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CONTENTS

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DISTRIBUTIONAL STATUS AND ECOLOGY OF BARN OWLS IN UTAH

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ABSTRACT. Past and present status of the Barn Owl (*Tyto alba*) in Utah is described. Distribution, breeding, food habits, and mortality are discussed. Data suggest that the Barn Owl is present in low numbers in much of the state and is reproducing at a rate above the minimum replacement rate. Food and nest sites do not appear to be limiting factors. However, winter cold and snow cover may limit the species in Utah.

Introduction

Until recently, little was known concerning the status and ecology of Barn Owls (*Tyto alba*) within the state of Utah. Behle (1941) published the first nesting record of this species near Kanab, Kane County, and later (1944) suggested it to be an uncommon resident, known to breed in the southern part of the state. Woodbury et al. (1949) proposed that Barn Owls were probably resident and widely distributed in the valleys and lower elevations throughout the state. More recently, Smith et al. (1972, 1974) presented information on Barn Owl foods and nesting ecology in the vicinity of Springville and Provo, Utah County.

In this paper we have attempted to summarize the available information on the distribution and ecology of this species in Utah. Since Utah is on the northern edge of the major Barn Owl distribution in the West, information in this paper may help to understand some of the factors limiting its distribution elsewhere. Field work was conducted during the course of our collective studies of raptor ecology in Utah: Smith from 1966 to 1972 and Marti from 1971 to the present. During these periods all portions of Utah were checked at least once and some, particularly the central and northern portions were thoroughly searched.

Distributional Status and Ecology

Although widely distributed throughout the United States and northward into southern Canada, the Barn Owl is of patchy occurrence in the intermountain area. Bailey and Niedrach (1965) considered it to be an uncommon resident in Colorado, Kansas, and Nebraska, and rare in Wyoming. Ligon (1961) reported few records from New Mexico and noted that Barn Owls were uncommon in the Southwest. Northward, they rapidly become rare, presumably because of their intolerance for cold weather, and, until recently, there was only a single record of this species in Idaho (Burleigh 1972).

Records of Barn Owls in Utah date from 1899. A summary of the occurrence records of this species within the state is presented in figure 1. Barn Owls have been recorded in twelve counties of Utah; specimens have been collected in seven of these counties, and nests have been found in six. The distribution is a narrow north-south crescent, from Cache and Box Elder counties in the north to Kane and Washington counties in the south, with an eastward extension along the central portion of the state into Uintah County. No observations of this species are from the western or southeastern portions of the state, and only a single observation is from the south-central.

Analysis of historical records suggests that the distributional status of this species may have changed several times over the past 76 years. Prior to 1930, Barn Owls were seldom recorded but were apparently widespread along their present north-south corridor. With one exception, all observations during this period were from the central and northern portions of the state, and all the nesting records were from Utah and Box Elder counties. The reserve is found from 1931 to 1960, during which time Barn Owls were frequently recorded in the southwestern counties and rarely observed northward. In this 30-year period, over 70 percent of the observations and almost all nesting records and specimen collections were from the southwest counties. Records dating from the early 1960s to the present reveal another reversal marked by a northward displacement which is evidently still occurring. This most recent trend is notable for the comparatively high number of Barn Owl observations in northern Utah and southern Idaho. The recent change in the status of Barn Owls in Idaho is striking. Burleigh (1972) reported a single Barn Owl record for the state from Latah County in northern Idaho in 1947. Trost (pers. comm.), however, found Barn Owls prevalent in the Pocatello region during a 1968-69 period of *Microtus* abundance, and Smith and Burkholder (in press) reported the first known breeding record in Idaho in 1969 and observed another nest in 1972. Both nests were near the northern Utah state line.

Observations over the past 15 years indicate that Utah has two separate Barn Owl populations. A northern population occurs from Utah County north to Box Elder County and east to Duchesne County. Barn Owl densities in this population appear to be highest in Utah and Box Elder counties; recent observations of nesting exist for both. A considerably smaller southern population is found in Iron and Washington counties, but there are no recent observations of nesting. Barn Owls observed in southern Utah were thought to be migratory, arriving each year in April to begin nesting (Behle 1941). In contrast, the adults of the Ironton colony located in central Utah were permanent residents in the area (Smith et al. 1974).

In central and northern Utah, at least, Barn Owls probably occupy a particular territory for a number of years, breeding whenever conditions are favorable and not breeding under suboptimum conditions. Observations suggest that young may occupy nearby areas when available or wander into new localities with the onset of colder weather. A given locality may be occupied continuously for a number of years and then abandoned for a time following the death of the adults.

Ecologically, Utah Barn Owls have been most commonly found in the settled valleys where they evidently find suitable roosting and foraging habitat. Although they may resort to the occasional use of natural cavities in trees and dry washes, they are usually found in association with man-modified habitats and structures. Furthermore, where natural roosting and nesting sites are used, the owls are frequently observed to utilize man-altered habitats for foraging. Utah Barn Owls are conspicuously absent from the western Great Basin Desert and mountainous areas. Their absence from the western desert areas may be due to a lack of suitable habitat but may also reflect an inability to compete there with the Great Horned Owl (*Bubo virginianus*), the predominant nocturnal raptor in that area. Their absence from higher elevations probably reflects their low tolerance of cold temperatures. Less explainable is their absence from the greater part of southeastern Utah where some habitat appears suitable.

