in size exhibited by Sharp-shinned Hawks. It appears that, under most conditions, the female could contribute whatever prey is needed by the brood without having to be 1.7 times as large as the male and capturing slightly larger prey.

Acknowledgments.—We thank Mary Tasker for her exceptional hospitality to often unsociable field biologists and James Tasker for aid in the observations. J. A. Feduccia, K. D. Meyer and R. H. Wiley offered helpful comments on the manuscript. We thank T. J. Cade, R. T. Reynolds and N. F. R. Snyder for constructive criticisms of an earlier version of the manuscript; this does not mean that we have followed all of their suggestions or that they endorse our interpretations.—HELMUT C. MUELLER, *Dept. Zoology and Curriculum in Ecology, Univ. North Carolina, Chapel Hill, North Carolina 27514,* NANCY S. MUELLER, *Dept. Biology, North Carolina Central Univ., Durham, North Carolina 27707,* AND PATRICIA G. PARKER, *Dept. Zoology, Univ. North Carolina, Chapel Hill, North Carolina 27514. Accepted 10 Nov. 1979.*

Wilson Bull., 93(1), 1981, pp. 92–97

Food deprivation and temperature regulation in nestling Ferruginous Hawks.—Nestling deaths from heat prostration may occur regularly in some falconiform species (e.g., Fitch et al., Condor 48:207–237, 1946; Nelson, pp. 64–72 *in* Peregrine Falcon Populations, Their Biology and Decline, Hickey ed., Univ. Wisconsin Press, Madison, Wisconsin, 1969; Olendorff, U.S.I.B.P. Rep. No. 211, 1973; Beecham and Kochert, Wilson Bull. 87:506–513, 1975). Beecham and Kochert (1975) concluded that 41% of Golden Eagle (*Aquila chrysaetos*) nestling mortality in their Snake River, Idaho, study area was caused by overheating and observed that young birds in nests with a southern or western exposure are most vulnerable to heat stress.

The Ferruginous Hawk (*Buteo regalis*) nests in the semi-arid regions of southern Canada and the western United States (Olendorff 1973; Tomback and Murphy, unpubl.). Throughout the breeding range Ferruginous Hawks nest primarily on rocky outcrops, tops of trees (especially junipers [*Juniperus* spp.] and cottonwoods [*Populus* spp.]) and occasionally on sagebrush (*Artemisia* spp.) or the ground (Smith and Murphy, Brigham Young Univ. Sci. Bull. 18:1–76, 1973; Oldendorff 1973; Woffinden, Ph.D. diss., Brigham Young Univ., Provo, Utah, 1975; Howard and Wolfe, J. Range Manage. 29:33–37, 1976; Lokemoen and Duebbert, Condor 78:464–470, 1976; Fitzner et al., Condor 79:245–249, 1977). Despite the high temperatures encountered in the latter stages of the nesting cycle (e.g., Smith and Murphy 1973; Fitzner et al., 1977), apparently shade availability is not a nest-site requirement for the species. In the Great Basin west of Utah Lake, Woffinden (1975) examined 56 nests of Ferruginous Hawks on rocky outcrops, on the ground, and in trees. Almost half of these nests were unshaded throughout the day. The nests on steep slopes received some shade only in morning or afternoon, depending on slope aspect.

Here, we present field data suggesting that underfed Ferruginous Hawk nestlings are especially vulnerable to heat stress. We predict that combined effects of inadequate food provisions and high temperatures may cause much nestling mortality in years when prey populations are low.

On 15 June 1977, we surveyed Cedar and Rush valleys, Utah Co. and Tooele Co. (elev. 1760–1895 m; 40°00′N, between 111°55′W and 112°35′W), for Ferruginous Hawk nests (for detailed description of study area see Smith and Murphy 1973). Thirteen light phase nestlings between ca 5 and 7 weeks old remained in 5 nests, including 2 tree nests in Utah juniper (*Juniperus osteosperma*), 2 nests on rocky outcrops on steep (ca 40°), west-facing slopes, and

1 ground nest on a southeast-facing slope (ca 30°). Using a YSI Tele-Thermometer (Model 43E), a YSI black bulb probe and 2 YSI plastic-tipped probes, we measured ambient and cloacal temperatures of 2 nestlings 5.5–6 weeks old at a rocky outcrop nest from 14:00–17:00 on 24 June. A plastic-tipped probe was inserted 3–4 cm into the cloaca of each nestling, taped in place and checked each time the nestlings defecated. We erected a low cardboard barrier, non-reflective and brown in color, to prevent the young from leaving the nest. The nestlings showed no signs of agitation whenever we left our tent blind and approached the nest to take temperature readings.

