. The base of the
neck is lightly, but securely, grasped with one hand and the body with the other, lifting the bird off its
feet and directing the legs slightly away from the handler. The body with the wings of the bird folded
in the natural position should be held next to the hip of the handler. Care must be used in controlling
the long legs to prevent them from flailing about. A cloth hood may help calm the bird down.
Manual restraint is adequate for physical examination, blood collection, and minor medical
treatments and procedures. Refer to Management, Chapter 3 for specific details on proper manual
restraint.

Anesthesia

General anesthesia is commonly used to facilitate positioning during radiography as well as to
provide immobilization and analgesia during laparoscopy and other surgical procedures. Isoflurane
is currently the preferred inhalant gas. Initially, the animal is manually restrained as described in
the Management Chapter (3). The anesthetic gas is administered via a facemask (a converted
one-liter plastic bottle or a large bell-shaped mask may be used). Due to the peculiar conformation
of the bill, the mouth can only be opened wide enough to introduce the endotracheal tube, thus
making visualization of the glottis difficult especially in smaller flamingo species (e.g. lesser
flamingos). The glottis, however, may be visualized most of the time in larger species. Blind intubation may be attempted. Maintenance anesthesia may also be performed via facemask, if intubation is not possible. Surgical placement of an air sac tube is an option in critical situations where more controlled anesthesia is needed and intubation is not feasible. Attempts should be made to limit anesthetic episodes to two hours or less.

Ketamine at a dose of 20 mg/kg intramuscularly can be utilized if Isoflurane is unavailable (Fowler, 1986). However, recovery can be unpredictable and is more likely to lead to post-anesthetic problems. Monitoring the anesthetized bird is extremely important. Heart rate, respiratory rate, and body temperature should be monitored frequently throughout the procedure. An ultrasonic Doppler may be used to monitor the pulse. The most common site used is the ulnar (or basilic) artery. Pulse oximetry is also useful. A reflectance probe placed against the upper palate or a clamp on a digit works well. Careful attention must be given to maintenance of body temperature. Temperature probes may be placed in the esophagus or cloaca. The animal may be placed on a water-circulating heating pad, and hot packs may be placed along the body of the animal to help maintain the bird’s position (like sand bags) and body temperature. Flamingos that become hypothermic while under anesthesia will have prolonged recoveries and fatalities may result. For longer procedures, warmed fluids should be administered intravenously at 20 ml/kg/hour. Subcutaneous fluids may be administered prior to recovering the flamingo if necessary.

Recovery from anesthesia may be dangerous because the bird may attempt to stand prematurely, which may traumatize the long legs. It is best to hold the bird until it has recovered. Alternatively, the bird may be placed in a 100% cotton, lightweight pillowcase, with the head extended through the opening. If the bird is held, the legs are usually extended and a finger is placed between the hocks to prevent abrasions.

Behavioral Signs of Disease in Adult Birds

It is important to observe the bird prior to going into the enclosure so that an accurate assessment can be made. Knowing individual bird behaviors may also be helpful. Clinical signs of disease may include lethargy, anorexia, one bird isolating itself from the flock or being picked on, “dull eyes”, plumage deterioration, long-term pair bond breaks, leg trembling in combination with other signs, weakness, and lack of breeding behavior and egg production.

Physical Examination

Unusual anatomy

Flamingos have long, thin legs and can stand on one leg with the head tucked beneath a wing for a considerable period of time. The bill is uniquely adapted for filter feeding. The neck is proportionately the longest of any bird, containing 17 cervical vertebrae (Fowler, 2001). The feet are fully webbed with four digits in Caribbean and Chilean flamingos (Fowler, 2001). The hallux is absent in James and Andean flamingos (Fowler, 2001). Flamingo legs are very delicate and are more easily damaged than other long-legged bird species.
Physical examination

The physical examination is an important diagnostic tool in flamingos. A complete oral exam is difficult to perform due to the inability to open the beak wide enough. The feet should be examined carefully because pododermatitis and cracks in the feet are common. A pectoral musculature score assessment adapted from a model used for psittacines (Romagnono, 1999) has been utilized in flamingos at Sea World. It has been especially useful when the weight of the bird is normal but the actual muscle condition has changed. Normal flamingos are usually 2 to 2.5 on a scale 1 to 5 (Henry, pers. comm. 1999). A normal keel score rating will vary with the species of flamingo. It is a subjective determination to be evaluated in the context of the overall health and body weight of the bird.

Keel Score Rating Guide
Linda Henry, Sea World San Diego

The guide is designed to provide a means for a more consistent assessment of a bird’s palpated weight. The keel score ratings are listed below with their description and a sketch example of the degree of flesh. Sometimes a bird may seem to be between two scoring possibilities. In this case, a score of 1.5 or 2.5 may be appropriate.

Where possible, always pair the assessed keel score with the gram weight of the bird. Keep in mind that what is a normal keel score rating will vary with the species. It is a subjective determination to be evaluated in the context of the overall health of the bird and the gram weight of the bird. If an increase in weight does not correspond with an increase in keel score, consider

<table>
<thead>
<tr>
<th>KEEL SCORE</th>
<th>DESCRIPTION</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Emaciated, keeling severely and sharply.</td>
<td><img src="image1.png" alt="Example 1" /></td>
</tr>
<tr>
<td>2</td>
<td>Keeling, only small amount of muscle dipped to either side of keel.</td>
<td><img src="image2.png" alt="Example 2" /></td>
</tr>
<tr>
<td>3</td>
<td>Keel palpable but muscle firm to either side.</td>
<td><img src="image3.png" alt="Example 3" /></td>
</tr>
<tr>
<td>4</td>
<td>Muscle appears straight across over keel, keel palpable between muscles.</td>
<td><img src="image4.png" alt="Example 4" /></td>
</tr>
<tr>
<td>5</td>
<td>Cleavage, keel not palpable, muscle mounded to either side of keel.</td>
<td><img src="image5.png" alt="Example 5" /></td>
</tr>
</tbody>
</table>
behavioral observations to determine if there is a health problem. Generally, keel score and weight are in agreement.

Factors that figure into weight vs. keel score ratings include age of the bird, pinioning, amputation, degree of hydration, and, in flamingos, height, etc.

This technique was borrowed and adapted from a parrot center in Florida.

Supportive Care

Tube Feeding

Tube feeding is similar to other avian species, although it is difficult to visualize the glottis in the flamingo. In addition, lesser flamingos have unusual tracheal anatomy and are more prone to having the trachea accidentally intubated and aspirating the formula (Lung, pers. comm. 1999). Personnel performing this procedure should be appropriately trained. Two people should be involved in tube feeding (one person to hold the bird and the other to place the tube) and should communicate with each other throughout the procedure. A 14 French red rubber feeding tube or similar type of tubing works well for this purpose (a smaller tube may be needed for lesser flamingos) and is directed toward the right side of the oral cavity and esophagus. The tube should be well lubricated prior to placement. Prior to administering fluids or gruel, the neck should be palpated to assure that the tube and the trachea can be palpated. It may be helpful to actually feel the tip of the tube as it goes down the esophagus, especially in lesser flamingos. A small amount of saline can be placed prior to administering formula to assure tube placement. If the bird coughs, the tube should be pulled out and redirected. It is recommended to make a gruel out of the flamingo’s regular diet. The bird should be well hydrated prior to administering a gruel diet. In very ill birds, it is a good idea to dilute the gruel initially.

An alternative to tube feeding is to feed with a catheter-tipped syringe placed in the beak. This method was utilized for supportive care of a flamingo at the Denver Zoo and seemed to be less stressful and caused less struggling than tube feeding (Baier pers. comm. 1999).

Fluid Therapy

Fluids are administered to flamingos in a similar fashion as with other avian species. Methods of administration will depend on the severity of illness in the bird being treated. Oral, subcutaneous, and intravenous (bolus, IV catheter) fluid therapy methods are most common. The medial metatarsal vein is the preferred site for indwelling catheters. Intraosseous fluid therapy may be an option in critically ill flamingos.

Sling Use and Construction

A very functional sling has been designed by Sea World (Henry, unpublished information, 2002). This sling design is suitable for long-term slinging of long-legged birds for recovery of leg injuries or for short-term slinging required during treatment of myopathy. Flamingos have been slung for up to
eight weeks continuously, with infrequent removal for routine weights or radiography. Ideally, flamingos should be in the sling for as short a time as is required for recovery.

Sea World Adventure Park San Diego has used this sling design for several years. Although the original sling consisted of nothing more than a foam pad, duct tape and cording, a few years ago several design elements were incorporated to make the sling more uniform, washable, adjustable and user friendly.

The Sea World sling now consists of fabric-covered foam pad with four webbing straps, which end in D-rings. The bird is suspended using additional straps that thread through the D-rings on the sling pad and are attached with hook and loop tape. The hook and loop segment at the D-rings allow for easy height adjustments to the sling without necessitating the removal of the bird. This is vital to finding a comfortable posture and height for the bird. The other end of the suspension straps is then affixed to the interior of the caging ceiling.

Once constructed, the sling can be machine-washed and dried, depending on the materials used. The Sea World sling is made using headliner fabric of 100% nylon fabric with polyester foam core. Velour may be substituted for the headliner fabric, but it is less durable. The foam insert is a medium density, one-inch polyurethane foam with a 1.9-pound resiliency. The hook and loop tape is nylon and is "sew-on" rather than adhesive. The webbing is polypropylene; cotton webbing is also available but not as sturdy. These supplies are readily available at upholstery suppliers or fabric stores.

To protect these long-necked birds from tangling and injuring themselves on the suspension webbing, it is recommended to cover the support straps with pipe insulation foam on all four straps, for approximately three feet of each strap.

**Sling Set-up and Use**

To place a bird in the sling, it is best to have two people, one to hold the body of the bird and a second person restraining and guiding the legs. Once in the sling, the flamingo must be wrapped into the sling around both the body and the sling. This is the portion of the slinging process that is the most difficult to standardize. Flamingos will often wriggle their way out of a sling if improperly secured. It often takes several attempts to find the wrapping method that works best for a particular bird. In general, the wrap should cover the body over the wings as well as secure the bird from forward and backward movement within the sling. Four-inch wide Vetwrap is the most effective bandage material for wrapping birds into the sling. Vetwrap is the product name for an elastic non-adhesive tape or bandage material that adheres to itself by the crimped nature of the product. Vetwrap comes in rolls and can be obtained through most veterinary or medical supply companies. It is important to monitor birds closely after slinging. Birds may loosen bandage material and come out of the sling; height and posture adjustments may be needed or bandaging may be too tight. Sometimes birds will appear limp and unresponsive. Such behavior may indicate further veterinary treatment. At other times, this behavior is the transition period where the bird is becoming familiar with the sling. It is recommended to wait 30-60 minutes, allowing time for the bird to acclimate to its new surroundings, before readjusting the sling. Once managers become more proficient at slinging and the bird becomes more accustomed to it, birds will not need to be watched as closely.

In slinging a bird, handlers must be mindful of the crop and vent locations. The vent should be unobstructed by either the sling pad or bandage material so that feces do not build up in this area.
The crop should not have undue pressure from the sling, which may interfere with proper feeding and natural processes of food digestion.