Observations by Counties

A detailed survey of distribution by counties is presented here. In this discussion university specimen and egg collection references are abbreviated as follows: Brigham Young University, BYU; Dixie College, DC; Southern Utah State College, SUSC; University of Utah, UU; Weber State College, WSC.

Box Elder. Observations: Occasional visitor on the Bear River Migratory Bird Refuge since 1928. Regularly seen during winters of 1972 through 1975 (Beall letter of 11 March 1975); other observations on the refuge area as follows: one observed 2 November 1968 (Scott 1969); three died, apparently of cold and starvation, during winter of 1972-73 (Kingery 1973); one noted 15 February 1975 (Kingery 1975). Platt (1969) flushed three immatures from a dry wash near Snowville in July 1969. Specimens: one, undated, taken near Brigham City (D. H. Madsen); one, UU, a male, found dead in an emaciated condition 12 December 1972 on the Bear River Refuge. Nests: a set of fresh eggs was taken in May from an old barn near Brigham City (Treganza letter of 5 January 1930); Platt (1969) found a female road kill with brood patch near Snowville in June 1969; Beall (letter of 11 March 1975) reported a nest containing two eggs located in an old Raven (*Corvus corax*) nest on an observation tower on the Bear River Refuge in spring 1974.

Cache. Observations: two, both south of Logan; one August 1938 (Cottam) and one September 1938 (Rasmussen).

Weber. Observations: Marti located a roost approximately 15 miles west of Ogden in fall 1972. Specimens: one, WSC, sex unknown, taken in Slaterville in fall 1965; one, WSC, sex unknown, given by the Utah Division of Wildlife in winter 1972.

Davis. Specimens: one, UU, sex unknown, dated 19 December 1972, from New State Gun Club; one, UU, sex unknown, found 1 mile west of Interstate 80, 13 April 1971.

Salt Lake. Observations: one seen 25 December 1948, during the Audubon Christmas count; one observed in September 1954 (Scott 1955); numerous sightings as follows: one north of Salt Lake City 10 September 1967 (Scott 1968); two roosted in a cavity in a clay bank in Salt Lake City during 1970-71 winter (Scott 1971b); and one in Salt Lake City in April 1971 (Kingery 1971a). Nests: a pair reported to have nested near Draper for several years sometime prior to 1920 (Lockerbie 1954); reported nesting in Salt Lake Valley in spring 1967 (Scott 1967) and again in Salt Lake City in spring 1971 (Kingery 1971a).

Utah. Observations: numerous, dating from March 1928, when one was caught alive in Provo (Hayward, unpubl. manuscript); other observations and dates by Smith as follows: between one and three individuals regularly roosted in the Utah railroad roundhouse and water tower at Provo, from at least 1966 until these structures were dismantled in 1970; one to several roosted in the upper framework of the Springville drive-in theater screen from 1966 to the present; many roosted at the now dismantled Ironton Steel Mill from 1962 until it was demolished in 1970-71; regularly roosted in trees bordering the eastern edge of Utah Lake during falls and winters from 1966 to the present; occasionally seen in silos and old barns, less frequently in woods in the Orem, Springville, and Provo area from 1966 to the present. Specimens: five, all BYU, three from Springville, dated 9 March 1959 and (2) 25 January 1969; two from Provo, dated 19 October 1965 and 10 April 1967. Nests: UU has in its oological collection a clutch of seven eggs dated 7 June 1899 from American Fork, which constitutes the earliest record of Barn Owls in Utah; a set of fresh eggs taken about the middle of May from an old barn at Provo sometime prior to 1930 (Hayward, unpubl. manuscript); 15 nests from the Ironton Steel Mill colony, 1968-70, details in Smith et al. (1974); Frost reported a nest of five young about 1-3 weeks old in a poplar in American Fork 21 April 1971; the Utah Division of Wildlife reported a nest containing six young in an old barn in west Orem in late spring of 1973. The barn owner reported that the same site was used for nesting the previous spring.

Duchesne. Observations: Carlston reported seeing a pair in willows along Strawberry River about three miles west of Duchesne in July 1968.

Uintah. Observations: One reported by several residents near Jensen; one seen by Stewart in 1936; at Hill Creek, 40 miles south of Ouray, one was flushed from a hole in the face of a high cliff (Twomey 1942).

Sanpete. Nest: Tanner reported a pair nesting near Indianola years ago; no other data available.

Iron. Observations: One freshly killed was found under a tree near Paragonah, 2 October 1954 (Scott 1955); one seen at Cedar City 30 October 1968 (Scott 1969); also reported from Cedar Valley 9 September 1970 and 29 October 1970 (Scott 1971a); two recorded in county (one actually seen) during Audubon Christmas count 26 December 1970 in Cedar City and Parowan; reported in Cedar City 27 May 1971 and 3 June 1971 (Kingery 1971b). Specimens: four, two, UU, both taken near Parowan sometime prior to 1936 (Hayward, unpubl. manuscript); two SUSC, both taken near Cedar City one 4 January 1966; no other data given.

