DEVELOPING AN ENERGY INTAKE MODEL FOR PARENT-REARED SADDLE-BILL STORKS (*EPHIPPIORHYNCHUS SENEGALENSIS)*

Michael L. Schlegel, PhD, PAS,[1]* Matt Farley, BS,[2] and Wendy Ranger, AS[2]

Departments of [1]Veterinary Services and [2]Birds, Zoological Society of San Diego, P.O. Box 120551, San Diego CA 92112-0551 USA

Abstract

A model was developed based on food disappearance to determine the quantity of food and estimate the metabolizable energy (ME) requirements for the growth of parent-reared Saddle-bill storks (*Ephippiorhynchus senegalensis*). Based on the initial observations in 2001, a feeding protocol was developed and utilized for parent-reared storks in 2002. Food disappearing from the food dish offered to two (1.1) adult Saddle-bill storks in 2001 was recorded daily beginning when two (0.0.2) chicks were seven-days old and continued until the chicks were 111 days of age. The storks were fed a diet of skinned-adult mice, whole-adult mice, whitebait smelt, trout, carnivore meat diet (Natural Balance, Pacoima, California 91331 USA), and insects. The ME content of the food items offered was calculated based on 75% of the determined gross energy content. Based on average adult body weights (5.52 kg), each adult stork required 509 kcal ME/day ($141.4*BW_{kg}^{.75}$). In 2001, peak total food disappearance occurred between the chick ages of 25 and 65 days when an average of 3128 ± 28.76 g (n = 36) and 3409 ± 31.5 kcal ME (n = 36) disappeared from the food pan daily, and provided, an average 2.35 times (1196 kcal) an adult's ME requirement per chick. In 2002, the same adult pair hatched and reared three (0.0.3) chicks. While the ME available per chick was lower in 2002 than the previous year, total food and ME removed from the feed pan between day 30 and 72 increased 27.6% and 24.6%, respectively. The energy intake model developed was effective to estimate the energy requirement of parent-reared Saddle-bill stork chicks and has been used for the basis of parent-reared chick diets for Painted (*Mycteria leucocephala*), Yellow-billed (*Mycteria ibis*), and Storm's (*Ciconia stormi*) storks.

Introduction

Multiple species of storks are exhibited and propagated at the San Diego Zoo's Wild Animal Park. There is a desire to allow the parents the opportunity to rear chicks in order to pass on this behavior to the offspring and decrease labor needed for hand rearing. To assist this effort, a model was developed based on food disappearance to determine the quantity of food and estimate the metabolizable energy (ME) requirements for parent-reared Saddle-bill storks (*Ephippiorhynchus senegalensis*). Based on the model developed, feeding protocols could be created for various stork species.

Methods

Food disappearance from a pair of wild caught birds (estimated birth: 1985) was determined in the fall of 2001 to develop a parent-rearing protocol for storks. The birds were housed in a 18.3 x 18.9 x 4.6 m covered vegetated flight pen at the Bird Breeding Complex at the San Diego

Zoo's Wild Animal Park. These birds have been paired since entering the collection in 1989. This was the first clutch of eggs that was successfully incubated and the parents reared two (0.0.2) chicks. Each adult bird received a diet consisting of four adult mice (118 g), three small-whole trout (270 g), five whitebait smelt (55 g), carnivore meat diet (341 g, Natural Balance, Pacoima, California 91331 USA), 30 crickets and 15 mealworms. Each small trout was injected with 1.5 ml of a Vitamin solution (5 IU Vitamin E/ml, 1.84 mg thiamin/ml). Chick diets were added in addition to the adult diet and consisted of extra-small trout (injected with .7 ml of a Vitamin solution, describe above), skinned and whole mice, and whitebait smelt. Food disappearance was measured daily for chick ages 7-111 days.