An additional consideration is the keel region. For most birds of adequate weight, the keel should be well protected by both the muscle/fat of the bird and the foam of the sling. However, for very thin birds or for birds in the sling for extended periods, the keel may need additional protection or cushioning. A small doughnut-shaped insert can be made of foam, with a cutout to accommodate the keel, and backed with hook and loop tape that can be attached to the sling pad for added protection for the keel.

Substrate for the bird to stand on while in the sling is another area of concern. Any soft matting are good substrates; even terry cloth toweling is sufficient. (See Housing, Chapter 2). Asphalt, bare concrete or other abrasive surfaces should be avoided.

Flamingos often will need to be tube fed during the slinging period. In the initial days, birds often refuse to eat. Even those eating may need supplemental tubing. We offer a food and water tray within easy reach of the bird, usually raised on an overturned crate to allow for easier access by the bird. The caution here is to prevent a struggling bird from inadvertently injuring itself by banging a leg into the food tray.

Adjustments to Height and Posture

If a bird is swinging too much, it may be unable to get its weight underneath enough to try to stand. If a bird fights too much, the front height may be too low. Generally, the front of the sling should be higher than the back. The goal is for the bird to be able to stand, even minimally, while in the sling. The sling functions to provide stability and safety.

Sling Construction

The following instructions work for both the large (Caribbean flamingo size) and the small (lesser flamingo size) slings. Full-size patterns are available from the AZA Ciconiiformes Taxon Advisory Group or the Aviculture Department of Sea World San Diego, California. Fabric yardages are available in standard widths of 60 inches. The half-yard specified might make more than one cover, but that is the smallest amount that you might be able to purchase for a single sling. Foam is available in bed sizes (i.e., full, queen, king). We recommend having more than one sling on hand.

Supplies list:  yardages given are for one large sling
   1/2 yard headliner fabric (e.g., Tempo)
   1/2 yard of one-inch foam
   Up to 9 yards of one-inch nylon webbing
   Four one-inch D-rings
   Up to 4 yards of pipe insulation foam
   Hook and loop tape (e.g., Velcro)

Sling Pad Construction:
   1. Cut two pad pieces (pattern A) from headliner fabric
   2. Cut one foam insert (pattern B) from one-inch foam
   3. Cut four eight-inch lengths from the one-inch webbing; melt the ends of the webbing
with a lighter flame to secure from ravel
4. Place fabric pieces A right sides together with webbing inserted between layers at
each “X”
5. Sew seams around edges leaving V-shaped area between dots open as specified on
pattern A
6. Reinforce stitching at each point where webbing is inserted
7. Clip corners and curves; turn right-sides-out
8. Insert foam at opening
9. Machine stitch opening closed
10. Sew D-rings to webbing straps

Support Straps: Cut four pieces of one-inch webbing at least 12 inches longer than needed. Sew
six inches of male and six inches of female hook and loop tape to each end of these straps.

Sling completion: Put one end of each of the long webbing pieces through each D-ring, securing
hook and loop tape. The other end of each long webbing piece should be secured to whatever is
used to suspend the bird. Our indoor caging is seven feet high and the strap ends are secured to
the caging ceiling (e.g. cable ties, bicycle rings).

Sling maintenance: Before using a sling, be sure to check each of the insert points of the webbing
to be sure that each attachment is secure. The hook and loop tape may need replacement if the
hook end becomes filled with lint/debris. This must also be very secure in its attachment. When
using washable materials, the sling can be machine-washed and dried using warm water and gentle
cycles.

Drug Therapy

Pharmacokinetic studies have not been performed on flamingos, thus drug dosages should be
extrapolated from other avian species. Flunixin meglumine (Banamine) has been documented to
cause renal toxicosis in flamingos and cranes, and thus should be avoided (Klein et al, 1994).
Fenbendazole (Panacur), a commonly used anthelmintic, has recently been found to cause bone
marrow suppression in several avian species (Howard et al, 1999). It should be used with caution
in flamingos.

Diagnostic Evaluation

Blood drawing, hematology, and serum biochemistry

Blood can be collected from the jugular, medial metatarsal, or ulnar (or basilic) veins. The jugular is
preferred if large volumes (>3.0 ml) are desired. The medial metatarsal vein is the preferred site for
indwelling catheters. Blood is usually collected into a heparinized syringe or green-top tube. Lead
poisoning is a concern for free-living birds (Aguirre et al, 1991), and whole blood collected to
diagnose lead poisoning should be preserved in EDTA (purple-top tube). A complete blood count
(CBC), chemistry panel, blood smear evaluation for hemoparasites, and plasma banking should be
part of initial diagnostic evaluations. Normal CBC and chemistry values have been published for
some flamingo species, and the results are consistent with other groups of birds (Tables 1 and 2,
and serum from captive flamingos is orange and should not be confused with hemolysis.
### Table 1. Reference range for hematologic parameters in flamingos (Norton 2002, Zoo and Wild Animal Medicine Fifth edition)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>RBC X 10^6/ul)</td>
<td>1.12-1.85</td>
<td>2.44-2.93</td>
<td>2.3-3.1</td>
<td>2.4-2.9</td>
</tr>
<tr>
<td>PCV (%)</td>
<td>37.95-57.83</td>
<td>41-51</td>
<td>43-57</td>
<td>46-54</td>
</tr>
<tr>
<td>Hemoglobin g/dl</td>
<td>9.22-17.65</td>
<td>14.1-18.1</td>
<td>16.6-20.9</td>
<td>15.2-19.5</td>
</tr>
<tr>
<td>MCV (fl)</td>
<td>234.31-419.06</td>
<td>161.7-182.4</td>
<td>168-210</td>
<td>179-195</td>
</tr>
<tr>
<td>MCH (pg)</td>
<td>57.82-125.35</td>
<td>57.3-64.8</td>
<td>62.9-73.9</td>
<td>55.4-70.5</td>
</tr>
<tr>
<td>MCHC (g/dl)</td>
<td>20.42-35.87</td>
<td>33.3-37.9</td>
<td>33.5-39.1</td>
<td>30.8-37.5</td>
</tr>
<tr>
<td>Leukocytes/ul</td>
<td>1,531-15,898</td>
<td>1,600-9,000</td>
<td>900-4,500</td>
<td>3,800-8,500</td>
</tr>
<tr>
<td>Heterophils/ul</td>
<td>589-12,445</td>
<td>410-4,740</td>
<td>570-2,620</td>
<td>1,700-6,870</td>
</tr>
<tr>
<td>Lymphocytes/ul</td>
<td>927-14,504</td>
<td>820-2,610</td>
<td>490-1,680</td>
<td>530-2,370</td>
</tr>
<tr>
<td>Eosinophils/ul</td>
<td>0-544</td>
<td>0-710</td>
<td>0-310</td>
<td>0</td>
</tr>
<tr>
<td>Monocytes/ul</td>
<td>3-1,418</td>
<td>0</td>
<td>0-130</td>
<td>0-340</td>
</tr>
<tr>
<td>Basophils/ul</td>
<td>0-4629</td>
<td>0-360</td>
<td>0-350</td>
<td>0-230</td>
</tr>
<tr>
<td>Thrombocytes</td>
<td>adequate</td>
<td>6000-33,000</td>
<td>1,400-35,000</td>
<td>3000-23,000</td>
</tr>
<tr>
<td>Plasma protein</td>
<td>5.29-8.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibrinogen (mg/dl)</td>
<td>40-600</td>
<td>130-360</td>
<td>140-330</td>
<td>140-290</td>
</tr>
</tbody>
</table>

### Table 2. Reference ranges for plasma biochemical parameters in flamingos (Norton 2002, Zoo and Wild Animal Medicine, Fifth edition)

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Total protein (g/dl)</td>
<td>3.18-4.94</td>
<td>4.5/0.4</td>
<td>4.3/0.6</td>
<td>4.9/0.5</td>
</tr>
<tr>
<td>Albumin (g/dl)</td>
<td>2/0.3</td>
<td>1.8/0.2</td>
<td>1.7/0.2</td>
<td></td>
</tr>
<tr>
<td>Globulin (g/dl)</td>
<td>2.5/0.4</td>
<td>2.5/0.4</td>
<td>2.5/0.4</td>
<td></td>
</tr>
<tr>
<td>Calcium (mg/dl)</td>
<td>4.95-21.78</td>
<td>10.9/2</td>
<td>10.2/0.6</td>
<td>11.0/0.8</td>
</tr>
<tr>
<td>Phosphorous (mg/dl)</td>
<td>1.11-6.76</td>
<td>2.4/1</td>
<td>4.3/2.5</td>
<td></td>
</tr>
<tr>
<td>Sodium (mEq/L)</td>
<td>139.5-160.2</td>
<td>157.5/2.7</td>
<td>153.1/3.0</td>
<td>153.1/3.0</td>
</tr>
<tr>
<td>Potassium (mEq/L)</td>
<td>1.86-6.76</td>
<td>3.2/1.3</td>
<td>2.2/0.3</td>
<td>2.2/0.3</td>
</tr>
<tr>
<td>Chloride (mEq/L)</td>
<td>110.55-123.30</td>
<td>117.0/4.5</td>
<td>116.4/2.8</td>
<td>116.4/2.8</td>
</tr>
<tr>
<td>Creatinine (mg/dl)</td>
<td></td>
<td>0.4/0.08</td>
<td>0.4/0.08</td>
<td></td>
</tr>
<tr>
<td>Urea nitrogen (mg/dl)</td>
<td>3.73-22.10</td>
<td>4.1/1.8</td>
<td>2.1/0.9</td>
<td></td>
</tr>
<tr>
<td>Uric acid (mg/dl)</td>
<td>345/50.7</td>
<td>345/50.7</td>
<td>345/50.7</td>
<td></td>
</tr>
<tr>
<td>Glucose (mg/dl)</td>
<td>107.22-288.32</td>
<td>238/52.9</td>
<td>162.4/40.8</td>
<td>270.7/55.7</td>
</tr>
<tr>
<td>LDH (IU/L)</td>
<td>47.74-696.94</td>
<td>175/115.5</td>
<td>151.0/72.6</td>
<td></td>
</tr>
<tr>
<td>ALP (IU/L)</td>
<td>18.26-737.55</td>
<td>17.9/6.4</td>
<td>1578.6/1692.4</td>
<td></td>
</tr>
<tr>
<td>CK (IU/L)</td>
<td>157.15-3,521.44</td>
<td>460.3/228</td>
<td>255.3/94.9</td>
<td></td>
</tr>
<tr>
<td>AST (IU/L)</td>
<td>70.42-475.72</td>
<td>221.9/36.8</td>
<td>233/140.2</td>
<td>255.3/94.9</td>
</tr>
</tbody>
</table>
Fecal Evaluation (Parasites, Special Stains, Culture)

Fecal cytology (modified Wright's stain or Diff Quick stain), fecal gram stain, fecal acid fast stain, fecal flotation and direct smear, and fecal culture for Salmonella sp. may also be part of initial data collection. The presence of inflammatory cells in the feces is suggestive of an enteritis. Fecal gram stains may be used to approximate fecal flora and identify budding yeast. Fecal acid-fast stains are used to screen for the presence of acid-fast bacteria; however, shedding of these organisms is often intermittent and inconsistent. If fecal acid-fast bacteria are identified, fecal culture for *Mycobacterium spp.* should follow. Fecal flotation and a direct smear with saline are used to identify ova, parasites, and protozoa from feces.