Kane. Observations: Investigations by Behle (1941) confirmed that Barn Owls utilized holes in banks of Kanab Wash, two miles south of Kanab, for roosting, Greenhalgh reported that these sites were used for many years and saw as many as 30 together at one time. Behle observed owls at this site 14 June 1939 and 10 to 12 June 1940. Specimens: four, all UU, Behle took three males in Kanab Wash, one mummy taken 14 June 1939, the other two 12 July 1940; one, a male, taken one mile south of Kanab 12 May 1946. Nests: Behle (1941) reported probable use of holes in Kanab Wash for nesting.

Washington. Observations: Tanner (1927) reported Barn Owls to be uncommon fall and winter residents in Zion Canyon; one reported near St. George, 19 April 1939 and 16 March 1940 (Hardy and Higgans 1940); two were seen in Zion Canyon in fall 1973, and Kingery (1974) noted that this is the first report of their occurrence in that area since 1941. Specimens: nine; seven from St. George and vicinity, earliest taken in March 1927 by Tanner (1927); one, no data, taken in April 1929 (Hayward, unpubl. manuscript); one, WSC, a female, taken 10 April 1939; one, DC, a female taken 30 June 1941; one, UU, a male taken from a family group 11 September 1941, two miles south of St. George; one, DC, a female, taken 4 May 1948; one, UU, wing only, found five miles southeast of St. George 28 December 1960; one, DC, no details, taken near Beaver Dam Wash; one, no details, BYU, taken near Bloomington 15 November 1933. Nests: a nest containing two young was observed in a cliff about three miles southeast of St. George across the Virgin River (Hayward, unpubl. manuscript); Behle (1943) reported a family group of four birds roosting 20 feet high in a dense willow thicket two miles south of St. George 8 to 10 September 1941.

Reproductive Activities

We have information on 23 Barn Owl nests in Utah. Fifteen of these were located at the Ironton Steel Mill, Utah County, and are discussed in detail by Smith et al. (1974).

Breeding Chronology. The discovery of Barn Owls nesting in fall 1968 (Smith et al. 1970) suggests that Utah Barn Owls may breed at any time of the year if conditions are favorable. The length of the 1969 nesting season, as judged from the time of deposition of the first clutch until the fledging of the last brood, was 5.75 months, a figure very close to the similarly determined 5.3-month nesting season found in southern Texas (Otteni et al. 1972). As judged by information on eggs, young, or both, 18 were spring nests (February to May), 3 were summer nests (June to August), and 2 were fall nests (September to December). Eggs were deposited in spring nests in February and March and occasionally as late as early April. Young were found from late March through May and had usually fledged in late May or early June. Summer nests contained eggs from early May through June, and young usually fledged by August. Fall nests contained eggs in September and early October, and the young usually fledged in late November and early December.

Nests. None of the pairs we observed made any attempt at nest construction. Instead, nests consisted of a mixture of broken pellets and fecal material, with a slightly hollowed central cavity in which the eggs were deposited.

Most nests were located in man-made structures. All 15 nests at Ironton were in the buildings and associated structures of the abandoned steel mill. Elsewhere, four nests were found in old barns, one in a silo, and one in an observation tower on the Bear River Migratory Bird Refuge (Beall, letter of 11 March 1975). The use of natural sites has been reported primarily from the southern part of the state. Behle (1941) confirmed that Barn Owls nested in cavities in Kanab Wash, Kane County, and also reported a nest located in a cavity in a cliff south of St. George, Washington County. Use of hollow trees for nesting sites has been reported from the central portion of the state; Frost banded four young in a nest located in a poplar in American Fork, Utah County.

Reproduction. Clutch size averaged 4.4 ± 0.9 eggs (range, 2 to 9). Two clutches were of two eggs; three of three; three of four; four of five; two of six; two of seven; and one of nine eggs. Brood sizes averaged 3.47 ± 0.22 young (range, 2 to 5). Five nests contained two young; two contained three; four contained four; and one contained five young. Both egg and brood size averages are within the ranges reported from other areas. Ten nests that fledged young averaged 1.95 young fledged per nest (i.e., 1.95 young per successful nest). It is of interest to note that the Barn Owl fledging rate for the state is significantly higher than that in the Ironton Steel Mill colony (1.3 young fledged per nest) although no obvious reason can be advanced to explain the difference.

Nesting Failures. Only 10 of the 20 nests for which we have sufficient information successfully fledged at least one young. Known reasons for the nesting failures included nest desertion, destruction of eggs, and death of the adults. Seven nests were deserted; in some cases, human interference was a probable cause. Three of these nests, however, were deserted during brief periods of cold February weather, and the potential effects of the cold weather on the adults must be considered as a possible factor. A similar desertion was observed by Marti (1969) in Colorado following an unusual April snowstorm. The eggs of one nest were destroyed by unknown persons, and the two young of another nest disappeared shortly after the adults were shot.

Food and Feeding Habits

Barn Owls are among the most nocturnal of the owls found in Utah; those we observed typically hunted during twilight and darkness from shortly after sunset until shortly before the first light of dawn. We did, however, observe some instances of diurnal hunting. Factors which appeared to prompt diurnal hunting included inclement weather (particularly extended periods of rain or snow), a persistent snow cover, and large broods of young. Observations of specific individuals by the senior author suggest that diurnal hunting represents an extension of the duration of the hunting period rather than a change in actual diel activity. That is, hunting by Barn Owls is a function of their individual food procurement requirements and difficulties. They compensate for poor conditions by hunting longer.

