J. Raptor Res. 30(1):21-27

BREEDING, GROWTH, DEVELOPMENT, AND MANAGEMENT OF THE MADAGASCAR FISH-EAGLE (*HALIAEETUS VOCIFEROIDES*)

RICHARD T. WATSON, SIMON THOMSETT,[1] DONNA O'DANIEL AND RICHARD LEWIS

The Peregrine Fund, 5666 West Flying Hawk Lane, Boise, ID 83709 U.S.A.

ABSTRACT.—Increasing population size and distribution in suitable unoccupied habitat is one of several management options that would help prevent the extinction of the Madagascar fish-eagle (*Haliaeetus vociferoides*), one of the rarest raptors in the world. Breeding studies from 1991 through 1994 show this species exhibits siblicide or Cainism. In 1993 we tested sibling rescue as a low-cost *in situ* method for increasing annual production of Madagascar fish-eagles. Of three nests tested, two fledged two young using an abbreviated captive rearing period in which removed siblings were reintroduced to artificially enlarged nests as soon as they could defend themselves from siblings and compete for food. Sibling rescue increased production from four to six young from a sample of 10 nests. Measurements of weight gain, feather development and description of the behavioral development of chicks in captivity and in the nest, provide new information and a better understanding of siblicide in this little studied species.

KEY WORDS: *Cainism; conservation; development; growth; Madagascar; management; siblicide.*

Reproducción, crecimiento, desarrollo y manejo de *Haliaeetus vociferoides*

RESUMEN.—Incremento del tamaño poblacional y distribución en hábitat adecuados pero no ocupados, es una de las varias opciones que podrían prevenir la extinción de *Haliaeetus vociferoides,* uno de los rapaces más raros del mundo. Desde 1991 a 1994, estudios de reproducción mostraron que esta especie exhibe fratricidio o Cainismo. En 1993, probamos el rescate de hermanos como método *in situ,* de bajo costo, para incrementar la producción anual de esta águila. De los tres nidos probados, dos volantones y dos juveniles fueron sometidos a un corto período de crianza y reintroducidos artificialmente en grandes nidos. Esto ocurrió tan pronto como fueron capaces de defenderse de sus hermanos y competir por el alimento. El rescate de hermanos aumentoo la producción de cuatro a seis juveniles en una muestra de 10 nidos. Medidas de ganancia de peso, desarrollo de plumaje y descripción conductual de polluelos en cautividad y nido, permiten proveer nueva información y una mejor comprensión del fenómeno de fratricidio.

[Traducción de Ivan Lazo]

The Madagascar fish-eagle (*Haliaeetus vociferoides*) is one of the rarest birds of prey in the world with a population size estimated at 50–70 breeding pairs (Langrand and Meyburg 1989, Watson and Rabarisoa 1995). Habitat degradation is one cause of the species' rarity but persecution, and other factors have reduced its density even where suitable habitat remains (Watson et al. 1993). Increasing population size and distribution in suitable unoccupied habitat is one of several management options that would help prevent extinction of the species.

Meyburg (1983) suggested sibling rescue as a technique for increasing annual production in birds of prey that exhibit sibling aggression in the absence of food shortage, known as siblicide or Cainism. He used the Madagascar fish-eagle as an example of an endangered species that may benefit from this form of management. Langrand and Meyburg (1989) surmised that siblicide was the basis for their observation that only one young was produced in each of three nests despite two eggs being laid in each. Between 1991 and 1994 we observed breeding success in Madagascar fish-eagles to determine the frequency of siblicide in this species.

In 1993 we tested sibling rescue, a technique pioneered by Meyburg (1978, 1983) in lesser spotted eagles (*Aquila pomarina*) and Spanish imperial eagles (*A. heliaca*) and demonstrated in black eagles (*A. verreauxii*; Gargett 1990, S. Thomsett pers. obs.; $N = 3$), augur buzzards *Buteo rufofuscus augur* (S. Thomsett pers. obs.; $N = 1$) and African hawk-eagles

[1] Present address: P.O. Box 42818, Nairobi, Kenya.

Table 1. Breeding of Madagascar fish-eagles on Lakes Befotaka, Soamalipo and Ankerika in 1993.