On 23 June 1979, in the Raft River Valley, Box Elder Co., Utah, and Cassia Co., Idaho (elev. 1400–1700 m; 42°00'N, 113°30'W), we found 3 Ferruginous Hawk nestlings in 2 nests in Utah juniper (for description of study area see Howard and Wolfe 1976). One nest contained a melanistic bird, dubbed "Othello," ca 5 weeks old, and the second nest contained 2 light phase nestlings, "Iago" and "Desdemona," ca 5.5 and 6 weeks old, respectively.

Prior to the trip, we calibrated 3 miniaturized temperature-sensitive radio transmitters (Mini-Mitter Co., Inc., Model T). On 23 June, a transmitter was wrapped in Black-tailed Jackrabbit (*Lepus californicus*) meat and fed to each Ferruginous Hawk nestling, and the 3 birds were placed on a recently active Ferruginous Hawk ground nest which was unshaded throughout the day. We hobbled the young so they could not leave the nest to find shelter. Within 30 min the nestlings no longer struggled against the restraint and settled into position. We monitored transmitter signals from the nestlings 15 m from the nest by means of a Lafayette 3-Channel 1.5 Watt Receiver (Mini-Mitter Co., Inc., Model Ch receiver) and recorded ambient temperatures with a YSI black bulb probe and YSI Tele-Thermometer (Model 43TD). As indicated by signal strength, the transmitters lodged in the crops of the nestlings until they were regurgitated in pellets ca 24 h later. Transmitter signals were converted into body temperatures as follows: the receiver was switched to 1 of 3 channels and the time required for 100 clicks was recorded on a stopwatch. This time interval was compared to the appropriate calibration curve. Every 15 min from 13:30–17:00, we took body temperature readings and paired them with a black bulb ambient temperature reading.

The nestlings were transported in and maintained for 2 nights in individual grass-lined cardboard cartons. We fed them several times a day with fresh jackrabbit meat, hamburger and water. Cast transmitters were recalibrated and again fed to the birds. On 24 and 25 June 1979, we placed the nestlings on a recently active Ferruginous Hawk rocky outcrop nest built on a steep (ca 40°), west-facing slope in Cedar Valley, Utah Co., Utah. The nest was not shaded in the afternoon and the nestlings were again hobbled. On 24 June, we measured ambient and crop temperatures from 14:50–18:00. We did not feed the young on 25 June until 15:00 in the hopes of duplicating the effects of low food availability; black bulb ambient and crop temperatures were taken only from 12:00–14:00 to avoid the extreme late afternoon temperatures.

The behavior of the 5–7-week-old nestlings encountered in Cedar and Rush valleys in June of 1977 strongly suggested that ambient temperatures were uncomfortable, if not stressful. All of the nests were unshaded for half the day or longer. Three nestlings had wandered several meters from their ground nest and crouched under a small sagebrush (*Artemisia tridentata*). At 1 rock outcrop nest, the 2 nestlings had moved to the shade of a nearby man-made, small rock shelter. Two young hawks had moved 3–5 m from the other outcrop nest to lay their heads in the shade of a large rock. The 3 nestlings in each of the juniper nests were apparently unable to leave the trees. However, they all tended to pant rapidly and salivate. Angell (Living Bird 8:225–241, 1969) also reported "shade-seeking" behavior in nestling Ferruginous Hawks 4–4.5 weeks old. This thermoregulatory behavior is obviously an important means by which nestlings avoid overheating in the weeks prior to fledging.

In 1977, there were few active Ferruginous Hawk nests in the Cedar and Rush valley study