Data on the seasonal food habits of Utah Barn Owls have been presented by Smith et al. (1972). In this report our discussion is limited to summary material and new analyses. We obtained information on Barn Owl food habits from an analysis of 941 pellets and pellet fragments which were collected from 1968 to 1972, and a tabulation of food items brought to five nests located in the Ironton Steel Mill, Utah County.

Food habits of adult Barn Owls are presented in table 1. The majority of pellets were collected from several roosting sites found in the vicinity of Provo and Springville, Utah County. Habitats in these areas varied considerably and included farms, pastures, marshes, cemeteries, vacant lots, and suburban and industrial sectors. A second collection of pellets was from Box Elder County, about 15 miles west of Corrine (contributed by J. B. Platt). Habitat in this vicinity was predominantly desert scrub with some farmland and a small marsh.

Pellet analysis followed methods described by Marti (1974). Vertebrate prey remains were identified by comparison with mammal and avian specimens in the Brigham Young University and Weber State College collections.

Collectively, we recorded a total of 3,182 food items of Utah Barn Owls. They included at least twelve species each of birds and mammals and two species of insects. Of these, mammals, primarily *Microtus* spp. and *Peromyscus* spp., were the most important, comprising over 90 percent of the total prey. Birds and insects were utilized far less frequently, especially in Box Elder County. The differences in food between the two areas undoubtedly reflected the availability of local prey species.

Comparison with numerous Barn Owl food habits studies from other areas of the United States reveals similarities and differences which again undoubtedly reflect locally abundant prey species. Almost all show a high incidence of predation on small mammals. However, Boyd and Shriner (1954) found a higher percentage of Starlings (*Sturnus vulgaris*) and House Sparrows (*Passer domesticus*) in the pellets of Barn Owls roosting in the center of a city than from those in outlying roosting sites, a discovery which closely parallels that of food habits of the Barn Owls in Utah County.

Food of Nestling Barn Owls. Information on food brought to nestling Barn Owls is presented in table 2. It was obtained from observations of food brought to the young of five nests located in Utah County during the 1969 spring nesting season. Food brought to the nest before the young had hatched represented food stockpiling and was found at every nest. Generally, the foods listed for weeks 5-12 of the nesting cycle were recorded during observations of the young from blinds because, except during the first two weeks, food was rarely found in the nest after the young had hatched and grown sufficiently to feed themselves. It is readily evident that the diet of nestling Barn Owls quite closely resembles that of the adults.

Diversity of Barn Owl Food Habits. The wide variety of prey found in the diet of the Utah County Barn Owls prompted an examination of the diversity of food selection in different areas. The results are presented in table 3. Comparative studies were selected to allow a variety of localities but included only studies based on a minimum of 500 or more food items, a number which should give an unbiased food sample size. Several European studies have been conducted over 20 or more years and represent a more exhaustive treatment than anything yet available from North America.

Diversity indices were calculated using the commonly accepted modification of the Shannon-Weaver formula as given in Orr et al. (1973):

$$H = -\sum_{i=1}^{s} P_i \log_{10} P_i$$

where s is the number of species and p_i is the proportion of the number of individuals in the i^{th} species. Two indices were caluculated for each locality: the Prey Species Diversity (PSD) index indicates the range and evenness of Barn Owl predation on all organisms taken as food.

The Trophic Diversity (TD) index provides some indication of the range of Barn Owl predation over major taxonomic groups and gives a measure of its niche breadth. Several interesting facts are revealed in table 3. First, the PSD of Barn Owls shows considerable variation throughout their range, thus confirming their ability to take locally abundant prey species. Second, the PSD of Utah Barn Owls falls within the range of recorded values observed in other areas of North America and Europe. The greater PSD of Barn Owls in Box Elder County compared to Utah County may be explained by the fact that the PSD is a measure of both richness and evenness; therefore, the more equal predation on the variety of small rodents in Box Elder County resulted in a higher PSD. Of considerable interest is the TD of Utah County Barn Owls, which ranks among the highest yet recorded. It reflects the diversity of habitats and fauna in Utah County and, more importantly, the ability of the Barn Owls to adjust their hunting habits to suit local conditions.

Mortality of Adults

Causes of mortality of adult Barn Owls in Utah included collision with automobiles, shooting, accidents, and severe winter weather. Six adults were collected as road kills, all from along major interstate highways in the central and northern parts of the state. This form of mortality may be of far greater significance than records indicate. Trost (pers. comm.) noted that one of his students picked up 35 dead Barn Owls in one day along the interstate highway between Pocatello and Jerome, Idaho. Two Barn Owls were shot at the Ironton Steel Mill, and several have been observed in taxidermy shops, indicating a high probability that Barn Owls are occasionally shot for sport and perhaps also as vermin. Observed accidental causes of mortality were limited and involved the entrapment of four Barn Owls in a structure at the Ironton Steel Mill (Smith and Murphy 1972). At least four Barn Owls died during severe winter weather conditions, and scattered reports indicate several more perished in recent winters. All reports are from the central and northern counties. One adult male was found dead in a silo about two miles west of Springville, Utah County, on 10 January 1971 in a very emaciated condition, with its stomach empty. Three individuals died at Bear River Migratory Bird Refuge in December 1972 (Kingery 1973; Beal letter of 11 March 1975), and one of them was reported in an emaciated condition. Winter mortality of Barn Owls is a familiar phenomenon and has been reported from a number of northern localities in the United States and Europe (Henny 1969). Winter mortality has been ascribed to cold temperatures and starvation. Smith et al. (1972) found a decline in the number of food items per pellet during periods of cold and snow cover, although none of the owls under observation died. It is, however, very probable that winter weather conditions constitute a potential source of mortality of Barn Owls throughout the northern portions of Utah.