Pair Name	Clutch Size	Number Hatched	Sibling Rescue Attempted	Number Fledged	Cause of Failure
Ankerika-1	1	0	No	0	Possibly infertile egg
Ankerika-2	2	2	Yes	2	
Ankerika-3	2	1	No	1	Infertile egg
Ankerika-4	0	0	No	0	Did not nest
Ankerika-5	2	0	No	0	Infertile eggs
Befotaka-1	0	0	No	0	Adults disappeared soon after breeding began
Befotaka-2	2	0	No	0	Fertile eggs deserted
Befotaka-3	2	2	Yes	2	
Soamalipo-1	2	0	No	0	Eggs covered by nest material
Soamalipo-2	2	2	Yes	1[a]	Chick fell and died
Total 15	7	6			

[a] Chick A fell from nest and died, chick B injured when nest fell from tree but later rehabilitated. Without human intervention, this figure may have been zero.

Hieraaetus spilogaster (S. Thomsett pers. obs.; $N = 2$), as a low-cost *in situ* method for increasing annual production in the Madagascar fish-eagle (O'Daniel 1995). In other species with siblicide, sibling aggression may diminish after 4–6 wk of age (e.g., African fish-eagles [*Haliaeetus vociferoides*]; Brown 1980) or it may continue throughout the nestling period, as demonstrated in experiments with black eagles (Gargett 1990). The procedure for sibling rescue has typically been to separate siblings for six or more weeks, leaving one in the nest and rearing the other by hand, followed by exchanging siblings weekly and ending with reintroduction of removed siblings to the nest for rearing to independence by their parents (Gargett 1990). By 6 wk, either levels of aggression have declined to allow coexistence, or chicks are capable of avoiding siblings in nests that are large enough to accommodate them (Gargett 1990).

In this experiment, we tested whether removal of one chick from its sibling for 3–4 wk until both appeared large enough to avoid siblings and compete for food in the nest would result in both young surviving to fledging after reintroduction of the removed siblings. This technique of abbreviated captive rearing (i.e., not for the full nestling period) minimized the time of human involvement, while also reducing the costs and equipment needed.

METHODS

Breeding was observed in 65 Madagascar fish-eagle nests between 1991 and 1994 (Watson et al. 1993). Nest contents were observed two to three times during each breeding season using the least intrusive method possible (in order of preference: binoculars from a distance, mirror pole from below nest, and climbing to nest) to determine clutch size, hatching rate and fledging rate. Logistics prevented obtaining complete data sets for all known pairs.

Sibling rescue was tested at three nest sites on Lakes Befotaka, Soamalipo, and Ankerika, respectively, in western Madagascar during the 1993 breeding season (May through November). Breeding pairs were observed at 2–7 d intervals to determine the number of eggs laid and hatching dates using least intrusive methods (as above) required to obtain the information. Of 10 pairs observed, three hatched two eggs each (Table 1).

The first-hatched nestling from each nest was removed within 2–8 d after hatching (after the second egg had hatched) and raised in a brooder for 10–22 d before being exchanged with its sibling for a similar period. A total of six chicks were thus held in captivity, and all were color-banded before being returned to the nest. Swapping brood mates allowed both to experience being fed by parents without interference from the sibling, which we assumed might help with habituation to parents and imprinting on conspecifics.

Brooders consisted of plastic bowls about 40 cm in diameter, lined with plastic doormat material that was cleaned daily. Brooders were heated by kerosene lamps at night and cotton towels were added for chicks less than about 3 wk old to help them keep warm. Bowls were surrounded by a vertically placed rigid clear plastic sheet which allowed adjacent chicks to see but not contact each other. It also caught feces. A large aluminum bowl was inverted and suspended above the brooder to help reduce drafts and maintain warmth while allowing free circulation of air.

Chicks were fed locally captured fresh fish (*Tilapia* spp.) with a calcium-rich vitamin supplement. While in captivity, chick weight was measured before and after every feeding using 1-kg or 3-kg Pesola scales. Behavior was described *ad libitum,* usually whenever new behaviors were noticed. Development of feathers (proportion of down remaining on each of the wing, back, breast and head) was visually estimated, and growth of tarsus, longest primary, and center tail feather was measured to the nearest millimeter.

The first reintroduction of a chick with its sibling was attempted when captive chicks showed the ability to defend themselves against conspecific attack. Aggression and defense was tested by placing two non-sibling chicks together in the same brooder or by using styrofoam models of chicks to elicit a response. All chicks were observed for at least 45 min after reintroduction to siblings to ensure that no fatal aggression occurred.