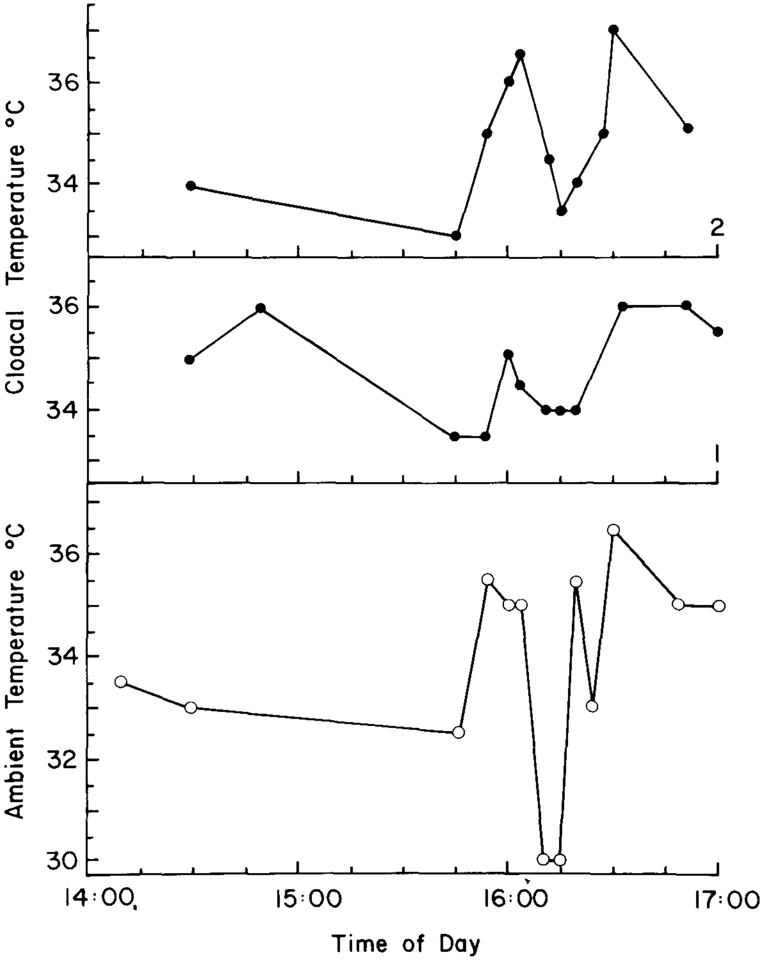

FIG. 1. Ambient temperatures and cloacal temperatures of 2 Ferruginous Hawk nestlings vs time of day at Cedar Valley nest, 24 June 1977.

areas (Murphy et al., unpubl.). The primary reason for the decline appeared to be a low population of Black-tailed Jackrabbits (Murphy et al., unpubl.). This jackrabbit is the principal food of the Ferruginous Hawk in the Great Basin region (Smith and Murphy 1973; Smith and Murphy, Raptor Research 13:1–14, 1979). Woffinden and Murphy (1977) showed a relationship between the annual numbers of Ferruginous Hawk nesting pairs and jackrabbit abundance. They also noted a high nestling mortality (an average of 49.5%) in 2 years of low jackrabbit density in 1973 and 1974.

In June 1977, we found no fresh jackrabbit remains at any of the nests we examined, although remnants of small prey items such as kangaroo rats (*Dipodomys* sp.), lizards (*Cnemidophorus* sp., *Phrynosoma* sp.) and birds (Icteridae) occurred at 2 nests. One or both

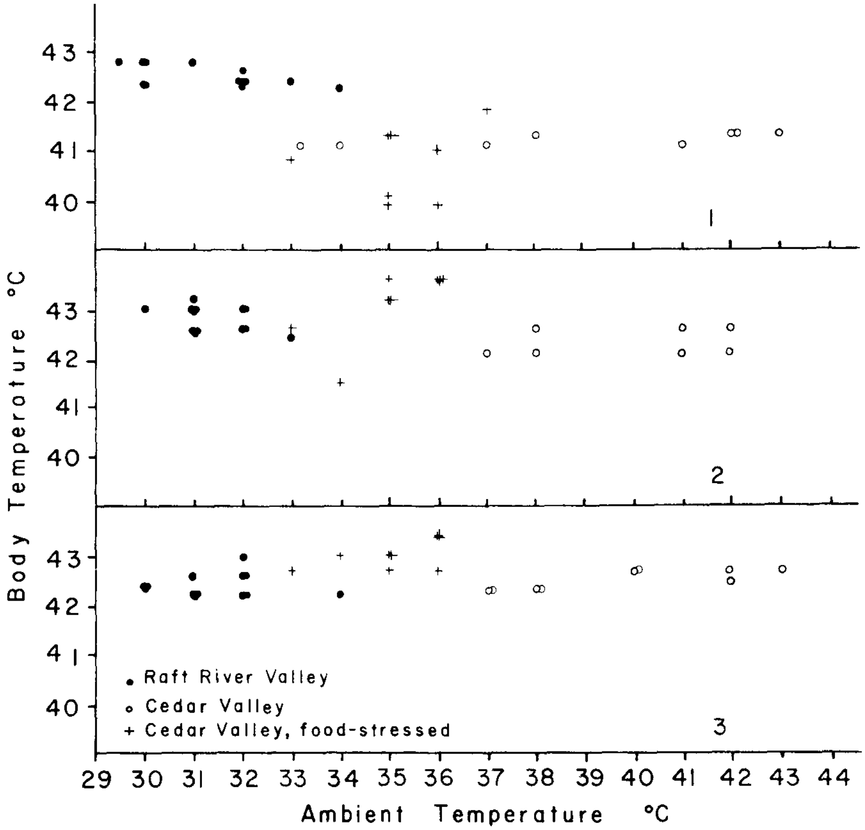

FIG. 2. Crop temperatures monitored by telemetry vs ambient temperatures for Ferruginous Hawk nestlings Iago (1), Desdemona (2) and Othello (3), June 1979.

parent birds circled overhead at all the nests we visited, indicating that the young were still attended.