To determine food disappearance, diet components were weighed (trout, carnivore meat) or counted (mice, whitebait smelt, insects) when offered at both the morning and afternoon feeding. The following day, all remaining diet components were counted. Food items were counted rather than weighed for ease of data collection and desiccation that occurred overnight. An average mass was determined for each food item, and subsequently used to calculate the mass of food remaining (Table 1). This pair of birds rarely consumed the carnivore meat diet, therefore; the remaining quantity was not determined, and not used to calculate total food disappearance.

To determine nutrient and calorie content of the diet removed from the feed pan, each diet component was analyzed for moisture, crude protein, crude fat, calcium, phosphorus[1], and gross energy (ME)[6] at a commercial laboratory (Michelson Laboratories, Commerce, California 90040 USA; and Covance Laboratories, Madison, Wisconsin 53704 USA). Metabolizable energy (ME) concentration of the diet was determined using the metabolizable energy coefficient of 0.75 * GE for birds consuming vertebrates.[5] Using the average male and female body weights of Saddle-bill storks in the collection (average 5.52 kg; males average 6.09 kg, n = 2; females average 4.94 kg, n = 3), the daily ME requirement[7] was calculated as 509 kcal ME/day (kcal ME required/day = 141.4 * (BW, kg)$^{.75}$). Multiples of an adult's ME requirement available to the chicks were calculated as:

Multiples of an adult's ME requirement available to chicks

$= [TMEd – (2 * aME)] * (aME * No. of chicks)^{-1}$

where:

TMEd = Total ME disappearance, kcal/d
aME = Adult ME requirement, kcal/d, an estimated average 5.52 kg body weight was used to determine requirements

Based on the multiples of the parent's requirement calculated in 2001, a parent-rearing protocol for Saddle-bill storks was developed (Table 2). In the case of Saddle-bill storks, each multiple of an adult's ME requirement would provide 509 kcal ME.

Using the protocol developed in 2001, food disappearance was monitored in 2002 when the same pair of storks incubated and hatched three (0.0.3) chicks. Food disappearance was monitor weekly (chick ages 1-141 days) and ME disappearance was estimated as previously described.

In both years, chicks were not weighed during rearing. Chicks fledged at 74 and 79 days of age and post-fledging weights were determined at 133 days of age in 2001 and when chicks were removed from their natal pen in 2002. One of the three chicks born in 2002 died from trauma at 105 days of age and was weighed at that time. At necropsy, it was noted that this chick had moderate osteopenia.

Results and Discussion

Based on food disappearance (Figure 1) in 2001 and 2002, total ME of food removed from the pan was calculated (Figure 2). In 2001, total food and ME disappearance increased from 7 to 25 days of age and reached a plateau till 65 days of age. During the plateau period, an average of 3128 ± 28.7 g (n = 36) of food and 3409 ± 31.5 (n = 36) kcal ME were removed from the pan daily. After 65 days of age, consumption decreased in conjunction with the chicks fledging at 74 days of age. This pattern of intake is similar to that observed in hand-raised Wood storks (*Mycteria americana*).[4] Kahl[4] observed a linear increase in food intake during the first 22 days of hand rearing followed by a plateau of maximal food intake from day 23-45, then a linear decrease in intake from day 46 to fledging. In 2002, food disappearance followed a similar pattern when the storks were rearing three chicks and food disappearance reached a plateau between 30 and 72 days of age. During the period of maximum intake in 2002, average food disappearance was 27.6% greater (3993 ± 55.3 g/d, n = 9) and ME disappearance was 24.6% greater (4247 ± 59.2 kcal/d, n = 9) than the previous year, due in part to the extra chick to feed.

To make the developed rearing protocol transferable to other stork species, multiples of the parents ME requirement available to the chick were calculated (Figure 3). In 2001, during the plateau in food disappearance (25-65 days of age), the parents provided, daily, an average 2.35 times their ME requirement (1196 kcal) to each chick with a range between 2.02 and 2.72 times. As per the protocol, maximum food offered was 3.64 times the ME required for an adult on day 56 to ensure adequate food available (Table 2).