The chicks and adults at Befotaka-3 nest were observed for 59 h on 12 d between 17 September (chicks aged 55 and 59 d, respectively) and 1 October 1993, using a 15–25× zoom telescope. The first 2 d of observation were from a blind built in a tree 100 m north of the nest. The remaining observations were done from 400 m east across the lake on the opposite shore. The second chick had been reintroduced to the nest on 24 August and both were within about 1 mo of fledging when observations began.

RESULTS

Breeding. Of 65 observed breeding attempts between 1991 and 1994, 17 pairs laid two-egg clutches, two pairs laid one-egg clutches, and clutch size of the remainder was undetermined. No nests successfully fledged two young, 33 fledged one young, and the remainder fledged no young. Of six nests known to hatch two chicks, all raised only one young, the second to hatch dying within 10 d after hatching. In these cases one egg hatched 2–4 d before the second, and the first-hatched chick almost doubled in weight before the second egg hatched. Sibling mortality was apparently related to observed aggression (O'Daniel 1995, Thomsett pers. obs.) by the older sibling causing death by battering, starvation or displacement of the younger chick from the nest.

Growth and Feather Development. Chicks were completely covered by white down until 16 d old, when brown contour and flight feathers first appeared on the head and wings. Down was lost from the head first; heads were fully feathered by about 45 d of age. The fleshy part of the wings lost all their down by about 55 d, the breast by 74 d and the back by about 76 d. Flight and tail feathers first emerged at 17 and 21 d, respectively, the longest primary (third from outermost) growing to a maximum length of 400 mm by 90 d (linear regression, $a = -91.26$, $b = 5.47$, $r^2 = 0.99$, $P < 0.001$) and center tail feather to 260 mm by 98 d (linear regression, $a = -71.71$, $b = 3.39$, $r^2 = 0.96$, $P < 0.001$) respectively. Tarsus length increased from 20 mm at 3 d to about 60 mm at 20 d and 100 mm at 45 d (linear regression, $a = 19.25$, $b = 2.13$, $r^2 = 0.96$, $P < 0.001$). Claws turned from pale olive at hatching to predominantly black by 16–18 d of age and the intact egg tooth dropped off the bill by 23 d.

Weights taken before first feeding of the day followed a typical sigmoid growth curve, from 80 g at 3 d after hatching up to about 2500 g at 54 d. Data were pooled for all chicks because no single chick was measured from hatching through fledging. Gompertz, logistic, and von Bertalanffy growth models were tested using nonlinear least squares method (Wilkinson 1990). The Gompertz model provided the best fit ($r^2 = 0.98$, asymptotic mass, $A = 2584$ g, mass at zero days, $B = 42.2$ g, growth constant, $k = 0.057$). Females are probably slightly larger than males, with about 3000 g being the weight of a fully developed female, as identified from observed copulation of banded adults ($N = 2$).

Captive fish-eagle chicks, when offered food *ad libitum,* fed from three to six times per day until about 20 d old, when the number of feedings dropped to twice a day. The amount of food eaten per meal increased from an average of 20 g at 3 d after hatching to an average of 300 g at about 54 d.

Behavioral Development. An aggressive reaction was observed from chicks aged anywhere from 2–56 d of age. Levels of aggressive behavior varied considerably among the six chicks held in captivity. Some were indifferent while others were aggressive toward other chicks or models of chicks.

A chick <25 d old, when pecked by a larger chick, would instantly bow its head and remain that way for 2–3 min whether attacked again or not. The same response could be elicited by any pinching of the chick's neck, even by humans. However, after about 25 d of age the victim would resist the attack by either moving away or fighting back.

On hatching, chicks were weak and unable to move. By 8 d chicks could move around the brooder with wings and legs working together. They could also stand on the tarsi, preen, and shake the tail. First pellets were cast between 11 and 15 d, by which time chicks were vocal and active, walking to receive food. By 12 d chicks were capable of picking up small pieces of food from a flat surface. Assuming that, as in other raptor chicks, a neck out and panting posture indicated that a chick was too warm, while a head over back posture indicated that a chick was comfortable or cool, by 13 d chicks tolerated temperatures from 21–30°C, appearing most comfortable at 25°C in dappled sunlight during the day. By 23 d old they could feed themselves while holding intact fresh fish in their feet. First wing flapping was seen at this time, with chicks jumping, falling over and facing into the wind. Chicks were returned to their nest and older sibling at 26, 31, and 39 d of age, respectively, after which behavioral development was observed in less detail. Chicks at Befotaka-3 fledged at 81–84 d after hatching.