At the rock outcrop nest where we took temperature readings, no fresh food was present during the 3 days of our visits. At all nests it appeared that young were inadequately provisioned during a time when food consumption rates should be maximal (Olendorff, Condor 76:766–768, 1974). A graph of black bulb ambient vs cloacal temperatures for the afternoon of 24 June (Fig. 1) suggests the nestlings had difficulty thermoregulating. The sky was partly overcast that day, and when the sun was exposed, black bulb temperatures at the nest increased rapidly from 30°–36.5°C. Nestling cloacal temperatures (range 33–37°C) increased and decreased rapidly with ambient temperature. These body temperatures are lower than those daytime temperatures reported for other falconiforms (e.g., McNab, Condor 68:47–55, 1966; Fitch, Condor 76:331–333, 1974; Rudeen and Powers, Condor 80:447–449, 1978), possibly a consequence of both the cloacal temperature (rather than deep core temperature measurement) and an impaired thermoregulatory capacity. Both nestlings began panting continuously each time their temperatures reached 35°C. Fluctuations in body temperature of nestling #2 were more extreme than those of #1 (F-test NS); nestling #2 was not found during our last visit on 25 June.

The 3 nestlings from Raft River Valley in 1979 were seemingly well-fed prior to our experiments, judging by the fresh jackrabbit remains. Body temperatures of the 3 nestlings monitored by telemetry ranged from 39.9–43.6°C (Fig. 2), and black bulb ambient temperatures ranged from 29.5–43°C. These body temperatures are higher than those of the 1977 Cedar Valley nestlings and indicate either that there is a difference between temperatures measured in cloaca and crop, that the 1977 nestlings were suffering from starvation and could not thermoregulate well, and/or that the 1979 Raft River Valley nestlings were stressed by heat and restricted movement on the nest. This latter possibility is unlikely, since we obtained similar crop temperatures for the Raft River Valley nestlings in a resting state in the laboratory (Tomback and Murphy, unpubl.). However, the 3 initial 23 June 1979 readings of 42.7°C for Iago and 1 initial reading of 43.2°C for Desdemona at the Raft River Valley nest (Fig. 2) may have been elevated by our handling.

Means and standard deviations (°C) for ambient and nestling body (crop) temperatures for the 3, 1979 experimental periods are as follows: Raft River Valley, 23 June—T_A 31.4 ± 1.06, Iago 42.5 ± 0.21, Desdemona 42.8 ± 0.25, Othello 42.4 ± 0.24; Cedar Valley, 24 June—T_A 39.4 ± 2.74, Iago 41.2 ± 0.11, Desdemona 42.3 ± 0.27, Othello 42.5 ± 0.20; and Cedar Valley, 25 June—T_A 35.1 ± 1.06, Iago 40.7 ± 0.72, Desdemona 43.1 ± 0.74, Othello 43.0 ± 0.29. F-tests indicated that ambient temperature varied more on 24 June than on either 23 June ($P \leq 0.01$) or 25 June ($P \leq 0.01$). Yet, the crop temperatures of both Iago and Desdemona fluctuated most extremely on 25 June, when the nestlings were deprived of food, than on either 23 June ($P = 0.01$, both nestlings) or 24 June ($P = 0.01$, $P = 0.05$, respectively). The crop temperatures of Iago varied more on 23 June than 24 June ($P = 0.05$), whereas those of Desdemona varied much the same. For Othello crop temperature varied similarly on all 3 days. However, the crop temperatures measured for both Othello and Desdemona under conditions of food deprivation were significantly higher than those temperatures monitored on either 23 or 24 June (Mann-Whitney *U*-test, $P \leq 0.001$), even though the ambient temperatures of 25 June were lower than those of 24 June. Body temperatures for Iago were lower on 25 June than on previous days (Mann-Whitney *U*-test, $P \leq 0.001$), even though they fluctuated more. Iago rarely panted on 24 June, while the other nestlings panted most of the time and occasionally held their wings out to the sides to facilitate cooling. The high temperatures on 24 June affected Othello most severely, as the panting and posturing of this nestling were pronounced and almost continuous. It is possible that Othello's dark plumage increased his heat burden (Hamilton and Hepner, Science 155:196–197, 1967; Lustick, Science 163:387–390, 1969; but see Wahlsberg et al., J. Comp. Physiol. 126:211–222, 1978).