Discussion

Analysis of available information indicates the presence of a substantial Barn Owl population in central and northern Utah. A somewhat smaller and perhaps more transient population is in the southwestern corner of the state. The known breeding records suggest that the northern population, at least, is currently maintaining its numbers, but this may be only a temporary situation brought about by the chance occurrence of sizeable prey populations and sufficient suitable nesting and roosting sites. Indeed, we are unwilling to predict the continued success of this species in northern Utah because of its poor adaptiveness to rigorous winter climates.

While undoubtedly having contributed indirectly to the benefit of the Barn Owl population through some types of habitat modification and building construction, man poses a continued threat to this owl both purposely, through shooting, and accidentally, by automobile collision. Other factors which may act to limit the distribution and success of Barn Owls in Utah include possible competition from other nocturnal raptors, such as the Great Horned Owl, and winter weather. Our food habits studies indicate that suitable food is available and is not therefore a limiting factor. Instead, Barn Owls, as with most species of raptors, are opportunistic in prey selection and have sufficient hunting ability to obtain food in many of the diverse habitats found in Utah.

Continued observation of this population should elucidate further the role of Barn Owls in the natural and man-modified habitats of the intermountain area.

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TABLE 1

TOTAL PREY IDENTIFIED FOR BARN OWLS IN UTAH

Prey Species	*Utah County* Number	*Utah County* Percent Frequency	*Box Elder County* Number	*Box Elder County* Percent Frequency
Mammals				
Microtus pennsylvanicus	2,345	78.1	23	12.9
Microtus montanus	–	–	24	13.4
Mus musculus	156	5.2	–	–
Phenacomys intermedius	35	1.2	–	–
Peromyscus spp.	13	0.4	76	42.7
Peromyscus maniculatus	98	3.3	–	–
Sorex spp.	3	0.1	2	1.1
Sorex vagrans	31	1.0	–	–
Perognathus spp.	–	–	15	8.4
Reithrodontomys megalotis	–	–	33	18.5
Dipodomys ordii	–	–	2	1.1
Sylvilagus spp.	1	tr.	2	1.1
Sylvilagus audubonii	3	0.1	–	–
Rattus norvegicus	23	0.8	–	–
Birds				
Sturnus vulgaris	169	5.6	–	–
Passer domesticus	53	1.8	–	–
Columba livia	7	0.2	–	–
Agelaius phoeniceus	21	0.7	–	–
Falco sparverius	1	tr.	–	–
Molothrus ater	2	0.1	–	–
Fulica americana	2	0.1	–	–
Colaptes auratus	5	0.2	–	–
Totanus flavipes	1	tr.	–	–
Turdus migratorius	7	0.2	–	–
Riparia riparia	2	0.1	–	–
Lophortyx californicus	1	tr.	–	–
Unidentified birds	18	0.6	1	0.6
Invertebrates				
Carabidae	2	0.1	–	–
Tenebrionidae	1	tr.	–	–
Unident. Coleopterans	4	0.1	–	–
Totals	3,004	100.0	178	100.0

TABLE 2

FOOD BROUGHT TO BARN OWL NESTS CONTAINING EGGS AND YOUNG (Data pooled from five nests)

Week of Nesting Cycle	*Microtus* spp.		*Peromyscus* spp.		*Mus* Musculus		*Sorex* spp.		Starlings		House Sparrows		Icterids	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Eggs in nest														
1	16	6.2	3	1.2	–	–	1	0.4	–	–	–	–	–	–
2	7	2.7	–	–	1	0.4	–	–	–	–	1	0.4	–	–
3	7	2.7	3	1.2	3	1.2	–	–	–	–	–	–	–	–
4	6	2.3	1	0.4	1	0.4	1	0.4	–	–	1	0.4	–	–
Young in nest														
5	25	9.6	7	2.7	1	0.4	–	–	2	0.8	1	0.4	–	–
6	19	7.3	3	1.2	–	–	3	1.2	–	–	–	–	–	–
7	37	14.2	1	0.4	4	1.5	1	0.4	–	–	–	–	1	0.4
8	31	11.9	5	1.9	5	1.9	–	–	3	1.2	1	0.4	1	0.4
9	14	5.4	5	1.9	2	0.8	2	0.8	1	0.4	–	–	1	0.4
10	9	3.5	1	0.4	–	–	2	0.8	6	2.3	3	1.2	–	–
11	6	2.3	–	–	–	–	–	–	–	–	1	0.4	–	–
12	2	0.8	1	0.4	–	–	–	–	1	0.4	–	–	–	–
Totals	179	68.9	30	11.7	17	6.6	10	4.0	13	5.1	8	3.2	3	1.2