By age 5 d the chicks produced at least three distinguishable vocalizations: first, a low volume "peep, peep, peep" call, second, the same call uttered louder and more frequently and associated with signs of discomfort (cold or hunger), and third, a monosyllabic three-hoot call of similar pitch to the adult's descending tone call (similar also to the African fish-eagle, Brown 1980). By age 10–13 d they began a new call "gwa, gwa, gwa" usually in "protest" at not getting food or when cold. This call persisted and increased in volume and harshness to become the begging call typical of most immature eagles.

Sibling Rescue. Reintroduction of siblings to Soamalipo-2, Befotaka-3 and Ankerika-2 nests was attempted after chicks could avoid, or defend themselves, from sibling attack and appeared capable of tolerating diurnal temperature variation without parental or human help. Sibling rescue failed in Soamalipo-2 but succeeded in the other nests. Of 10 known pairs on all three lakes, including the three manipulated nests, six young fledged, two of which would not have succeeded without applying sibling rescue (Table 1).

Reintroduction at Soamalipo-2 nest. Eggs in Soamalipo-2 hatched on 7 and 9 July, 11 and 41 d ahead of first-hatched eggs in Befotaka-3 (20 and 24 July) and Ankerika-2 (15 and 17 August). We removed the older of the two chicks (chick A) at age 8 d, reared it in captivity for 10 d, then exchanged it for its younger sibling (chick B). When removed, chick A had a mass of 245 g and chick B 155 g. Chick B was taken from the nest at age 16 d and mass of 640 g, and exchanged with chick A (580 g, 18 d). Chick B was returned to the nest with its sibling on August 4 (1200 g, 26 d). Chick A was not weighed on this date. No aggression was seen between chicks during 45 min of observation after reintroduction. The next day at 1630 H both chicks had full crops. Chick A had a few scratches on the face. On 7 August, chick A was found dead under the nest. Injuries indicated the chick had most probably died as a result of falling from the nest that day. The dead chick was more developed but weighed less (1100 g dead at 30 d) than chick B (1200 g alive at 26 d), although the mass difference may have been from water loss after death. In our opinion, the nest was too small and poorly built to support two chicks. The frailty of the nest was demonstrated on 14 August when a strong wind blew it out of the tree. Although we believe the chick did not die from sibling attack directly, the possibility exists that it was driven from the nest by its sibling.

Nest Enlargement and Reintroduction at Befotaka-3 and Ankerika-2 Nests. We enlarged the nests at Befotaka-3 and Ankerika-2 before the remaining reintroductions. Both nests appeared small for the size of a fish-eagle with diameters of nest material capable of supporting an eagle of less than 1 m (adult mass ranges from 2150–3000 g, $N = 6$, and wing length = 520 mm). On 23 August Befotaka-3 nest was enlarged by weaving a 1-m diameter nest from local materials, and positioning it next to the original nest. The chick in the nest at the time (chick A, 1800 g, 34 d) was transferred to the new nest by 1200 H. The adult female flew into the new nest at 1330 H. Chick B (1300 g, 32 d) was placed in the original nest on 25 August, and a 0.4 m high fence of sticks built to separate the chicks while allowing each to be visible to parents. Chick B had been in captivity for 22 d. It was offered fish on five occasions by the adult, but appeared frightened by its parents during the first day. Both chicks were hand fed the following day and daily until 27 August when they were both seen to be fed by the parents. On 29 August two adults were seen feeding one chick each in their adjacent nests. Both chicks fledged by 16 October.

A similar procedure was used at Ankerika-2 where an artificial nest (1 × 2 m) was placed on top of the original nest on 1 September when the chicks were exchanged. Chick A was returned to the nest at age 17 d and chick B, aged 16 d, was taken into captivity. Chick A was left in the nest at 1200 H and was being attended by the adult female by 1400 H. Chick B (1400 g, 39 d) was reintroduced to the nest on 24 September, and both fledged after 28 October (exact date unknown as they were next seen in January 1994).