In 2002, the amount of food available to the parents for each chick was 2.11 times (range: 1.94-2.25) each parent's ME requirement during the plateau of maximum intake. Although the adult pair of storks removed a greater quantity of food and calories from the pan in 2002, the calories were distributed over three chicks, each chick receiving a reduced amount when compared to 2001. The quantity of food offered for the chicks in 2002 did not exceed 2.66 times the adult ME requirement per chick (Table 2, Day 21). The reduced quantity may be a result of the maximum capacity each parent could provide. Using the information published by Kahl,[4] Wood stork chicks consumed 1.6 times the adult Wood stork's ME requirement (based on a 2.38 kg body weight).[3] This value for Wood storks may be lower because hand rearing may not provide the number of feeding bouts that a parent-reared chick would receive.

Periodic body weights throughout rearing would be ideal to determine growth rate and the availability of adequate energy and nutrients. Based on the body weights that were obtained (Table 3), chicks appear to be growing appropriately, since body weights exceeded the average adult male and female weights.

Although the chicks on average received adequate energy for growth, the actual components and nutrient profile of the diet that each chick receive is not known. Larger chicks may receive a greater percentage of preferred food items (e.g. trout) than smaller chicks and as a result receive a deficient diet. This may explain the osteopenia noted in the chick that died from the 2002 hatch.

The energy intake model developed was effective to estimate the energy requirement of parent-reared Saddle-bill storks and has been successfully used for the basis of parent-reared chick diets for Painted (*Mycteria leucocephala*), Yellow-billed (*Mycteria ibis*), and Storm's (*Ciconia stormi*) storks.

LITERATURE CITED

1. AOAC International. 2000. Official methods of analysis, 17th ed. AOAC International, Gaithersburg, Maryland.

2. Bernard, J.B., and M.E. Allen. 2002. Feeding captive piscivorous animals: Nutritional aspects of fish as food. Nutrition Advisory Handbook, Fact Sheet No. 005.

3. Dunning, Jr., J.B. 1992. CRC Handbook of Avian Body Masses. CRC Press, LLC., Boca Raton, Florida.

4. Kahl, M.P. 1962. Bioenergetics of growth in nestling wood storks. Condor 64:169-83.

5. Karasov, W.H. 1990. Digestion in birds: chemical and physiological determinants and ecological implications. Stud. Avian Biol. 13:391-415.

6. Parr Instrument. 1981. Oxygen bomb calorimetry and combustion methods, Manual No. 160. Parr Instrument. Moline, Illinois.

7. Robbins, C.T. 1993. Wildlife Feeding and Nutrition, 2nd ed. Academic Press, Inc. San Diego, California.

Table 1. Selected nutrient composition of diet components offered to Saddle-bill storks.

Ingredient	Moisture, %	GE, kcal[1, 2]	ME, kcal[1,2,3]	CP, %[1, 2]	CFat, %[1, 2]	Ca, %[1]	P, %[1]
Carnivore meat diet	68.87	5.85	4.39	58.8	21.5	2.03	1.29
White-bait smelt *(Clupea harengus)*[5]	80.91	4.09	3.07	76.48	10.0	2.32[4]	1.95[4]
Rainbow trout *(Salmo gairdneir)*[6]	75.50	5.92	4.44	65.7	25.3	1.95	1.82
Adult mice *(Mus domesticus)*							
Whole[7]	69.10	6.21	4.66	57.93	28.48	2.38	1.81
Skinned[8]	71.50	5.89	4.42	58.95	24.91	2.89	2.15

[1]Dry matter basis.
[2]GE, gross energy; ME, metabolizable energy, CP, crude protein, CFat, crude fat.
[3]ME = 0.75 * GE; Karasov, 1990.
[4]Bernard and Allen, 2002.
[5]10.65 g/fish, n = 100.
[6]Small trout: 12.7-20.3 cm, 52 g/fish, n = 41; extra-small trout: less than 12.7 cm, 13 g/fish, n = 456.
[7]29.30 g/mouse, n = 20.
[8]23.44 g/mouse, n = 10.

Table 2. Parent-rearing protocol for Saddle-bill stork chicks (*Ephippiorhynchus senegalensis*).