TABLE 3

DIVERSITY INDICES OF BARN OWL PREDATION CALCULATED FOR UTAH AND OTHER SELECTED LOCALITIES

Location	No. Prey Indiv.	No. Prey Species Birds	No. Prey Species Mammals	Trophic Diversity	Prey Species Diversity	Source
Utah						
Box Elder Co.	178	1	8	0.03	2.31	This study
Utah Co.	3,004	12	12	0.48	1.45	This study
California	933	10	13	0.27	2.19	Selleck & Glading 1943
Colorado	4,366	6	16	0.10	2.76	Marti 1974
Michigan	6,815	5	13	0.07	0.98	Wallace 1948
Pennsylvania	6,175	7	17	0.03	1.46	Latham 1950
Texas	11,408	6+	10	0.66	3.35	Otteni et al. 1972
Germany	76,664	51	32	0.19	2.69	Uttendorfer 1952
England	47,865	8+	17	0.13	2.29	Glue 1974

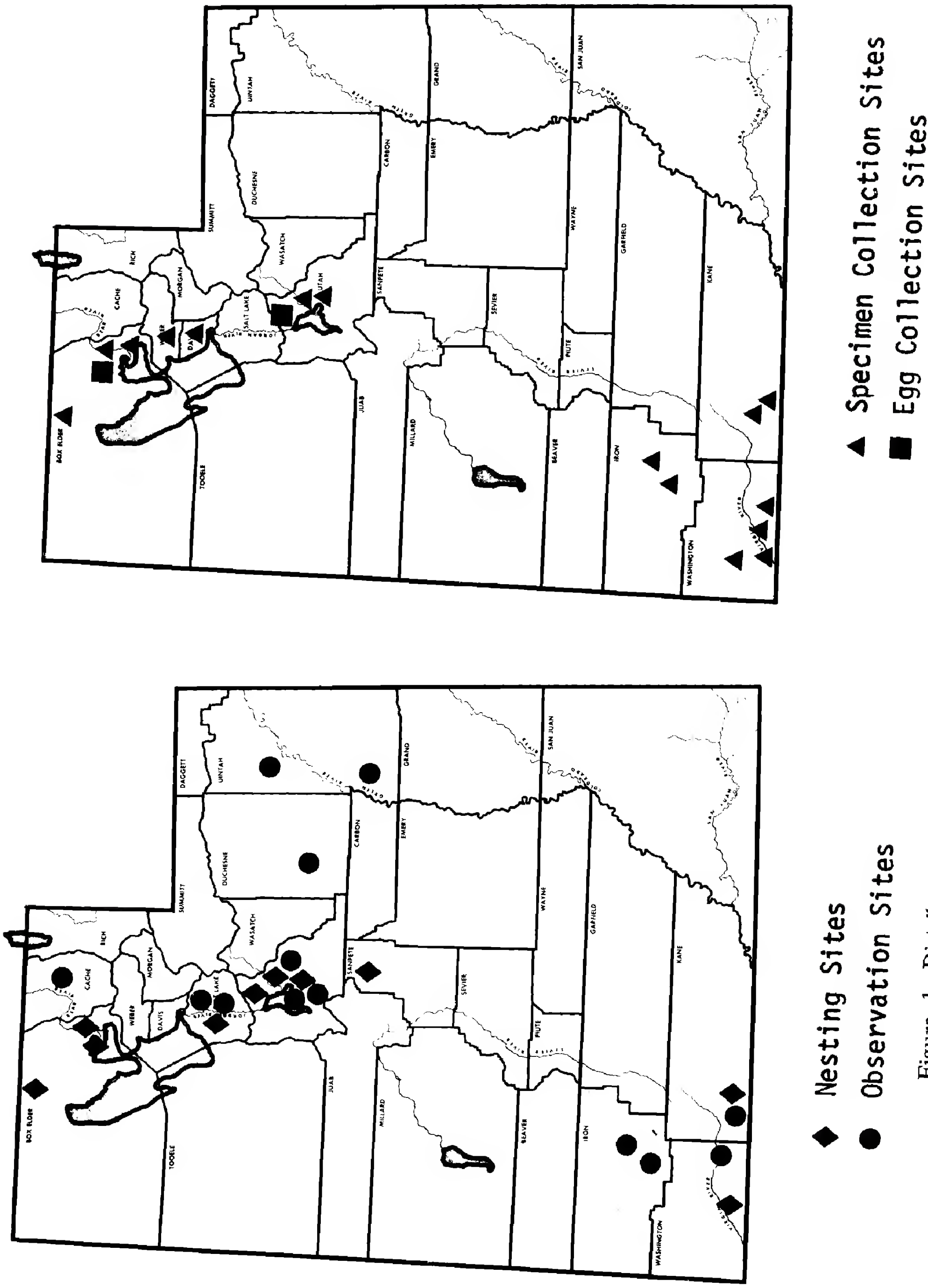

Figure 1. Distributional records of Barn Owls in Utah by observation, nesting sites, and specimen and egg collection locales. Locations shown are approximate.

NUTRITIVE VALUES OF WHOLE-ANIMAL DIETS FOR CAPTIVE BIRDS OF PREY

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Introduction

A recent upsurge in the number of birds of prey held for captive-breeding and rehabilitation purposes has led to a pressing need for information concerning their health requirements in captivity. Essential to their well-being is a reasonably sound diet. Although most falconers can supply one or two birds with fresh food obtained from the wild, larger aviaries usually must resort to domestic stock, fresh and/or frozen. Many questions have arisen, however, as to the nutritive values of the various food-types for captive birds of prey (see transcripts of 1971 and 1972 Raptor Research Foundation, Inc., conferences at Sioux Falls, South Dakota). The present study represents an attempt to obtain a partial analysis of the nutrient contents of some commonly used domestic animals.