Behavior of Chicks and Adults in the Nest: Befotaka-3. Chicks in Befotaka-3 nest were separated by a stick fence when observations began on 17 September, 24 d after reintroduction. In addition to color bands for identification, several physical and

Table 2. Comparison of number of call bouts between older (A) and younger (B) chicks, number of visits by adults to each chick and the separating fence, number of fish loads brought to each chick by adults, and time spent feeding by chicks, at Befotaka-3 nest. (nr = not recorded, ? = chick not visible in the nest.)

Date	Observation Time, hr	Call Bouts by Each Chick		N of Visits by Adults to Each Chick and Fence			Fish Loads Brought by Adults to Each Chick		Time (min) Spent Feeding by Chicks	
		A	B	A	B	Fence	A	B	A	B
Sep 17	7.5	nr	nr	1	4	0	0	1	0	72
Sep 18	1.0	nr	nr	1	1	0	1	1	?	0
Sep 24	4.0	101	0	0	6	0	1	2	21	30
Sep 25	3.5	67	1	3	2	1	2	0	89	0
Sep 26	4.5	303	0	0	3	0	0	2	0	44
Sep 27	4.5	368	0	0	8	0	0	1	0	86
Sep 28	12.0	91	0	0	9	0	0	0	39	11
Sep 29	12.0	31	0	1	12	1	0	0	62	24
Sep 30	5.0	92	43	0	2	0	0	0	62	15
Oct 1	5.0	0	0	0	7	0	0	0	0	0
Total	59.0	1053	44	6	54	2	4	7	273	282

behavioral differences were apparent between the chicks that remained obvious throughout the period of observation. The older, chick A, had a mass of 1800 g on 23 August at age 33 d and appeared slightly larger, when observed from a distance, than chick B which had a mass of 1300 g at age 32 d on 26 August. Chick A had more down remaining on the underside of its wings, a higher pitched and louder vocalization than chick B, and its behavior was always the more aggressive of the two. During the first 2 d of observation the chicks appeared to ignore each other. From 24–27 September, chick B was seen to sit on top of the fence, looking into the opposite side at its sibling for a total of 3%, 6%, 13% and 9% of each observation day (Table 2), respectively. On 28 September chick A jumped into chick B's side of the nest, while chick B was being fed by an adult. They remained together on the same side of the nest until fledging.

Chick A vocalized almost continuously (Table 2) except immediately after it was fed on 25 September and after it fed on chick B's side on 28 September. Before this occurred, the adults landed on chick B's side of the nest four times more often than chick A's side (Table 2), and chick B was seen feeding over twice as long (232 min) as chick A (110 min, Table 2). The number of fish loads brought to chick B's side was almost twice that brought to chick A's side (Table 2). In contrast, the first 3 d both chicks were together, chick A fed for 163 min while chick B fed for only 50 min. Up to this point, chick B had hardly ever vocalized, but on 30 September it called 40 times before being fed at 0930 H when it stopped calling.

Chicks were observed from dawn to dusk on 28 and 29 September (Table 2) to document behavior once they were no longer separated by the fence. When chick A first jumped into chick B's side of the nest and began feeding, chick B and the adult simply looked on. After 2 min, the adult flew from the nest. The first day together the chicks sparred occasionally with their bills, but inflicted no wounds. Thereafter, they fed side by side and coexisted without fighting. However, chick A usually appeared dominant over chick B, seizing fish brought to the nest by adults and feeding first. Chick B never responded aggressively to this behavior; it would circle chick A and wait to feed on the food remains. Chick B sometimes fed first, usually during the second or later meal of the day. Apart from the first night in chick B's side together, chick A always settled in the center of the nest, displacing its sibling to the edge.

Chicks began exercising their wings before 17 September, first flapping in place on the nest, followed by sustained flapping above the nest beginning on 24 and 26 September at 62 and 68 d of age. Both chicks showed a pattern of exercising frequency in which exercising on the nest reached a peak 3 d ahead of aerial flapping while hovering above the nest. Chick B reached peak frequency of exercising in place on 24 September, while chick A reached its peak on 27 September.

Three different adults regularly visited the nest and fed chicks. The largest of the adults (assumed to be female) was colorbanded and wore a tail-mounted radiotag. The other two adults could not be distinguished unless seen simultaneously. During observations, the female spent over twice as much time at the nest (316 min) as the other two adults combined (136 min). The female was twice seen to fly to one of the other adults, take a fish from it and deliver the fish to the nest. Adults were seen actively feeding the chicks as well as simply delivering fish to the nest for the chicks to feed themselves.