Serology

After a review of the initial lab work is complete, banked plasma may be used to run additional tests such as protein electrophoresis and *Aspergillus spp.* and West Nile virus serology. Additional serology that may be useful but that has not been validated for flamingos includes titers for diseases such as equine encephalomyelitis virus, avian influenza, Paramyxovirus, and Mycoplasma spp.

Microbiology

Microbiology can be very useful in identifying specific etiologic agents. *Escherichia coli, Proteus spp.*, *Pseudomonas spp.*, *Enterobacter spp.*, and *Edwardsiella tarda* may be part of the normal flamingo intestinal flora but also may be pathogenic in some cases (Lamberski, 1998; Aguirre et al, 1991; Baylet et al, 1979; Glunder and Siegman, 1989; Shane et al, 1984). *Escherichia coli, Salmonella spp.*, *Aeromonas hydrophila, Pasteurella multocida*, and *Streptococcus spp.* should be considered to be potential pathogens, as these organisms have been isolated from healthy as well as sick birds (Aguirre et al, 1991; Lamberski, 1998; Baylet et al, 1979; Glunder and Siegman, 1989; Shane et al, 1984).

Laparoscopy/Biopsy

Laparoscopy and biopsy of specific organs or lesions are often necessary to confirm a diagnosis. Laparoscopy is also used to surgically sex birds. These procedures are conducted similarly to other avian species.

Radiology

Radiography is a very useful diagnostic tool. Flamingos are positioned similar to other bird species (lateral and ventrodorsal views of the entire body). Due to their large size, it is not possible to include both the wings and legs on one cassette. Multiple cassettes are used. Animals that have lesions on the bottoms of their feet or have traumatized pinion sites should have these areas radiographed to rule out osteomyelitis.
Neonatal Medicine

(Refer to the Chick Management section of Chapter 2 for additional details)

Routine Physical Exam

A health assessment should take place when chicks are handled for other reasons. If feasible, a blood sample can be taken for CBC, plasma biochemical profile, sexing, and plasma banking. Normal clinical pathology for growing flamingo chicks has not been established.

Supportive Care and Medical Treatment

Medical and supportive care for flamingo chicks is similar to other avian species. If the chick is being parent-reared, the goal should be to get the chick back to the parents as quickly as possible. If aggressive therapy is needed, a commitment to hand-rearing may be necessary. Supportive care may include tube feeding (see Supportive Care section of Medical Chapter) fluids or formula, fluid therapy (subcutaneous, intravenous, or intraosseous depending on the severity of the problem), providing a warm dry environment, etc.

Rickets-like syndrome

A rickets-like condition was reported in young flamingos at WWT/Slimbridge, UK and has been noted at several other institutions (Humphreys et al, 1975). The birds exhibited bending of the tibiotarsus and thickening of the head of the bone. Affected birds became lame, appeared painful, and were stunted. The condition has been found in birds from four weeks to fully feathered. This syndrome has always been observed at the end of the breeding season. Radiographic examination reveals the upper third of the tibiotarsus to be bent medially with severe thinning of the bone. The medullary canal follows the curvature of the bone. On the lateral side of the tibiotarsus there is extensive soft replacement bone extending from below the bend to the epiphyseal junction. Remnants of the original shaft may be seen projecting downwards from the proximal epiphysis. There is an unusually large gap between the already ossified proximal epiphysis and the metaphysis due to thickening of the epiphyseal growth line. There appears to be an interruption of normal ossification, which allows bending as the body weight increases. This condition differs from true rickets in that abnormalities in other long bones have not been demonstrated (Humphreys et al, 1975, Fowler, 2001). Similar conditions have been described in fast-growing broilers, which were fed a high protein diet and grew faster than normal (Humphreys et al, 1975). More research is needed in this area (refer to the necropsy protocol).

Metabolic Bone Disease

Metabolic bone disease is rare in captive flamingos, but it may occur if the parents are on a calcium-deficient diet, if chicks are not exposed to ultraviolet irradiation, or if birds are hand-reared on a calcium/vitamin D deficient diet (Fowler 1978; Fowler 1986). Many zoos have large indoor exhibits that do not have access to natural sunlight.
Fractures/trauma

Physeal fractures of the tibiotarsal-tarsometatarsal bones are not uncommon in chicks handled for pinioning and other procedures (eleven days to three months is the critical time for these fractures to occur). Fractures of any bone are possible. Physeal fractures are very difficult to repair (Fowler, 2001).

Tibiotarsal Rotation

Tibiotarsal rotation does occur in flamingos. However, it is not observed as commonly as in other long-legged birds such as cranes. Although there is not any published information on medical management of this problem, it should be handled in a manner similar to other species (i.e. decrease rate of growth by diet manipulation, increase exercise in hand-reared birds, surgical correction).

Omphalitis/Incomplete Closure of the Umbilicus

Omphalitis is most commonly caused by gram-negative bacteria in flamingos and other avian species (Griner, 1983). It may be prevented by providing a clean environment and swabbing the umbilicus at hatching with dilute povidine iodine. Antibiotics may be warranted in some situations. The umbilicus may require surgical removal.

Incomplete closure of the umbilicus may accompany a small yolk sac protuberance (Griner, 1983). If this protuberance starts to dry and turn black due to constriction, it is best to keep the area clean and place the chick on appropriate antibiotic therapy. It should not be forced into the abdomen and will usually fall off in a few days.

Noninfectious Diseases

Heat Stress

Captive flamingos are susceptible to heat stress, and care should be taken when handling or shipping birds in hot weather (refer to Management, Chapter 3 for details).

Capture or Exertional Myopathy

This condition may occur with prolonged restriction of limb movement, which may occur during shipping or recovery from anesthesia (Young, 1967). Vitamin E/selenium deficiency may predispose the bird to this condition (Dierenfeld, 1989). Lactic acid builds up in the muscles and causes necrosis of the muscle fibers. The flamingo may have difficulty standing or be unable to stand. A plasma biochemical profile will reveal elevations in muscle enzymes (creatine
phosphokinase, AST). Prognosis is guarded, but treatment can be successful. Treatment may consist of placing the bird in a sling, vitamin E/selenium supplementation (IM or oral), hydrotherapy, supportive care, and anti-inflammatory (dexamethasone) and muscle relaxant (robaxin) drugs as needed. Handling should be minimized. Supplementation of the diet with vitamin E prior to and after handling or shipment may aid in prevention of this problem.

Some flamingos have died while being handled (Fowler, 1978, Humphreys, 1975) and based on clinical assessment, the cause of death was thought to be cardiac related (Henry, pers. comm., 1999). Postmortem evaluation did not reveal typical gross or histopathological lesions suggestive of capture myopathy (Henry pers.comm., 1999). Further clinical attention and research are needed in this area.

Trauma

Leg fractures are the most common cause of morbidity and mortality in captive flamingos and usually occur when they are startled or when physically restrained. Growth plate fractures of the tibiotarsal-tarsometatarsal bones may occur when chicks are physically restrained. Fractures of the tarsometatarsus and the proximal tibiotarsus are the most common in adult birds.

Avulsion of the ligament of the femoral head, producing coxofemoral dislocations, and medial collateral avulsions of the intertarsal joint occasionally occur. Wing and rib fractures may also occur secondary to trauma. Leg tendon injuries are not uncommon. The tarsometatarsal fractures are almost always compound, involve the diaphysis, and frequently include damage to metatarsal dorsalis and superficial arteries and veins and extensor and flexor tendons. Wounds are usually contaminated, and significant blood loss is common (Reiderson pers. comm., 1999). The flamingo should be treated for shock, and supportive care should be instituted prior to surgical repair. Once the bird is stable, the bird should be anesthetized (refer to Anesthesia section) with Isoflurane. A lateral approach to tarsometatarsal fractures is recommended. A type 1 Kirshner-Ehmer external fixation apparatus where four to five pins are driven through both cortices and skin surfaces with one connecting bar has been successful in repairing these fractures. Closure of the skin and scales over the fracture is usually impossible, owing to the extensive skin damage and surgical swelling. The defect should be covered with a protective water-resistant transparent dressing, which allows good oxygen and moisture vapor permeability such as Tegaderm (3M Health Care, St. Paul, MN 55144, USA), BioDres (DVM Pharmaceuticals, Inc., Miami, FL 33178), or Duoderm.

One Chilean flamingo drowned when its lower beak became wedged between a leg band and the leg. The leg band had been placed around the distal segment of the leg rather than above the tibia-metatarsal articulation (Griner, 1983).

Predation by various predators is another common cause of flamingo mortality in captivity and the wild. Predator control is recommended. See the Management Chapter for additional information.
Foot Problems

Frostbite

Frostbite of the interdigital webs and digits has been documented when flamingos are exposed to below freezing temperatures (Fowler, 2001). Clinical signs include lameness, darkening of the interdigital web and eventual necrosis of the affected tissue. Prevention should include limiting exposure to temperatures below freezing. Refer to the Housing Chapter for details.

Pododermatitis/Bumble Foot

Flamingos are susceptible to abrasions of the feet due to contact with hard or rough surfaces such as concrete, which may result in pododermatitis. The skin on the plantar surface of the foot becomes cracked and swollen. This may lead to bacterial invasion (Staphylococcus sp is most common), which eventually may lead to osteomyelitis, joint infections, renal disease (the kidney is the most common site for bacteria to lodge in a variety of avian species) (Phelan et al, 1990)), and/or septicemia.

Clinical signs range from inconspicuous to severe lameness. Foot lesions may start as cracks or fissures (Grade 1) which get infected and then become nodular (Grade 2 when nodules are small). The nodules increase in size (Grade 3 when nodules are large), and then other structures become involved such as tendons and bone (Grade 4). Proliferative wart-like lesions may be secondary to a papilloma virus (Heldstab and Studer-Thiersch, unpublished data, 2002).

The following are predisposing factors for pododermatitis:

a. The condition occurs slightly more often in zoo-hatched birds than in birds from the wild (Heldstab and Studer-Thiersch, pers. comm., 2002).
 b. Males develop symptoms more frequently than females (Heldstab and Studer-Thiersch, pers. comm., 2002).
 c. Cold weather and water causes cracks in feet.
 d. Larger flamingo species may be more susceptible to the condition.

Treatment may consist of one or all of the following depending on the severity:

1. Local antiseptic cleaning and bandaging
2. Various lubricating or moisturizing ointments
3. Systemic antibiotics
4. Surgical debridement

Prevention may include:

1. Providing a substrate of grass or similar short, dense vegetation and a shallow pool.
2. Good sanitation of the exhibit and water.
3. Winter housing should be well designed and allow birds access to outdoors when possible.
4. Increase the activity of the birds by stimulating them to forage, providing a larger flock size to stimulate normal social behaviors, and artificially increasing day length.
5. Salt water around the feeding areas may decrease the incidence of the condition (Heldstab and Studer-Thiersch, pers. comm., 2002).
6. When flamingos are confined for medical reasons, rubber or mesh mats should be utilized (rubberized flooring, 3M matting-Nomad, Dri-Dek).
7. Regular examination of feet so treatment can be initiated early in the course of the disease.
8. Some institutions have had success with birds walking through moisturizing-type solutions on a regular basis.