Age, day	Frequency	Diet per chick (Quantities added to parents diet)	Multiples of an Adult's ME requirement[1]	Comments
1	Divide diet into an AM and PM feeding	0 - whole adult mice 2 - skinned adult mice 0 - inverted pelted mice 227 g - extra-small trout 3 - smelt, white-bait	.64	**All mice in parents diet should be skinned.**
7	Divide diet into an AM and PM feeding	0 - whole adult mice 4 - skinned adult mice 0 - inverted pelted mice 454 g - extra-small trout 6 - smelt, white-bait	1.28	
14	Divide diet into an AM and PM feeding	0 - whole adult mice 8 - skinned adult mice 0 - inverted pelted mice 681 g - extra-small trout 9 - smelt, white-bait	2.02	
21	Divide diet into an AM and PM feeding	0 - whole adult mice 10 - skinned adult mice 0 - inverted pelted mice 908 g - extra-small trout 12 - smelt, white-bait	2.66	
28	Divide diet into an AM and PM feeding	0 - whole adult mice 12 - skinned adult mice 0 - inverted pelted mice 1135 g - extra-small trout 12 - smelt, white-bait	3.25	

Table 2 (continued). Parent-rearing protocol for Saddle-bill stork chicks (*Ephippiorhynchus senegalensis*).

Age, day	Frequency	Diet per chick (Quantities added to parents diet)	Multiples of an Adult's ME requirement[1]	Comments
35	Divide diet into an AM and PM feeding	0 - whole adult mice 10 - skinned adult mice 2 - inverted pelted mice 1135 g - extra-small trout 12 - smelt, white-bait	3.31	1. Addition of pelt to diet to encourage cast formation 2. Information from Dallas Zoo suggest that whole (pelt on) mice could be fed as soon as Day 30 3. Parents would not select mice with visible, fur, therefore, the pelts were left attached and inverted to fool parents. 4. Skin mice in parents diet.
42	Divide diet into an AM and PM feeding	0 - whole adult mice 8 - skinned adult mice 4 - inverted pelted mice 1249 g - extra-small trout 12 - smelt, white-bait	3.60	1. Invert pelts on mice in parents diet.
56	Divide diet into an AM and PM feeding	0 - whole adult mice 6 - skinned adult mice 6 - inverted pelted mice 1249 g - extra-small trout 12 - smelt, white-bait	3.64	1. Invert pelts on mice in parents diet.
70	Divide diet into an AM and PM feeding	0 - whole adult mice 6 - skinned adult mice 4 - inverted pelted mice 1135 g - extra-small trout 12 - smelt, white-bait	3.24	1. Invert pelts on mice in parents diet. 2. Chicks fledged around day 74.

Table 2 (continued). Parent-rearing protocol for Saddle-bill stork chicks (*Ephippiorhynchus senegalensis*).

Age, day	Frequency	Diet per chick (Quantities added to parents diet)	Multiples of an Adult's ME requirement[1]	Comments
77	Divide diet into an AM and PM feeding	2 - whole adult mice 4 - skinned adult mice 4 - inverted pelted mice 908 g extra-small trout 9 - smelt, white-bait	2.76	1. Start adding whole (pelted) mice to diet. 2. Invert pelts on mice in parents diet.
84	Divide diet into an AM and PM feeding	4 - whole adult mice 4 - inverted pelted mice 681 g - extra-small and small trout 6 - smelt, white-bait	2.18	1. Leave mice whole in parents diet. 2. Incorporate more small trout into diet
91	Divide diet into an AM and PM feeding	6 - whole adult mice 568 g - extra-small and small trout 3 - smelt, white-bait 114 g carnivore meat	2.04	1. Reduce the amount of mice and trout as appetite decreases 2. Leave mice whole in parents diet.
172	Feed in AM only	4 - whole adult mice 272 g - small 6 - smelt, white-bait 114 g carnivore meat	1.25	.

[1]An adult's metabolizable energy (ME) requirement = 509 kcal/day.