DISCUSSION

Siblicide in eagles is either obligate (a chick is always killed by its sibling) or facultative (mortality may or may not occur) for each species (Edwards and Collopy 1983, Mock 1984). Our observations of breeding attempts by territorial pairs of Madagascar fish-eagles between 1991 and 1994 suggest the species exhibits siblicide which may be obligate. In addition, the mass difference between first and second hatched chicks when the second hatched, and the growth constant (k = 0.057) for Madagascar fish-eagle nestlings, are consistent with eagle species that typically raise only one young (k = 0.024–0.064, Bortolotti 1986). These observations help justify the use of sibling rescue as a technique for increasing annual production in this species.

Once the second egg hatched, it was easier to take the older chick from the nest first because this minimized human involvement in the labor intensive period of the first 8 d while chicks were feeble and required most attention. After 8 d, chicks could move around the brooder on their own and by 12 d they could pick up food on their own. Given the reaction to parents of the chick kept for 22 d compared with that of chicks exchanged each 10 d, swapping appeared to help chicks habituate to parents and may be important for the success of this method. Exchanging siblings after one had been in captivity about 10 d may have improved the chances of imprinting on conspecifics.

Introduction of both siblings to the nest once they appeared capable of thermoregulation and could remain separated by a physical barrier worked only after the nest had been enlarged. The barrier prevented sibling aggression until chicks reached an age when they were capable of crossing the barrier. By this time (66 d in Befotaka-3 nest) aggression had declined sufficiently to allow chicks to coexist in the same nest. Although dominance by one chick over the other continued, it was not life-threatening under the circumstances observed in which adults appeared capable of providing sufficient food to satisfy both chicks.

Frequent vocalizing appeared to indicate hunger, since it dropped to zero immediately after feeding. Based on observed feeding bouts and vocalization rate, the motivation for Befotaka-3's chick A to move to the chick B's side of the nest appeared to be hunger. Chick A was dominant over chick B subsequent to this move. Similar dominance by heavier siblings has been documented in black eagles (Gargett 1990) that were experimentally placed together at 10 wk of age and has been recorded in tawny eagles (*Aquila rapax*; Steyn 1973) and golden eagles (*A. chrysaetos*; Beecham and Kochert 1975) although aggression in the latter did not cease. Although chick A was dominant over chick B when together, when they were separated by the barrier, chick A vocalized more often but received less food than chick B. The adult's stimulus to feed chick B more often was unknown, but may have been simply the greater ease of landing on chick B's side of the nest. Parents appeared to have no difficulty in feeding both chicks although parental effort was not measured in this study. Three adults at one nest have been reported in bald eagles (*Haliaeetus leucocephalus*; Sherrod et al. 1976, Heglund and Reiswig 1980, Fraser et al. 1983), but the high frequency of occurrence seen among Madagascar fish-eagles seems unusual (Watson et al. 1993).

Using our method, Madagascar fish-eagle chicks can be reintroduced to their nest by about 4 wk of age instead of ≥9 wk of age when aggression has diminished. This technique abbreviates the captivity period and is therefore easier to apply under remote field conditions of Madagascar than techniques involving lengthy rearing of young chicks. The method may also be useful in other raptors in which siblicide is invariably fatal regardless of the chick's age.

The Madagascar fish-eagles in this study may be unusual for the amount of human activity and intrusion tolerated at and around the nest. Our subjective impression is that the study pairs may be more tolerant of human intrusion at the nest than pairs elsewhere in Madagascar that have been subject to human persecution. This method may not be so readily applied elsewhere.

Although sibling rescue increased fledging rates, its use may negatively affect other critical population parameters, such as adult survival or fecundity, or chick A survival to recruitment (Magrath 1991, Mock and Forbes 1994). For example, parents raising two chicks beyond the normal point of brood reduction may suffer increased mortality or reduced fecundity in future seasons, or chicks fledging from a two-chick nest may be less robust and suffer higher mortality between fledging and recruitment to the breeding population. Future attempts at sibling rescue should measure parental effort and body condition to look for negative consequences of caring for two-chick broods. Studies of survival, adult fecundity and impact on population recovery should be implemented if sibling rescue is adopted as a conservation tool for this species. It would be beneficial to test alternative methods for conservation management, such as sibling rescue followed by hacking in unoccupied suitable habitat, that do not require intensive intervention at the nest and that minimize possible negative effects on siblings or parents.