Unusual Forms of Pododermatitis

An unusual form of pododermatitis occurred at one institution while birds were housed for the winter. The housing situation was sub optimal (e.g. concrete floors with Dri-Dek being provided sporadically). Two birds presented with similar lesions on two different occasions. A hemorrhagic fluid-filled bullae developed on one foot. Local and systemic antibiotics were used to treat the lesion. The bullae disappeared, however, the skin sloughed and the interdigital webbing became very dark and dry. Eventually the skin sloughed, leaving a healthy granulation bed. The lesion resolved in a month. Approximately 1.5 years later, the flamingo avulsed her nail and developed an osteomyelitis on the adjacent bone. The cellulitis and infection spread despite antibiotic treatment until the base of the foot and distal tendons of the leg were involved. The infection ruptured through the scales approximately two-thirds down the length of the leg, which allowed drainage to occur. The tendons in the area were necrotic. The flamingo developed similar bullae on the interdigital webbing during this episode. Approximately, 3-4 cm of necrotic deep and superficial digital flexor tendons were removed. Once the necrotic tendons had been removed, healing was quite rapid. Two years later, the bird was still walking well. A second bird developed a very similar problem and was handled the same way and is now walking with no obvious abnormalities (Wallace, pers. comm., 1999).

Nutritional Diseases (Refer to Nutrition, Chapter 5 for further details)

The following are examples of nutrition-related diseases:

a) **Metabolic bone disease.** Chicks fed a diet low in calcium, an improper calcium/phosphorous ratio, or a diet low in vitamin D, or lack of exposure to ultraviolet irradiation, are the most susceptible to metabolic bone disease (Humphreys, 1975; Fowler, 1978). Some zoos have their flamingos housed indoors without access to natural sunlight.

b) **Tibiotarsus rotation** (see Neonatal Medicine).

c) **Atherosclerosis** occurs sporadically in some zoological collections. The etiology of this condition remains unknown (Griner, 1983).

d) **Vitamin E/selenium deficiency.** This condition may predispose birds to capture myopathy (Dierenfeld, 1989). Currently captive diets appear to be low in vitamin E, thus supplementing the diet is recommended (see Nutrition, Chapter 5 for details).

e) **Vitamin D toxicosis.** A toxic nephropathy has been noted in captive flamingos from Europe. Vitamin D toxicosis leads to hypercalcemia, resulting in calcium deposition in renal tissue. It was suspected that there was a dietary excess in vitamin D (Phalen, Ambrus, and Graham, 1990).
Neoplasia

Neoplasia is relatively uncommon in flamingos. A few cases have been reported and are as follows:

a) Complex hepatocellular carcinoma was found in a lesser flamingo. The bird presented with bilateral pododermatitis and had a systemic trematode infestation (Campbell et al, 1993).
b) Cholangiocarcinoma was documented in a lesser flamingo (Wadsworth et al, 1985).
c) Cholangiocarcinoma and hepatic megalocytosis was reported in a Caribbean flamingo (Lopez and Marino-Moncada, 1986).
d) An ovarian adenocarcinoma was found in a Caribbean flamingo (Wadsworth et al, 1985).
e) A cholangioma was found in two Caribbean flamingos by one of the authors (JR).

Gout

Visceral gout has been observed with some frequency in flamingos housed at several North American zoological institutions. It is not clear if these are primary cases of gout or secondary to dehydration caused by other clinical diseases. A survey will be conducted on morbidity and mortality factors in the North American captive flamingo population, and elucidating the causes of this condition will be one of the primary goals.

Toxicities

Heavy metal toxicity is not common in captivity but possible. Zinc toxicosis has been suspected at a few institutions however, the source of zinc remains unknown. Lead poisoning has been reported in free-ranging greater flamingos and Caribbean flamingos secondary to ingestion of lead shot consumed while foraging (Aguirre et al., 1991). The clinical signs included emaciation and high mortality. At necropsy lead pellets were found in the gastrointestinal tract. There was evidence of enteritis, and the ventricular lining was stained an intense green. Therapy has not been reported but should be similar to that used in psittacine birds and waterfowl.

Flunixin meglumine has induced renal toxicosis in flamingos and cranes, thus is not recommended to use this drug in flamingos (Klein et al, 1994).

Vitamin D toxicosis is covered in Nutritional Diseases (see above).

Algal Toxicosis

Microcystins are hepatotoxic cyclopeptides produced by some types of cyanobacteria. Ten adult captive Chilean flamingos (Phoenicopterus chilensis) died acutely. Concurrently, an algal bloom was noted in the exhibit pond in which the flock of over 100 birds resided. The 10 affected flamingos presented dead or moribund with clinical signs of extreme weakness, lethargy, recumbency, and dyspnea. Bleeding from injection sites was noted in the five birds in which venipuncture and treatment were attempted. Blood abnormalities included severe hypoglycemia and marked elevations in AST, CK, LDH, and iron. Therapeutic efforts focused on controlling shock,
hypoglycemia, dehydration, and delayed hemostasis. Despite treatment attempts with fluids, dextrose, vitamin K, oxygen, vitamin E/Se, dexamethasone, and piperacillin, all birds died within eight hours of presentation. Initial differential diagnoses included toxicosis (e.g. anticoagulants, blue-green algae toxins), trauma, sepsis, or capture myopathy. Necropsies were performed on seven birds. Cultures from the liver, kidney, lung, and brain of three birds showed mixed bacterial growth but did not provide a causative etiologic agent for the epornitic. Consistent gross and histopathological lesions included multifocal areas of hemorrhage in the muscle, gastrointestinal, and respiratory tracts, severe hepatocellular dissociation and necrosis with hemorrhage and splenic congestion. High performance liquid chromatography (HPLC) was used to determine the presence of toxicological agents in pond water samples and internal organs of two birds. Liver tissues were negative for seven different anticoagulant rodenticides, while gastrointestinal contents and pond samples contained microcystins. Under light microscopy, pond water samples also contained non-filamentous granular clumps of cells surrounded by a clear calyx, consistent with the morphology of organisms of the genus *Microcystis*. It was determined that blue-green algae toxicosis caused the acute deaths seen in this flamingo flock. Further flamingo access to the exhibit pond was prohibited and no further mortalities occurred (Chitick et al, 2002).

**Stress**

Some flamingos fail to adjust to captivity (Humphreys et al, 1975). Malnutrition may develop. Occasionally captive flamingos collapse and die acutely. Acute deaths have been noted in physically restrained flamingos and are thought to be related to cardiac arrest. Chronic stress can cause immunosuppression and predispose to various infectious diseases (e.g. aspergillosis, malaria) (Humphreys et al, 1975).

**Cardiovascular Diseases**

Examples are as follows:

a) A lesser flamingo’s heart contained a myocardial infarct as well as foci of myocarditis. The bird’s liver contained a granuloma of undetermined etiology (Griner, 1983).

b) Atherosclerosis has been seen in the aorta, brachial, carotid, and internal iliac arteries of a Chilean flamingo (Griner, 1983). The intimal plaques in the left brachiocephalic trunk had almost occluded the vessels. The left pectoral muscles were ischemic, soft, and moist. Atheromatous plaques were also seen on the intimal surface of the aorta and brachiocephalic trunk of an American flamingo (Griner, 1983). Multiple renal granulomas, micro-calculi and glomerulosclerosis were also observed in this flamingo. A form of atherosclerosis characterized by intimal and medial fibromuscular hyperplasia and mineralization and sometimes with atheromas and cartilagenous metaplasia has been noted at necropsy in the aorta of several adult American flamingos by one of the authors (JR).

c) Cardiac arrest (see above for details).

**Sand/Sand-like Impactions**

Lesser flamingos appear to be predisposed to developing impactions with sand and material with similar consistency to sand (Henry, pers. comm., 1999). It is not clear in each case the source of material causing the impactions. Most birds have been found extremely debilitated or dead.
Parasitic Diseases

Parasites have only occasionally been reported to cause clinical disease in captive flamingos (Fowler, 2001) and are most commonly incidental in wild flamingos.

External Parasites

Lice belonging to the same genera as those found on waterfowl are seen in captive and free-living birds (Lamberski, 1998).

Internal Parasites

*Tetrameres americana* and *T. coccinea* are commonly found in ductal areas of the proventricular glands with no associated inflammation in wild *Phoenicopterus ruber ruber* (Aguirre et al, 1991; Griner, 1983; Rollin, 1981; Threlfall, 1981). *Tetrameres spp.* have been problematic in some captive flamingos at The Wildfowl and Wetlands Trust in Slimbridge (Humphries et al, 1976).

Cestodes in the genus *Amabilia*, *Cladogynia*, *Sobolevicanthus*, and *Gynandrotaenia*, have been found incidentally in free-ranging flamingos (Aguirre et al, 1991), however, cestodes were found to cause an intestinal diverticulosis in a captive lesser flamingo (Poynton et al, 2000). Artemia of saline lagoons have been recognized as intermediate hosts for the cysticercoides of cestodes parasitizing free-living flamingos in Camargue, France (Gabrion and MacDonald, 1980).

Trematodes are frequently found incidentally in wild flamingos (Aguirre et al, 1991). A disseminated trematode infection has been reported in a captive flamingo with concurrent hepatic neoplasia (Campbell et al, 1993). Schistosome ova were detected in histologic sections of six Chilean flamingos that died at the Calgary Zoo over a 10-year period. Death could be attributed in part to the presence of trematode ova in only one flamingo. Ova were most numerous and most consistently found in the pancreas, spleen, ventricular muscle, and proventricular submucosa. Other sites in which ova were found included the cerebellum, liver, kidneys, lungs, and skeletal muscle. Moderate inflammation was present around ova trapped in the hepatic parenchyma but was minimal or absent in all other sites. Examination of necropsy records suggested that infections occurred before the birds were caught in Chile in 1988. On the basis of ova found in the aorta and in arterioles, the trematode was tentatively identified as belonging to the genus *Dendritobilharzia* (Pare and Black, 1999).

Acanthocephalids have been reported in free-ranging flamingos (Aguirre et al, 1991). Besnotia-like sarcocysts were found in smooth muscle of small intestine in a wild Caribbean flamingo and Sarcocystis sp. merozoites were found in pectoral muscle tissue in free-living Caribbean and lesser flamingos (Aguirrre et al, 1991; Fowler, 2001). *Sarcocystis phoeniconaii n sp.* Murata was identified as a new species of Sarcocystis in the lesser flamingo (*Phoeniconaias minor*). Tiny rice-like grains, measuring 3-5 x 1 mm were found in the skeletal muscle (Lamberski, 1998).

Flamingos may harbor hemoparasites asymptomatically and occasionally develop clinical disease. In one report, *Plasmodium spp.* (type of malaria) caused a flamingo to become anemic and weak (Fowler, 2001). A diagnosis was made by microscopic examination of a blood smear. Mosquitoes are the vector of this parasite.
Treatment

Antiparasitic drugs and dosages used in other avian species should be effective and safe in flamingos. Due to the possibility of causing bone marrow suppression, fenbendazole should be used with caution in all avian species (Howard et al, 1999).