Table 3. Body weights of saddle-bill stork chicks (Ephippiorhynchus senegalensis).

Chick Number	Year of hatch	Sex	Age, day	Body weight, kg
1	2001	M	133	NR[1]
2	2001	M	133	6.34
2	2001	M	232	6.50
3[2]	2002	M	101	5.40
4	2002	M	252	6.38
5	2002	F	250	5.05

[1]Not recorded.

[2]Body weight taken when bird died of trauma.

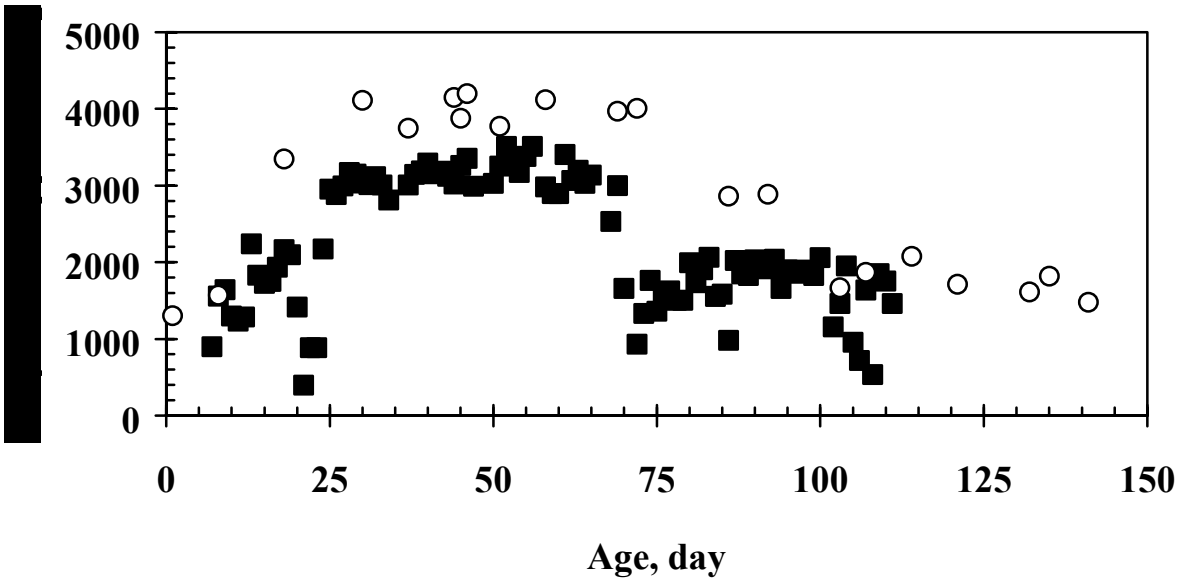

Figure 1. Disappearance of food offered to Saddle-bill storks rearing chicks in 2001 (squares) and 2002 (circles).