ACKNOWLEDGMENTS

This work is dedicated to the memory of Frank G. Wells. Funding was provided by Environment Now, Claude Albritton, and the John D. and Catherine T. MacArthur Foundation. We thank Stefania Strzalkowska, Jules Mampiandra, and others for valuable field assistance. We thank the Direction des Eaux et Forêts, ANGAP and UNESCO for collaboration. Ian Newton, Gary Bortolotti, Douglas Mock, and David Anderson provided valuable comments on drafts of this paper.

LITERATURE CITED

BEECHAM, J.J. AND M.N. KOCHERT. 1975. Breeding biology of golden eagles in southwestern Idaho. *Wilson Bull.* 87:506–513.

BORTOLOTTI, G. 1986. Evolution of growth rates in eagles: sibling competition vs. energy considerations. *Ecology* 67:182–194.

BROWN, L. 1980. The African fish eagle. Bailey Bros. and Swinfen Ltd., Folkstone, U.K.

EDWARDS, T.C., JR. AND M.W. COLLOPY. 1983. Obligate and facultative brood reduction in eagles: an examination of the factors that influence fratricide. *Auk* 100:630–635.

FRASER, J.D., L.D.FRENZEL, J.E. MATHISON AND M.E. SHOUGH. 1983. Three adult bald eagles at an active nest. *Raptor Res.* 17:29–30.

GARGETT, V. 1990. The black eagle. Acorn Books, South Africa.

HEGLUND, P.J. AND B. REISWIG. 1980. 1980 raptor survey, the breeding bald eagle population, Amchitka Island, Alaska. Unpubl. Rep., USDI Fish Wildl. Serv , Aleutian Islands National Wildlife Refuge, AK U.S.A

LANGRAND, O. AND B.-U. MEYBURG. 1989. Range, status and biology of the Madagascar sea eagle *Haliaeetus vociferoides*. Pages 269–278 *in* B.-U. Meyburg and R.D. Chancellor [EDS.], Raptors in the modern world. World Working Group on Birds of Prey, Berlin, Germany.

MAGRATH, R.D. 1991. Nestling weight and juvenile survival in the blackbird, *Turdus merula*. *J. Anim. Ecol* 60:335–351.

MEYBURG, B.-U. 1978. Sibling aggression and cross-fostering of eagles. Pages 195–200 *in* S.A. Temple [ED.], Endangered birds: management techniques for preserving threatened species. Univ. Wisconsin Press, Madison, WI U.S.A.

———. 1983. The significance for captive breeding programmes of fratricide and cainism in birds of prey. *Int. Zoo Yearb.* 23:110–113.

MOCK, D.W. 1984. Infanticide, siblicide, and avian nestling mortality. Pages 2–30 *in* G. Hausfater and S. Blaffer Hardy [EDS.], Infanticide: comparative and evolutionary perspectives. Aldine, New York, NY U.S.A.

——— AND L.S. FORBES. 1994. Life-history consequences of avian brood reduction. *Auk* 111:115–123.

O'DANIEL, D. 1995. Raising Cain . . . and Abel. *Living Bird* 14:30–35.

SHERROD, S.K, C.M. WHITE AND F.S.L. WILLIAMSON. 1976. Biology of the bald eagle on Amchitka Island, Alaska. *Living Bird* 15:143–182.

STEYN, P. 1973. Observations on the tawny eagle. *Ostrich* 44:1–22.

WATSON, R.T AND R. RABARISOA. 1995. Madagascar fish-eagle offshore survey. Pages 231–239 *in* R.T. Watson [ED.], Madagascar project: wetlands conservation project. Prog. Rep. II, 1993 and 1994. The Peregrine Fund, Boise, ID U.S.A.

———, J. BERKELMAN, R. LEWIS AND S. RAZAFINDRAMANANA. 1993. Conservation studies on the Madagascar fish-eagle *Haliaeetus vociferoides*. *Proc. Pan-Afr Ornithol. Congr.* 8:192–196.

WILKINSON. 1990. SYSTAT: the system for statistics SYSTAT, Inc., Evanston, IL U.S.A.

Received 9 December 1994; accepted 8 August 1995