In conclusion, the temperature fluctuations of the underfed nestlings at the Cedar Valley nest in 1977 and the significantly higher and more varied body temperatures of the underfed nestlings in 1979 suggest that food deprived nestling Ferruginous Hawks cannot cope with heat stress. Reduction in prey probability are known to result in high nestling mortality in the Ferruginous Hawk (Woffinden and Murphy 1977). Heat prostration may be a major cause of nestling deaths under such conditions, especially since Ferruginous Hawk breeding grounds are characterized by high summer temperatures and nests are unshaded for all or part of the day.

Acknowledgments.—We thank Dan Johnson, Kent Keller and Philip Murphy for their invaluable help in the field and Clayton White for Raft River Valley nest information. Fieldwork in 1977 was funded in part by a grant from the Chapman Memorial Fund of the American Museum. At that time D. F. Tomback held a postdoctoral fellowship from Brigham Young University. Data and manuscript preparation by D. F. Tomback was supported by the Department of Biology, University of California at Riverside. Keith L. Bildstein, a reviewer, provided helpful suggestions concerning the manuscript.—DIANA F. TOMBACK, *Dept. Zoology and Entomology, Colorado State Univ., Fort Collins, Colorado 80523,* AND JOSEPH R. MURPHY, *Dept. Zoology, Brigham Young Univ., Provo, Utah 84602.* *Accepted 10 Jan. 1980.*

Wilson Bull., 93(1), 1981, p. 97

Aerial "play" of Black Vultures.—Occasionally I have seen Black Vultures (*Coragyps atratus*) engage in playlike, aerial acrobatics at Cerro Verde (13°50'N, 89°38'W; 2000 m elev.), El Salvador. On 15 November 1971, I was present during a violent "Norte," a prolonged windstorm which may attain gale velocity on mountain tops. I noticed, without heeding at first, sounds I attributed to a child tooting a musical toy. Then a trio of Black Vultures shrilled past my head, producing a sound like that of an aeolian harp, caused undoubtedly by wind passing through the feathers of wings and/or tails.

A dozen or more Black Vultures were soaring in the strong upslope winds on the north side of Cerro Verde, being carried upwards as much as 500 m above the summit. From time to time one or more birds "peeled off" to dive precipitiously towards the southeast, the wind behind them. Some leveled off where I could see them; others continued out of sight, descending more than 700 m. Recordings of their sounds, made at the time, suggest diving wire-strutted biplanes of the First World War.

One trio was especially notable, diving again and again as a team. I watched them make some 25 dives, 3 of which ended near me. The birds dove sometimes in V-formation, sometimes in line and attained impressive speeds. They ended the dives in 2 steps: (1) a slight increase in angle of attack which checked their speed slightly and flattened the dive; and (2) a sharp increase in attack angle plus spreading and lowering the tail which forced them into a shallow climb. They then used their forward momentum to circle along the lee side of the mountain into the upward current again. The leader of a dive also led in the following ascent but I could not ascertain whether it retained that position in subsequent dives.

I have heard since, under less favorable conditions, the shrill of diving Black Vultures during strong Nortes. I add only that twice I saw single vultures diving as described above. I noted that a single bird produces several tones, suggesting that several feathers are involved.

Bent (U.S. Natl. Mus. Bull. 167:29, 1938) described similar diving sounds produced by courting Black Vultures. Brown and Amadon (Eagles, Hawks and Falcons of the World, McGraw-Hill, New York, New York, 1968:181) reported sounds like ripping heavy paper as Black Vultures dive for food. The birds at Cerro Verde were not diving for food and did not seem to be courting. Brown and Amadon (1968:101) refer to certain otherwise unclassified aerial maneuvers of falconiformes as communal displays. However, a display implies communication between a sender and an intended observer; this does not apply to lone birds. I have no notion of the incentive which governed the vultures I watched, but to me the exuberant quality of their behavior, so unlike our usual impression of the species, had "all the appearances of play and seemed to serve no other function than the release of pent-up energy" (Pettingill, Ornithology in Laboratory and Field, Burgess Publ. Co., Minneapolis, Minnesota, 1970:254).—WALTER A. THURBER, *Cornell Univ. Laboratory of Ornithology, 159 Sapsucker Woods Road, Ithaca, New York 14853.* *Accepted 30 Nov. 1979.*