Materials and Methods

Rats, mice, chickens, and two strains of day-old chicks were used in this study. Frozen whole carcasses were randomly selected, ground in a meat-grinder, freeze-dried, thoroughly mixed, and reground to a finer mesh for chemical analyses.

Nitrogen and crude fat contents of the samples were determined by the Kjeldahl method and the direct ether extraction method, respectively. Crude fiber is the loss on ignition of dried residue remaining after digestion of a sample with 1.25 percent sulfuric acid and 1.25 percent sodium hydroxide solutions. To obtain ash values the samples were left overnight in a muffle furnace at 600C. The details of these analytical techniques are described in *Official Methods of Analysis* (Association of Official Analytical Chemists 1980). Gross energy values were obtained by using a Parr Oxygen Bomb Calorimeter (Parr Instruments Company, Moline, Ill.).

To prepare for mineral determinations, the samples were digested with a mixture of nitric and perchloric acids (25:4, v/v). For the determination of calcium, the absorbance values of the diluted digest, containing 1 percent (w/v) of added lanthanum, were measured at 422.7 nanometers using an atomic absorption spectrophotometer. Total phosphorus values were determined on the diluted digest using molybdovanadate reagent as described by the Association of Official Analytical Chemists (1970). Trace mineral determinations (zinc, copper, manganese, and iron) were made on the nitric-perchloric acid digest (with appropriate dilutions, but without the addition of any reagents) by atomic absorption spectrophotometry at

213.9, 324.7, 279.5, and 248.3 nanometers, respectively. Distilled-deionized water was used throughout the mineral determinations.

Thiamine contents were measured (through the assistance of Hoffman-La Roche) by a gas chromatographic procedure modified after Seifert and Miller (1973).

Results and Discussion

Information on the nutritional needs of birds of prey is scarce, thereby making it difficult to draw conclusions on the partial analysis of the nutrient contents of some commonly used domestic animals as presented in table 1. No statistically significant differences are implied in the following discussion though an attempt is made to elaborate on several salient points.

Figures representing percent dry matter, crude fat, and crude protein (N x 6.25) show little variation among the species analyzed. Ash content, which reflects the general mineral content of the sample, is slightly lower in day-old chicks than in other species. As expected, crude fiber is much lower in chicks than in full-grown animals. This low content might be of some importance to birds of prey in terms of pellet casting, a habit which has yet to be proved physiologically necessary. Mendelssohn and Marder (1970) observed, however, that raptors fed only lean meat ingested other materials to form their pellets. It has also long been recognized by falconers that casting acts to swab out accumulated mucous in the digestive system and that pellets may serve as an index of health and well-being.

Gross energy contents reported here in all species are fairly constant and closely coincide with figures reported by Duke et al. (1973) for mice and day-old turkey poults, but are considerably greater than those reported by Graber (1962) for several species of mice.

Although dietary requirements for birds of prey may vary somewhat from those of poultry, certain desirable traits (e.g., feather growth and egg production) are likely controlled by the same nutritional factors in both avian groups. Hence, mineral and thiamine requirements of breeding hens, as recommended by National Academy of Sciences-National Research Council (1971), are presented in table 2. The recommended calcium level (particularly the Ca:P ratio) is much higher than that previously reported for birds of prey by Wallach and Flieg (1970). Since raptors, unlike poultry, are not expected to lay eggs on a continual basis, the requirements of 2 percent of the total diet recommended by the latter researchers is surely sufficient. The Ca:P ratio of 1.5:1 reported by them is in close agreement with the remarkably constant ratio shown for all species examined, in table 1.

With regard to trace elements, it is obvious that zinc and iron are adequate, copper could be marginal. If, however, the National Research Council suggestions for layers and breeders are to be used as a guide, some form of manganese supplementation of all four diets may be necessary because manganese deficiency has been implicated in fertility problems (Underwood 1971). In laying and breeding birds, for instance, manganese deficiency results in lowered egg production and hatchability, as well as in reduced eggshell strength.

Much controversy has surrounded the dietary value of day-old chicks (see transcripts of 1971 and 1972 Raptor Research Foundation, Inc., conferences at Sioux Falls, South Dakota). Because the nutritional makeup of day-old chicks could possibly vary with different sources, as a result of different feeding programs of the parent birds and other factors, chicks from two hatcheries were examined during this study. There are distinct differences—for example, in values for zinc and thiamine—in the two strains.

Low levels of calcium in day-old chicks have been discussed by Cooper (1975) though no figures were given, and radiological examination depending on methodology might not reveal sources of calcium in muscles and other tissues. It is apparent from table 1 that calcium is below the 2 percent level suggested by Wallach and Flieg (1970) for growing and laying birds of prey, and slightly more than half the values reported here for mice and rats. This situation can be remedied, however, simply by tearing open the abdominal flesh of the chick and rolling the entire carcass in bone meal. The calcium content and phosphorus content are then increased to 2.9 percent and 1.6 percent, respectively, on a dry matter basis, and the Ca:P ratio is little altered.