Prevention

Routine fecal examinations should be performed on captive flamingos. The parasite load in the particular group of birds being examined should dictate the frequency of fecal examinations. A minimum of twice-yearly fecal examination is recommended. Preventive deworming is rarely needed but should be instituted if chronic parasite problems exist.

Infectious Diseases

Bacterial

*Escherichia coli*, *Proteus spp.*, *Pseudomonas spp.*, *Enterobacter spp.*, and *Edwardsiella tarda* may be part of the normal flamingo intestinal flora (Lamberski, 1998). *Escherichia coli*, *Salmonella spp.*, *Aeromonas hydrophilia*, and *Pasteurella multocida* should be considered potential pathogens, as these organisms have been isolated from healthy as well as sick birds (Aguirre et al, 1991). Staphylococcal septicemia and synovitis have been reported (Griner, 1983). Septicemia occasionally arises from the infected lesions of bumblefoot, and pneumonia may occur in newly imported or stressed flamingos (Humphreys, 1975). *Salmonella spp.* can cause enteritis and septicemia in flamingos (Humphreys, 1975). Flamingos may also be asymptomatic carriers of *Salmonella spp.*

*Mycobacterium*

*Mycobacterium avium* complex is not a common problem in captive flamingos. It was found in six (1.9%) out of a sample of 306 flamingos examined over a 28-year period at The Wildfowl and Wetlands Trust in Slimbridge (Brown and Pickering, 1992). Some speculate that the low incidence of *Mycobacterium avium* in captive flamingos may suggest that they have some natural immunity (Cromie et al, 1991). However, *Mycobacterium avium* infections have also been reported in free-ranging flamingos (Cooper et al, 1975; Kock et al, 1999; Sileo et al, 1979). An epizootic in free-ranging lesser flamingos in Kenya resulted in more than 18,500 deaths over a few months in 1993. The disease was concentrated along the shores of Rift Valley Lakes Bogoria and Nakuru and did not involve any of the other avian or mammalian species frequenting the lakes. Discrete necrotic and granulomatous lesions were often noted in spleen and liver, and *Mycobacterium avium serovar I* was isolated from both organs. Furthermore, *Escherichia coli* and *Pseudomonas aeruginosa* were recovered in pure culture from the liver of a high percentage of the birds. Histopathology revealed lesions indicative of an acute septicemia. Algal toxicosis was initially suspected as the cause of the deaths due to a concurrent algal bloom; however, this was not confirmed (Kock et al, 1999).
Viral

Pox Virus

Cutaneous poxvirus lesions have been reported in captive flamingo chicks and adults. The lesions are usually on the legs in the adults and around the mouth and eyes in chicks. Surgical resection may be curative (McManamon et al, 1992), however, the condition can also be fatal in chicks (Arai et al, 1991). Sea World of Florida vaccinates their chicks with a commercially available avian pox vaccine (M. Walsh, pers. comm., 1999). Gross appearance of the lesion, histopathology and electron microscopy may be used to make a diagnosis.

Herpes Virus

Herpes viral infections are widespread in avian species and have been reported in Ciconiiformes (Ritchie, 1995; Kaleta, 1990; Gomex-Villamandos et al, 1998). Natural and experimental herpesviral infections have been previously reported in black and white storks and green herons (Gomex-Villamandos et al, 1998). A series of cases in three species of stork with hemorrhagic necrotic enteritis was recently reported (Gomex-Villamandos et al, 1998). Stork herpes viral infections are often fatal. Viral replication occurs in different cell populations resulting in tissue necrosis and organ failure. The stork herpes virus is currently unclassified.

A novel herpes virus has recently been identified as being responsible for mortalities in captive Caribbean flamingos in one zoological collection (Pers. comm. J. Raymond, 2002; Montali et al, 1998). Term embryo and neonatal flamingo chicks appear to be most susceptible to infection. Clinical signs are usually nonspecific and include weakness, lethargy, dyspnea, and diarrhea.

Gross necropsy lesions include an enlarged liver and spleen with pinpoint foci of necrosis, evidence of inflammation in the cloaca and intestinal tract, pale gritty kidneys, lesions indicative of pneumonia, and inanition. Histopathologic findings include bursal lymphoid depletion, necrotizing hepatitis, cloacitis, pneumonia, air sacculitis, enteritis, and eosinophilic intranuclear inclusion bodies in the liver, cloaca, and kidney. Syncytial cells have been observed in the liver and cloaca of infected chicks. Other less frequent histologic lesions are yolk peritonitis, renal gout, splenitis, and colitis. Electron microscopic examination of hepatocytes has been used to identify intranuclear viral particles with ultrastructural features compatible with herpes virus. Refer to the necropsy protocol for recommendations for collecting and processing tissues.

Treatment options are currently unknown. Some flamingo chicks infected with herpes virus may develop concurrent septicemia, and the use of antibiotics and supportive care are recommended. Acyclovir has been documented to reduce mortality in psittacine birds infected with herpes virus (Norton et al, 1991) but has not been evaluated in flamingos. Acyclovir pharmacokinetic data is available for psittacine birds (Norton et al, 1992) and could be extrapolated for use in flamingos.

Managerial changes that involve the reduction of stress (e.g. not pinioning chicks) and prevention of septicemia (e.g. prophylactic antibiotics) have decreased mortality from the virus at the National Zoological Park. The mode of transmission is currently unknown but appears to have a vertical component. Immunosuppression appears to play a role in the pathogenesis of this disease as evidence by the bursal lesions found in all flamingo chicks infected with herpes virus. The exact
source of the herpes virus is still undetermined but may be indigenous in flamingos. Presently, the virus has not been isolated, but molecular viral techniques have identified it as a novel alpha herpes virus.

Paramyxoviruses

Newcastle’s disease virus has caused mortality in free-living Caribbean flamingos (Fowler, 2001). The central nervous system is primarily affected. Clinical signs include tremors, paresis and paralysis. Free-living birds have been shown to have elevated antibodies to arboviruses. Paramyxovirus serotype 3 was isolated from tissues of captive flamingos (Phoenicopterus ruber) in Israel. The virus caused a high mortality, with respiratory system pathology being most notable (Shihmanter et al, 1998).

West Nile Virus

West Nile virus is caused by a flavivirus and is usually transmitted by mosquitoes. This virus may affect numerous avian species including flamingos. It also can affect humans and other mammalian species. Clinical signs are usually nonspecific; however, birds may exhibit signs of neurological disease such as abnormal head or neck posture, ataxia, tremors, circling, disorientation, unilateral or bilateral posterior paresis, and impaired vision. A bird may be found dead with no premonitory signs. The course of clinical illness is usually less than one week but may range from 1-24 days (Calle et al, 2000). Treatment is limited to supportive care and prevention of secondary infectious diseases. Vaccine trials are currently being conducted on flamingos at several institutions. The virus has affected flamingos in several North American captive collections.

Fungal

Aspergillosis

Aspergillosis may result in emaciation, lethargy, dyspnea, and increased mucous production in captive flamingos. Other than traumatic injuries, aspergillosis was the most important cause of mortality (3.1%) in the captive flamingo collection at The Wildfowl and Wetlands Trust at Slimbridge. Various forms of stress and housing birds indoors on straw in humid conditions were predisposing factors. Diagnosis and treatment are similar to other avian species. Prophylactic treatment may be a consideration under stressful conditions.

Cladosporium herbarum (Sooty Mold)

Fungal infections of the plumage associated with Cladosporium herbarum (“sooty mold”) have been reported in the UK (Beer and Kear, 1975) and in Florida (S. Clubb, pers. comm., 1999). The fungus appears to be associated with Osier willows. This saprophytic fungus forms a black sclerotia, which ruptures the feather cortex, weakening it so that the distal part of the barb breaks off. The plumage of the back becomes unkempt, frayed, and the birds look wet and lack waterproofing. A black dust
is often noted and is especially visible on birds with pale plumage. Birds may become wet through to the skin and chilled. Death by pneumonia or drowning (due to a loss of waterproofing and buoyancy) is a consequence. The condition has been described in Chilean, Andean, James’ and Caribbean flamingos. The mold is slow growing at the optimal temperature of 24-25° C. Growth is reduced or inhibited at higher or lower temperatures. Because of this temperature requirement, only the outer feathers are affected. Badly affected feathers may be pulled out or cut off.

Prevention includes the following (N. Jarrett pers. comm., 2002):

a) Raising the environmental temperature to 30° C will inhibit growth of the fungus.

b) Good hygiene of enclosures and exhibits.

c) Removal of Osier willows or keeping birds away from the trees.

d) Provide winter quarters with ambient air temperatures of 15° C to prevent mold growth.

e) Provide clean water to encourage bathing after gross contamination has been removed or when lack of water for bathing has stopped the bird from preening.

**Geotrichum candidum**

*Geotrichum candidum* was isolated from skin lesions of three Caribbean flamingos that died showing necrotic inflammation of the skin of legs and the digital webbing of the feet (Spanoghe et al, 1976). Abundant mycelium and arthrospores were observed in the dermis and epidermis. This fungus was subsequently inoculated into chickens and mice where it produced granulomas or more purulent nodules with central growth of abundant mycelium. *Geotrichum candidum* was re-isolated from 20 of 28 experimental animals. The authors suggested that prolonged contact with pond water and the presence of small wounds, as well as the advanced age of the affected birds, were predisposing factors in development of this disease. *Geotrichum candidum* is a common saprophytic fungus frequently found associated with mucous membranes and skin of humans and animals but rarely associated with disease. In this case report, seven of 21 flamingos had lameness and the presence of whitish skin lesions on the legs and digital webs. The lesions were observed during the first warm period after a cold winter. Three birds died after the onset of the lesions. These birds had been kept at this zoo for 16 years. The remaining four birds were separated from the flock, placed in a dry environment, and treated with an acaricide and an antibacterial ointment. The lesions disappeared approximately three weeks after the onset of the disease, even though no antifungal therapy was used. As the lesions in the affected birds were only in areas with maximum exposure to the pond water, it was surmised that this was a predisposing factor.

**Amyloidosis (J. Raymond, pers. comm., 1999)**

Amyloidosis is a disease that involves pathologic proteinaceous substance deposited between cells, causing tissue and organ failure (Landman et al, 1998). There are a number of biochemically distinct forms of amyloid; however, the protein is always composed of nonbranching fibrils arranged in beta-pleated sheets. Ninety-five percent of amyloid is composed of fibril proteins and 5% is composed of the glycoprotein called P component. Amyloidosis occurs in most avian orders, however, Anseriformes, Gruiformes, and Ciconiiformes have the highest incidence. The disease is progressive, fatal and has a high incidence in older birds. Systemic amyloidosis can be associated with a variety of infectious and noninfectious chronic inflammatory conditions as well as stress (Landman et al, 1998).
There appears to be a high incidence of amyloidosis in some captive collections of Caribbean flamingos. Stress and concurrent inflammatory conditions play major roles in the development of the disease. Most cases of amyloidosis in flamingos have been associated with infectious and noninfectious inflammatory disease(s); however, some flamingos with amyloidosis have no evidence of concurrent disease.