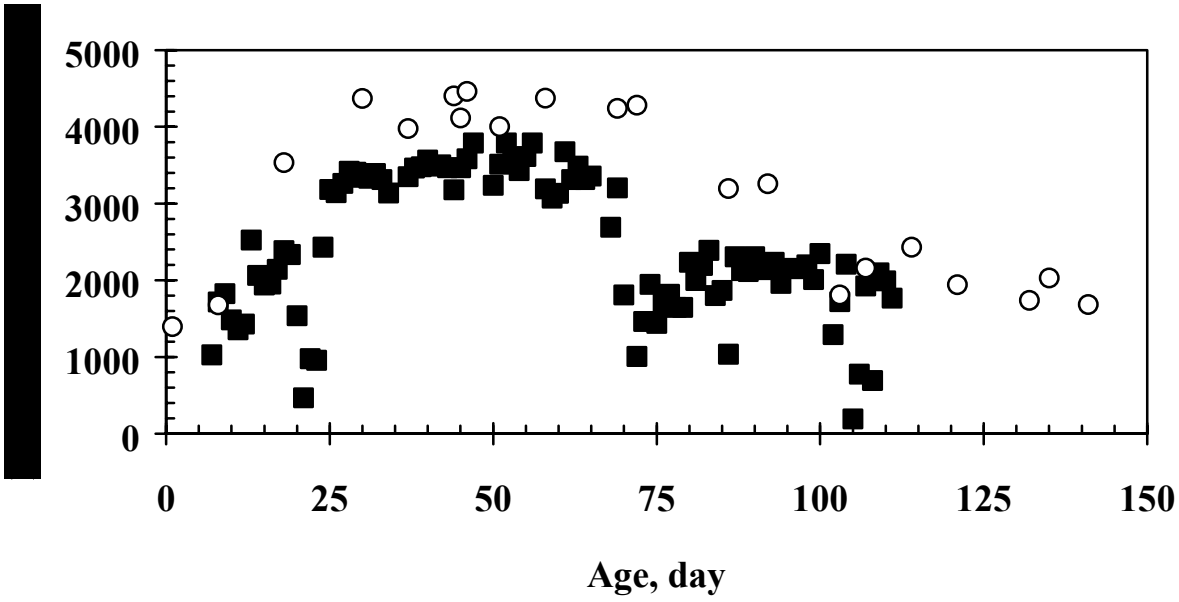

Figure 2. Metabolizable energy (ME) disappearance from food offered to Saddle-bill storks rearing chicks in 2001 (squares) and 2002 (circles).

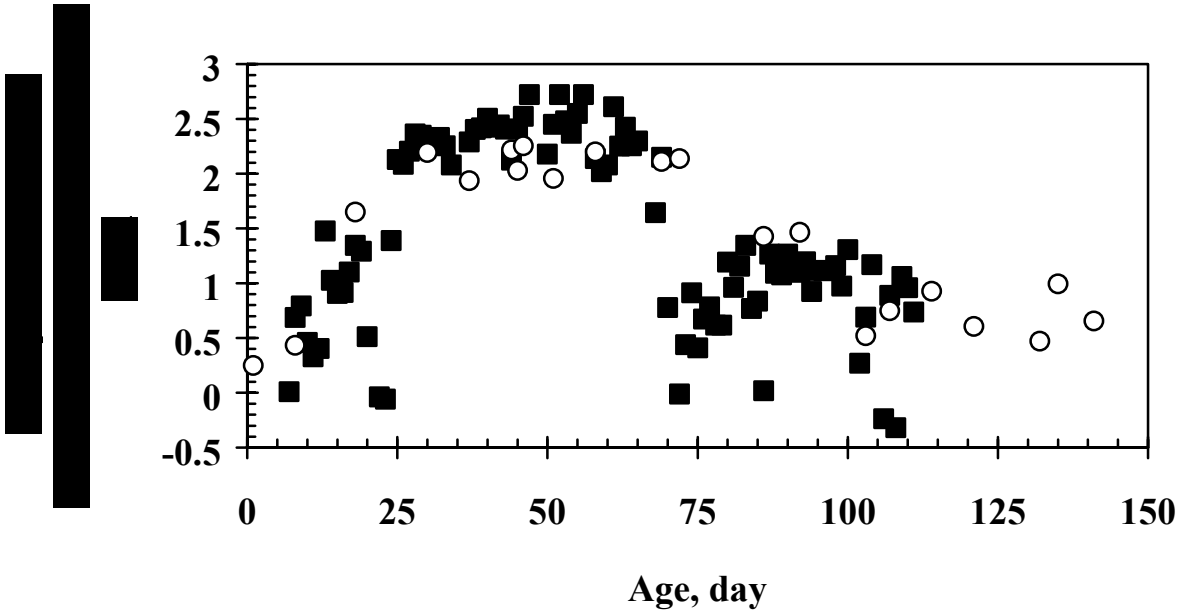

Figure 3. Multiples of an adult Saddle-bill stork's metabolizable energy (ME) requirement (550 kcal/day) available for chicks in 2001 (squares) and 2002 (circles).