The most common gross lesions associated with amyloidosis in flamingos are an enlarged, tan-brown spleen, light brown, swollen liver and enlarged tan kidneys. Histologically, amyloid deposits are found primarily in the spleen, kidney and liver. Blood vessels in the heart, pancreas, liver, spleen, thyroid glands, and kidneys frequently contain amyloid deposits. Other organs less frequently affected with amyloid include adrenal glands, ovaries, and testes.

In the kidneys, amyloid deposits are primarily found within glomerular tufts. In cases of glomerular amyloidosis, flamingos can present with clinical signs suggestive of renal failure, which includes dehydration, lethargy, weight loss, anorexia, and shock. Many of these flamingos have elevated plasma uric acid and phosphorous levels. Most of these flamingos have concurrent urate nephrosis.

Enteritis due to a variety of causes is a common concurrent inflammatory disease associated with amyloidosis in flamingos. Other common concurrent inflammatory diseases are pododermatitis, hepatitis, dermatitis, arthritis, and nephritis.

There is no treatment for amyloidosis. Supportive care, including fluids, is an option to use in flamingos with renal disease due to amyloidosis. Treatment and prevention of various inflammatory diseases may aid in decreasing the incidence of the disease in flamingos.

**Preventive Medicine**

A good preventive medicine program is the best way to ensure a healthy and long-lived captive flamingo population. Preventive medicine begins with quarantine. All new arrivals should be housed separately from the existing collection for a minimum of 30 days. During this time period, the following is recommended:

- a) A thorough medical and husbandry history should be acquired from the sending institution. Dietary and methods of feeding changes should be avoided or at least very gradually changed. Flamingos may stop eating even with very subtle changes to their environments. It is preferred to move flamingos in groups.
- b) Monitor fecal quality and quantity closely during quarantine.
- c) Physical examination at the beginning and preferably end of the quarantine period including assessment of body condition, examination for ectoparasites, and examination of the plantar surface of the feet. If physical examination at the end of the quarantine period is not possible, a visual exam should suffice.
- d) Body weight (refer to the Management Chapter for details on methods of weighing) should be obtained at the beginning and end of quarantine period and opportunistically (i.e. quarantine exam).
- e) Feces should be collected at weekly intervals for a total of three samples for fecal flotation, direct smear, fecal cytology, and fecal gram stain.
f) Cloacal swab or fecal culture for *Salmonella spp.* should be done at least once and preferably 2-3 times during the quarantine period. Placing feces in enrichment media may increase the yield of enteric bacterial pathogens.

g) Blood collection for CBC, chemistry, sexing, and plasma banking.

h) Animals should be permanently identified using leg bands or microchips.

i) If animals are to be housed in open outdoor enclosure, provisions should be made to restrict flight such as wing clipping or pinioning.

Birds housed in the collection should be examined opportunistically (i.e. when bringing in for the winter or moving for other management purposes). The husbandry and veterinary staffs of the individual institution should dictate the frequency of examination. It is important to catch birds prior to the breeding season, as not to disturb the nests and/or eggs. Routine health assessments should include the following:

a) Physical examination, including assessment of body condition, examination for ectoparasites, and examination of the plantar surface of the feet.

b) Body weight determination (refer to Management, Chapter 3 for details on weighing methods).

c) Feces should be collected at regular intervals for fecal flotation, direct smear, fecal acid-fast stain, fecal cytology, and fecal gram stain.

d) Cloacal swab or fecal culture for *Salmonella spp.*

e) Blood collection for CBC, chemistry panel, and serum banking. *Aspergillus spp.* serology and protein electrophoresis can be evaluated in healthy birds in order to establish reference intervals for these individuals.

**Postmortem Evaluation**

A thorough necropsy should be performed on all flamingos that die. Institutions are encouraged to perform a cosmetic necropsy for museum specimens; however, this should not compromise obtaining a complete set of tissues.

A complete and detailed history should be included. The bird should be sexed at necropsy and, if it was sexed antemortem, methods of sexing should be included so that sexing techniques may be standardized.

a) Collect a small section of all major tissues (heart, lung, air sac (on a piece of paper towel), thymus, bursa, crop, proventriculus, multiple sections of intestine, pancreas, kidney, adrenal gland, gonad, oviduct, muscle, bone marrow, gizzard, eye, tongue, esophagus, trachea, aorta, spleen, skin, peripheral nerve, and brain in 10% buffered formalin. Collect bone from chicks with suspected boney abnormalities.

b) Include a description of the gross findings, body weight in grams at the time of death, and important clinical history (including current diet).

c) Anaerobic, aerobic, and fungal cultures of various lesions should be taken when indicated.

d) Liver, kidney, spleen, bursa and any abnormal tissue should be frozen (-70 °C) pending histopathology findings.

North American zoos should send the pathology report (gross and histopathology) or glass slides and culture results to Dr. James Raymond. If you suspect herpes virus, please call or email Dr.
Raymond for instructions and send a complete set of slides or formalinized tissues in conjunction with frozen (-70°C) samples of liver, kidney, spleen, and bursa of fabricus mailed overnight in a cooler of dry ice to:

Dr. James Raymond
Zoo Path
PO Box 1398
Harpers Ferry, WV 25425
Phone and fax number: 304-725-9212
Email: Zoopath2@aol.com
References


Young, E.  1967. Leg paralysis in the greater flamingo and lesser flamingo following capture and transportation. International Zoo Yearbook, 7:226.
Foot problems are normally inconspicuous and therefore often not detected. Only when a bird begins to limp, we realize that something might be wrong.

**Short description of the symptoms:**

Two different and independent ways of infections occur: an infection with bacteriae and one with the papilloma virus. The bacterial infection leads to infected wounds as cuts, fissures -> nodes -> balls (extremely large nodes); the virus infection to warts.

Both probably start with small cracks, cuts or fissures in the skin and may occur together.

**Adult birds:**

In the Basel zoo foot problems in the flamingos were recognized since long and were regarded mainly as problem of reduced blood circulation in the feet. Therefore, when the new exhibit for the flamingos was built in 1991, we tried to improve the conditions for the feet by natural precautions:

- by increasing the general activity of the birds i.e. foraging, walking around, stimulating social behaviour,
- by including the winter quarter into the exhibit enabling a regular moving in and out of the birds whenever possible also in the cold seasons,
- by adding a saltwater circle (concentration between normal seawater to double seawater-concentration) around the feeding pan
- by providing the resting places with dense, short vegetation.

Before the birds were transferred to the new exhibit in May 1991 the symptoms at the feet of all birds were checked and noted. This was repeated a few years later in December.

The comparison of the two checks showed following results:

- At both places (old and new exhibit) foot infections occurred a little more often in the zoo hatched birds than in birds from the wild.
- At both places (old and new exhibit) the males had somewhat more symptoms than the females.
- The feet had clearly become better in the new exhibit, the amount of the symptoms and the degree of infections having decreased.
- Active infections had become very rare.
- The papilloma infection had decreased only slightly.
In birds from the wild the decrease of symptoms was more pronounced than in the birds hatched in the zoo.

**Young birds:**
The young birds of the year are caught for the first time in August/September for individual leg banding. In October-December they are separated from the group and, if they remain at Basel, spend the winter at a different quarter.

Between late summer (scarcely any symptoms) and early winter there is a clear increase in cracks or cuts and nodes, virus infections are very rare.

In the winter quarter:
1. Odd asphalt floor covered with straw:
   - Dramatic increase of symptoms, concerning bacterial and virus infections. (These birds are still living in our group. We lost 2 males in the following months due to foot problems, but the feet of the others underwent a drastic change, most of symptoms having disappeared within the following months in the outdoor exhibit. If these birds retain a susceptibility to later infections is not known.)
2. Smooth concrete.
   - Increase of the virus infections, but only to a low degree.
   - Combined with very shallow saltwater (for resting): no increase or even slight decrease of bacterial infections
   - Combined with Encamat mats (for resting): slight increase of bacterial infections but compared to the asphalt floor only to a low degree.

**Summary of the experiences in the Basel zoo:**

1. Males generally seem to suffer to a somewhat higher degree from the infections than females, as do birds hatched in the zoo compared to birds from the wild.
2. The infections leading to bumble feet are a dynamic process, the feet can get worse in a short time but the contrary is also true. Especially in young birds symptoms may disappear without leaving clear traces. Old chronic infections may also be reduced, but leave scars.
3. A steady disinfection of the feet by saltwater seems to reduce the rate of infections.
4. Papilloma infection seems to be more difficult to reduce and the degree may perhaps also be influenced by stress and similar factors. Indirectly this infection may be reduced by reducing the rate of small wounds, a probable entrance of the virus.
5. The cold and dark seasons seem to favour foot problems.
The conditions in the outdoor exhibit during the warm seasons could be improved by the different preventive measures. But there remain problems during the cold and dark seasons: Due to the low temperatures blood circulation will be reduced in the legs causing the skin of the feet to become hard and brittle leading to cracks and cuts in the skin thus enabling infections. Additionally the decreasing day length and the lacking sun reduce the general activity of the birds.

Under different climatic conditions than those in Middle Europe the situation might be different.

Proposals to reduce foot problems in flamingos by general preventive measures (not by medical treatment):
1. Saltwater through which the birds have to pass regularly, in outdoor and indoor enclosures.
2. Soft and slightly humid floor at the resting places (outdoor: short and dense vegetation, indoor: we experienced with woodchips this winter.)
3. Prolongation of the period the birds stay indoor at night to avoid the low night-temperatures
4. Increasing the general activity:
   Outdoor:
   • by offering large areas of shallow water with plankton production for extended foraging behaviour,
   • by offering different resting places for different day times according to the position of the sun,
   • by stimulating social behaviour.
   Indoor:
   • by adding artificial light to extend the short day length in winter and compensate for the lacking sun.
   • by large winter quarter allowing display behaviour.
Chapter 7

Behavior and Research
Facilitators: Catherine King, Rotterdam Zoo; Sue Maher, Disney’s Animal Kingdom; Elizabeth Stevens, Disney’s Animal Kingdom

Authors’ note: in determining the best way to approach this chapter, we felt it would be most useful to summarize flamingo behavior using classic references on flamingos. Rather than summarize every single research project that has been done, the reader is directed to the reference chapter for an extensive list of flamingo research projects that have been published. Lists of some current research projects and potential research projects with captive flamingos are included in this chapter. To provide readers and potential researchers with some guidance these projects have been divided into topics: Research Currently Underway, Workshop Projects, Potential Studies of Captive Flamingos to Benefit Wild Populations.

Flamingo Behavior

Flamingos have the longest legs and necks relative to body size of any group of birds and are well known for their unusual bill. These morphological attributes are accompanied by a set of unusual behaviors. Flamingos are extremely social during all phases of the life cycle. While breeding colonies of some flamingo species can be relatively small, numbering tens of pairs, colonies are often huge, including many thousands of individuals. A colony of 1,100,000 lesser flamingos has been documented (del Hoyo et al. 1992). Once they leave the nest at approximately a week or two of age, chicks remain in a creche. The term creche means “day nursery” in diverse languages, but when used in relation to flamingos, creche refers to a group of chicks congregated together, chaperoned by a single or small group of adults. The parents visit only to feed their young, and how they find their own offspring among the teeming mass of vocalizing chicks remains somewhat of a mystery. Flamingos are one of the few groups of filter-feeding birds and are the only filter-feeding birds to feed the young a “milk” secretion. The production of such a secretion in the upper digestive tract of the parents is a rearing strategy shared by just a few groups of birds.

Observations on flamingo behavior have long appeared in the literature, but the first formal comparative study of reproductive and ritualized flamingo behavior, initiated in the 1950’s, was undertaken by Adelheid Studer-Thiersch at Basle Zoo in Switzerland and in the wild in Spain (Studer-Thiersch 1964, 1967, 1972, 1974 and 1975). Through his comparative study of ritualized flamingo behaviors, Phil Kahl (1975) also made a substantial contribution to our understanding of flamingo behavior and to descriptions and terminology for these behaviors.

Group Displays

Flamingos nesting in temperate latitudes are seasonal breeders. In the sub-tropics and tropics, where the flamingos mainly live, flamingos are nomadic, and breeding is opportunistic, occurring year-round when conditions are favorable. Food availability, primarily dependent on rainfall, is thought to be the most important factor determining timing of breeding. Group-displays are a spectacular part of flamingo breeding. Most of the displays appear to be derived from comfort
behaviors, and as the behaviors became ritualized they became more stiffly performed, more contagious among group members, and “non-functional” in the sense of the comfort behaviors they resemble. Both sexes participate in group-displays, and it is thought that these displays are necessary to synchronize the physiological reproductive state of flamingos. Sizes of groups of marching flamingos can be enormous, however many common ritualized behaviors (e.g. wing salute, inverted wing salute, twist-preen, wing-leg stretch) are mainly performed by smaller groups within large congregations of flamingos.

Kahl (1975) studied ritualized behaviors of all six taxa (the Andean, James, Caribbean and Chilean flamingos of the New World, and the greater and lesser flamingos of the Old World), however some taxa were more closely observed than others. He reported some subtle differences between taxa: in general, he found that the closely related Caribbean, greater, and Chilean flamingos perform displays that are more similar than those performed by the other taxa. Studer-Thiersch (1975) concluded that the Caribbean flamingo is the most primitive of the three *Phoenicopterus* taxa in ritualized behavior. Based on her comparative study of their behavior she concurred with the current, most widely used taxonomic treatment, i.e. differentiating Caribbean and greater flamingos at sub-species level and awarding Chilean flamingos full-species status.

**Behavioral Research: the Basics**

A prerequisite to almost any flamingo research project is being able to individually identify individuals. Plastic rings/bands with individual codes appropriate for marking flamingos are now widely available from different sources, as discussed in the Management Chapter. Zoos are strongly urged to use such rings/bands if they do not already do so, as these rings/bands are also essential to the most fundamental flamingo management, e.g. identifying breeding pairs.

An ethogram is a catalogue of an animal’s different behaviors. It is a standard tool used for any behavioral study. Depending upon the research question of the behavioral study, the ethogram is constructed to allow the researcher to measure the particular behaviors addressed in the research question, therefore no two ethograms are necessarily the same. Below is a sample ethogram taken from Beastly Behaviors (Janine Benyus, Addison-Wesley Publishing, 1992) that, with some additions, is designed to be a complete listing of all flamingo behaviors. Many behaviors (e.g. filter-feeding, treading, wing stretch) have been seen in chicks as young as five days old. Descriptions of ritualized behaviors are largely adapted from Kahl (1975). Names of some displays have been altered to depict only movements involved rather than motivation, in keeping with current philosophy (e.g. Hancock et al. 1992).

**Sample Ethogram**

**Locomotion**

- **walking** - individually or in groups.
- **running** – an integral part of becoming airborne for flight (except in sufficiently high wind), and a common response to perceived danger. Is also associated with marching (described in ritualized behaviors), as flamingos may alternate running with walking during marching episodes. A group of flamingos may at other times begin running for no apparent reason.
- **flying** - a flamingo flies with neck outstretched and legs trailing behind.
landing - a flamingo circles overhead before landing, then runs several meters before stopping.

swimming - a flamingo swims with the head above water and wings folded, using the feet to propel itself.

Feeding

treading - a flamingo places its bill in the mud or water, lifting and then setting down one foot at a time in a treading motion, presumably to stir the mud or water contents. The flamingo may slowly walk in a circle as it treads or it may tread in place.

mud dredging - a flamingo walks forward, moving its filtering bill back and forth through the algae-coated mud.

tipping up - a flamingo in deeper water submerges its head, tipping the distal part of the body up. This allows flamingos to feed at greater depths than other wading birds of similar size can reach.

filter-feeding - flamingos primarily feed with the bill lowered “up-side down” into the mud or water. The tongue acts as a piston, pumping water or mud in and out of the bill. Tiny food particles are allowed through lamellae lining the inner part of the mandibles. The (species characteristic) distance between the lamellae as well as the size of the gap between the two mandibles determines the size of food items that can be filtered.

ground feeding - a flamingo picks up pieces of food from the ground, without using filter-feeding mechanism.

Comfort Behaviors

preening

stretching

bathing

foot shaking

sleeping - usually on one leg with neck folded along the back and bill tucked into their feathers. Flamingos may also sleep sitting up with the legs tucked under the body.

wing salute, inverted wing salute, twist-preen, wing-leg stretch: these terms refer to ritualized forms of some flamingo comfort behaviors: when performed as (stretching) comfort behaviors the behaviors are performed by individual flamingos, usually following a period of physical inactivity. The ritualized versions are performed by groups, are usually stiffer or otherwise more exaggerated in execution, and often are performed in predictable sequences.

Ritualized Behaviors

alert posture - a flamingo stands erect with neck stretched vertically upward, moving the head side to side in horizontal arcs with bill held high and nearly horizontal. Is performed when something occurs in surroundings, and is accompanied by a honking vocalization. Performance of alert posture by a flamingo usually triggers performance by other nearby individuals.

hooking - a flamingo extends neck fully and inclines it forward between 30°- 60° from the vertical, with the bill tip aiming toward its own chest. Scapulars and back feathers are erected. A flamingo may approach another flamingo in the hooking posture. Hooking is often performed by the dominant bird before and after a fight and is regularly performed (particularly by males) before or after copulation. Hooking is sometimes also performed by groups of marching flamingos.
neck-swaying - A flamingo extends its neck horizontally, swaying it sinuously in wide horizontal arcs. A series of low grunting calls accompanies the display. Neck-swaying is often performed on the nest, usually following hooking and preceding a physical fight.

sparring - two or more flamingos direct neck-swaying displays at each other, just missing contact between the bills.

pecking - one flamingo directs pecks at another.

feather sleeking - flamingo lowers its head and sleeks its feathers. Is associated with withdrawal from an agonistic encounter with one or more conspecifics.

marching - a group of flamingos masses closely together, walking with an erect posture in a synchronized “quick-step”, going first one direction and then another. The tail may be wagged during marching. Size of marching groups can range from a few flamingos to many thousands. Marching can be performed any time of the year but is particularly common during the onset of breeding attempts.

false-feeding - marching flamingos suddenly slow down, bending their necks forward in unison, and trail the bills in the water making chomping movements with the bill, the group then proceeds with marching again.

head-flagging - exaggerated alert posture, the head is flagged from side to side in precise, horizontal arcs; some species issue loud honks when flagging. Head -flagging is often associated with marching.

wing-salute - usually follows head-flagging: while still standing erect with the neck stretched upward, a flamingo quickly opens its wings fully to the sides, revealing its black primary feathers. A series of short grunting vocalizations is made.

inverted wing-salute - commonly follows head-flagging and wing-salutes; with neck extended, the flamingo tilts its body forward and down, cocking the tail higher than the shoulders; it then lowers its neck, flashes its wings partially open, and holds the wings behind its back for a moment, with black primaries tipped skyward. The display is accompanied by a soft, nasal call.

twist-preen – a flamingo twists its neck and bill back along the body to one side and briefly flashes the wing on the same side downward, exposing the black primary feathers. The flamingo appears to preen behind the wing for 1-2 seconds with its bill, but does not actually do so.

wing-leg stretch – The leg and wing on one side are stretched outward to the rear. A brief, sighing call accompanies performance of this behavior.

pair-walk – performed by a pair: the female leads and the male follows step for step. Side by side or parallel, their strides are highly synchronized and ritualized, in contrast to pairs moving together to feed or to another location. The pair-walk generally precedes copulation, but can also terminate without a copulation attempt being made.

copulation - male mounts female and cloacal contact is made. While the entire copulation process often takes several minutes, actual cloacal contact only lasts a few seconds. Copulation attempts performed by same-sex pairs may be similar to those performed by male-female pairs.

triumph ceremony - the pair calls together with necks stretched out, sometimes directed towards the ground, following copulation.

Parenting Behavior

nest building – a pair of flamingos wanting to nest pulls nesting material (e.g. mud, pebbles, feathers and grasses) to one place to form a mound. Once incubation of an egg begins, the sitting bird continues to incorporate material around it into the
mound, and mounds can become quite high if much material is available. Mounds may be virtually non-existent if nesting material is unavailable.

- **incubation** - the parents take turns incubating the egg. Sitting is interspersed with standing and stretching behaviors.
- **contact call** – adult puts its head close to the egg and makes a high-pitched contact call. Presumably the chick responds with its own contact call.
- **feeding chick** - both parents (and sometimes helpers) drool a “crop milk” secretion from their bills into the chick’s bill. The secretion is initially blood red, but can become less red as the chick ages.
- **creching** - when flamingo chicks band together, chaperoned by a few adults.
- **food begging** - chicks call and peck at an adult’s neck.

References


Flamingo Research: Past, Present and Future

If you are interested in any of the below projects you can contact the primary researcher if one is noted. It was agreed at the Flamingo Specialist Group Meeting in 1998 that North American and European zoos wishing to support field research or conservation projects or carry out ex situ research would communicate their activities to their respective Taxon Advisory Groups (TAGs). The TAGs can facilitate contacts with relevant parties and help to avoid duplication of effort when it would not be useful.

Published Research

See the Bibliography for published papers.

Research Currently Underway

There are a number of several projects being worked on currently. Contributions on some current long-term projects, in the field as well as in zoos, are found in Conservation Biology of Flamingos, G. Baldassarre, F. Arengo and K. Bildstein, eds. Waterbirds Vol. 23, Special Publication (1): 2000.

Some other projects are included here with a short summary.

1. Flamingo Crop Milk Secretion and Gland Development.

   **Primary Researcher:** A. Studer-Thiersch, Basle Zoo, Switzerland (Oberwilerstr.135, CH-4054 Basle Switzerland, (Adelheid.Studer@datacomm.ch)

   **Summary:** Crops of all dead flamingos from Rotterdam Zoo and Basle Zoo were removed during postmortem examinations for histological study. The stage of development of crop milk secretion glands and their prevalence will be compared with age, sex and reproductive status of the birds at the time of their deaths.

2. Understanding the Movements of Lesser Flamingos and Greater Flamingos Between the Alkaline Lakes of the East African Rift Valley: Relationship between Alkalinity and Food Supply

   **Primary Researcher:** Andrew M. Burton (Mexico), Neil and Liz Baker (Tanzania), Mike Winterbourn (New Zealand). (andrew@ucol.mx or spizaetus@yahoo.com) or http://www.ucol.mx/ocean/ or http://www.zool.canterbury.ac.nz/mjw.htm

   **Summary:** The goal is to determine the movements of flamingos between the East African soda lakes beginning in northern Tanzania. The main objective will be to unravel the complex interrelationship between water alkalinity, food availability, and movements of flamingos.

3. Correlates of Reproductive Behavior in Captive Chilean Flamingos

   **Primary Researcher:** Chuck Siegel, Dallas Zoo (csiegel@mail.ci.dallas.tx.us)

   **Summary:** Data on group-display activity and on steroid levels in fecal urates and blood are being collected throughout the year to be analyzed in relation to each other.
4. Flamingo Reproductive Behavior
   **Primary Researcher:** Catherine King, Rotterdam Zoo (C.King@RotterdamZoo.nl)

   **Summary:** This is a long-term project to evaluate stability of pair and triad associations, whether copulation success among associations improves over time, how newly acquired birds integrate into the group, reproductive success of flamingos born into the colony. Nesting habits (e.g. nest location, neighbors, position in laying-order) will be analyzed to determine whether these are consistent among individuals and associations over the long term.

5. Flamingo Dominance Study
   **Primary Researcher:** Catherine King, Rotterdam Zoo (C.King@RotterdamZoo.nl)

   **Summary:** This project evaluates the social position of individual birds within the hierarchy of the colony. The relationship between social position and breeding success, as well as the relationship between position of parents and position of offspring within the group will be evaluated.

6. Factors Influencing Copulation Behavior of Phoenicopterus ruber in Captivity
   **Primary Researcher:** Catherine King, Rotterdam Zoo (C.King@RotterdamZoo.nl)

   **Summary:** Study is being undertaken to determine which factors influence copulation success of Phoenicopterus ruber and the relative importance of these factors.

7. Previously Undescribed Behaviors of Chilean Flamingos
   **Principal Researcher:** Sherry C. Mossbarger, Dallas Zoo (birdkeeper44@yahoo.com)

   **Summary:** Descriptions of previously undescribed Chilean flamingo behaviors.

   **Primary Researcher:** A. Studer-Thiersch, Basle Zoo, Switzerland (Oberwilerstr.135, CH-4054 Basle Switzerland, (Adelheid.Studer@datacomm.ch)

   **Summary:** An effort will be made to systematically determine how factors such as substrate, diet, water quality, temperature, nutrition and space influence manifestation of bumblefoot in zoos. More flamingo managers willing to periodically assess foot condition of their flamingos are needed for this project.

   **Researchers:** Ann Ward (Award@fortworthzoo.org), Amy Hunt, and Mike Maslanka, Fort Worth Zoo, and Chris Brown, Dallas Zoo (cdbrown@mail.ci.dallas.tx.us)

   **Summary:** Crop milk samples (30 ml) were collected from juvenile (6-7 weeks old) Caribbean flamingos (Phoenicopterus ruber ruber, n = 14) in the Ria Lagartos Biosphere Reserve (El Cuyo, Yucatan, Mexico) on the northern coast of the Yucatan Peninsula. The samples are being analyzed for dry matter, crude protein, fat, minerals (calcium, phosphorus, magnesium, manganese, sodium, potassium, iron, copper, manganese, molybdenum, zinc), vitamin A, vitamin E, lutein and zeaxanthin, beta-cryptoxanthin, echinenone, canthaxanthin, and beta-carotene. In addition, anthropometric measurements and blood samples were taken at the time of sample collection. This information will allow us
to learn more about crop milk and avian lactation and, most practically, to aid in flamingo hand-rearing efforts.

10. In-situ lesser flamingo conservation research in the Rift Valley of Kenya.

**Primary Researcher:** Dr. R. B. Childress, Department of Biology, University of Leicester, UK and the Wildfowl & Wetlands Trust, Slimbridge, UK.

**Summary:** The research focuses on four areas: 1. Health – Using blood samples from both well and sick birds, research will attempt to discover the cause of recent die-offs and develop a protocol for monitoring the species’ health in the wild. 2. Ecology & Behaviour – The use of Ecological monitoring will be used to identify the essential lake ecosystem properties that sustain large numbers of lessers and to understand the birds’ response to changes in these properties. Distribution on the lakes at various times, habitat usage, and time budgets in different climatic conditions are also being documented. 3. Biometric dataset – A long-term ringing program has been established which will enable migration patterns and longevity to be studied over time. 4. Gender Determination and Condition Indices – Principal component analysis is being used to develop condition indices for the various ages and genders as an additional method for monitoring the well being of this species.

**Workshop Projects**

The (by no means inclusive) list of topics below were brought up at the husbandry guidelines meeting or have been discussed on the AZA flamingo listserv as research areas that would aid in captive management of flamingos. These topics include:

1. Flamingo substrate use: What factors influence substrate (including water) use, and what recommendations can be made regarding substrate?
2. Regulation of pigmentation in feathers: How do nutrition, feeding of young and other variables influence feather pigmentation?
3. Other nutritional questions that could be analyzed across institutions: hypervitaminosis, mineral absorption, iron storage, relation of diet to physical occurrences (e.g. excess fat of orange color).
4. Chick leg problems: How do problems relate to (parental) nutrition, parental resources (e.g. number of eggs laid already in current season), time of reproductive season and time of year of hatch? Survey pathology and clinical records for leg problems such as rickets and excessive shakiness.
5. Sexing methods: What are the advantages and disadvantages of different methods? Can a combination of morphological measurements be reliably used to sex young of the year?
7. Triggering breeding: influence of management practices, e.g. separation/reunion of flocks, use of mirrors, concentrating birds into a small area, and other potential flock stimuli on reproductive success.
8. Onset of Chilean flamingo breeding seasons in northern-hemisphere zoos: Is this species tending to breed progressively later in the year? If yes, what could be the explanation and what management steps could be taken to stimulate this species to breed earlier, as late breeding is often unfavorable for chick rearing.
9. Causes of mortality, nutritional needs and behavior of lesser flamingos compared to other flamingo taxa to determine special management requirements for this “difficult” species.

10. Fledgling age-determination (for management purposes) of useful chick age equivalent to fledging. The usual demarcations; leaving the nest, acquiring feeding independence and flying, are not appropriate: a chick usually leaves the nest within a week but may continue being fed by its parents for more than a year. Learning to fly is gradual and in most cases the chick will never fly because of pinioning.

Topics for Potential Studies of Captive Flamingos That May Benefit Wild Populations


1. Display performance as an indicator of age: Qualitative and quantitative variation in performance of displays between individuals can be analyzed to ascertain if these provide proximate cues for assessing age as (at least greater) flamingos may have an age-assortative mating system.

2. Sexing and aging young flamingos in the field: An in depth study of growth rates and other aspects of morphological development might lead to finding reliable indicators of age independent of sex, so that ages of young birds can be more accurately assessed in the field. Sexual dimorphisms in growth need to be more closely studied, as these could also be important in interpreting field data. Developing a set of reliable morphometric measurements to sex young-of-year could be useful for both wild and captive birds.

3. Manipulation of gender of offspring: records on sex and hatching date of offspring and fate of eggs of known parents could be used in studies of potential manipulation of gender of offspring.

4. Flock synchronization: Relationships between display and breeding synchrony of individuals within groups, and between degree of synchronization among individuals and reproductive success.

5. Winners and losers: Factors (e.g. size, reproductive status, familiarity with surroundings) that can influence outcome of agonistic encounters


7. Recognition of vocalizations: Experimental studies involving transfer of eggs in various stages of hatching and of newly hatched chicks could help to determine when parental recognition of chick vocalizations and chick recognition of parental vocalizations occurs.

8. Coping with salts: Studies of behavioral and physiological response to salts, e.g. salt avoidance, processing and secretion are important in understanding flamingo ecology.

9. Nocturnal feeding: What are the advantages and disadvantages? Flamingos in the Camargue are reported to feed mainly at night when items eaten are actually less available. How prevalent is nocturnal feeding in captivity?

11. Molt: A thorough study of molt of individuals in relation to environmental factors and social interactions might shed light on stimulus and constraints of molt, and explain differences in timing and completeness of molt.

12. Flamingo vision: A study of flamingo vision would be interesting to help understand why flamingos are pink and what aspects of their visual systems allow them to be highly active both night and day.

13. Chick nutrition: Samples of chick crop contents can be collected in different institutions and analyzed to see how nutritional content of the crop secretion varies throughout chick rearing and whether the nutritional value of the crop contents varies with parental diet.

14. Flamingo marking: Methods for marking flamingos and fitting transmitters for radio and satellite tracking can be easily tested in captive flamingos.

15. Susceptibility to Tuberculosis (TB): While flamingos appear to have natural immunity to TB, huge numbers have died in the wild because of TB. A study of factors that can influence immunological response to this disease could be important in conservation of wild populations in the future.

16. Nutrient cycling: Information obtained by determination of fecal chemical composition and output of captive flamingos can be integrated into quantitative models of nutrient cycles in flamingo environments.

Summary

As can be seen in the Bibliography, numerous publications referring to flamingos have appeared. Nonetheless there is still much to be learned about these beautiful birds. The possibilities for research in zoos to benefit both captive management of flamingos and their in situ conservation are immense.

The lists of projects above also demonstrate that zoos can, with little effort, collect information that is useful in further developing captive management practices and in developing techniques useful in the field. There are also many field projects that zoos can help finance or provide materials and/or manpower. Zoo personnel are encouraged to review the list of projects and consider how you can contribute. As mentioned above, these lists are not complete. Perhaps you can think of other projects that you know would be useful and are within your capacity. Again, it is helpful to take up contact with your region’s TAG so that the TAG can support you in carrying out your efforts as effectively as possible. Cooperation is essential in achieving our common goals: furthering knowledge and management expertise for flamingos both in the wild and in captivity.
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Jeanette T. Boylan, Ph.D., Zoologist, Dallas Zoo

This bibliography contains over 2600 references and strives to be as complete as possible for all references regarding flamingos. Many sources were used for references and many of the historical references were not verified. The bibliography is divided into two sections – a historical bibliography and current bibliography. The historical bibliography contains references before 1975 and is ordered by author’s last name. The current bibliography contains references from 1975 to 2005 and is divided into sections for ease of finding articles (Captive management and behavior; Conservation, Disease and veterinary aspects; Distribution, breeding sites and population size; Natural history and ecology; Species accounts, guide books; Taxonomy; and Miscellaneous).

Many people assisted with the input and validation of the references. Of special note are Kim Williams and LaVona Purcell of the Dallas Zoo, Cathy King of Rotterdam Zoo and Adelheid Studer-Thiersch of Basel Zoo. Please send any corrections, additions or copies of reprints to Jeanette T. Boylan, Dallas Zoo, 650 South R.L. Thornton Fwy, Dallas, TX 75203 (jboylan@mail.ci.dallas.tx.us).

** indicates references that the Dallas Zoo has available in its reprint library.

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