Figures for day-old chicks in table 1 lend little credence to the possibility of thiamine deficiency in them when compared to figures for rats and chickens. Some breeders, in order to avoid the messiness of yolk on birds and equipment, may allow the chicks to live a day or two before killing them and thus deplete the yolk supply in their bodies. Since yolk is likely to be an excellent source of vitamin A and other nutrients, the practice is unwise, especially if chicks constitute a major part of the diet.

It has been suggested that feeding day-old chicks to breeding raptors may cause parent birds to mistake their young for food items (see transcript of 1971 Raptor Research Foundation, Inc., conference, Sioux Falls, South Dakota). More experimentation is needed to determine whether this problem exists. We have maintained a reasonably large colony of American Kestrels (*Falco sparverius*) on a diet of 90 percent day-old cockerels for three years and have yet to lose kestrel chicks for that reason. The size of the cockerel relative to the size of an adult kestrel may be important here.

Until the dietary requirements of birds of prey are more clearly defined by analysis of wild prey and/or controlled experimentation on captive birds, it is impossible to state whether or not the figures in table 1 represent adequate amounts in raptor diets. The larger hawks and falcons in our aviary seem to thrive on predominantly frozen-thawed whole rats with occasional feeds of whole chicken. Likewise, our kestrel colony is fed almost exclusively, year-round, on day-old cockerels supplemented during breeding time by bone meal and occasional doses of SA-37 vitamin additives (Rogar-STB Division of BTI Products, Inc., Pointe Claire, Quebec). These birds have not shown any serious poor performance in terms of either general health or reproduction.

In summary, it appears that the day-old chick compares reasonably well with other food species fed to captive raptors. However, calcium supplements may be required for growth and egg-laying. Although this partial analysis does not indicate any significantly low levels of the nutrients examined, with the possible exception of manganese, these results will be much more meaningful when dietary requirements of birds of prey are determined by further research.

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TABLE 1

PARTIAL ANALYSIS OF NUTRIENT LEVELS IN DOMESTIC RODENTS AND POULTRY

		Rats	Mice	Chickens	Day-old Chicks Strain 1	Day-old Chicks Strain 2
No. of animals		10	30	10	30	30
Average weight (g)		325.7	26.7	386.7	41.2	39.6
Dry matter percent (freeze dried)		34.4	35.4	33.5	27.6	26.4
Crude fat (percent DM*)		22.1	24.9	26.9	24.2	23.4
Crude protein (N x 6.25) (percent DM)		62.8	56.1	56.7	62.2	62.5
Ash (percent DM)		10.0	10.4	9.5	7.4	7.1
Crude fiber (percent DM)		2.4	1.7	2.0	0.8	1.1
Gross energy (kcal/g DM)		5.78	5.84	5.93	6.02	6.00
Calcium (percent)	DM:	2.06	2.38	1.94	1.36	1.24
	as fed:	0.69	0.84	0.65	0.38	0.33
Phosphorus (percent)	DM:	1.48	1.72	1.40	1.00	0.94
	as fed:	0.51	0.61	0.47	0.28	0.25
Ca:P ratio		1.39	1.38	1.39	1.36	1.32
Zinc (mg/kg)	DM:	129.2	134.6	158.0	106.9	136.4
	as fed:	43.3	47.7	52.8	29.9	36.3
Copper (mg/kg)	DM:	4.5	8.0	4.5	3.2	3.4
	as fed:	1.5	2.8	1.5	0.9	0.9
Manganese (mg/kg)	DM:	7.5	11.7	9.0	3.0	2.4
	as fed:	2.5	4.1	3.0	0.8	0.6
Iron (mg/kg)	DM:	175.7	239.1	146.8	121.8	120.1
	as fed:	58.9	84.6	49.1	34.0	31.9
Thiamine (mg/kg DM)		13.3	Not available	8.5	16.0	10.6

*DM = Dry matter

TABLE 2

RECOMMENDED* MINERAL AND THIAMINE REQUIREMENTS FOR THE DIETS OF GROWING AND BREEDING HENS

	Adult Chickens	Starting Chickens (0-8 weeks old)
Ca	2.75 percent of diet	
P	0.60 percent of diet	
Ca:P ratio	4.58	
Zinc	65 mg/kg diet	50 mg/kg
Copper	?	4 mg/kg
Manganese	33 mg/kg diet	55 mg/kg
Iron	?	80 mg/kg
Thiamine	0.8 mg/kg	

*By National Academy of Sciences, National Research Council

ABSTRACTS OF THESES AND DISSERTATIONS

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A PRELIMINARY COMPARISON OF TEXAS AND ARIZONA HARRIS' HAWK (*PARABUTEO UNICINCTUS*) POPULATIONS

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ABSTRACT. Nineteen Harris' Hawk nests found in west Texas were associated closely with Mesquite. Nest site characteristics were measured. Eight successful nests fledged 15 young, averaging 1.87 per nest. Only one nesting threesome was found. In a similar Harris' Hawk population in southern Arizona, approximately half the nests were attended by threesomes. The difference in the numbers of threesomes in the two populations may be a result of differential nest success and/or the effects of population shifts associated with an arid environment.

Introduction

To a student of polyandrous breeding behavior, William Mader's (1976a, 1976b) work on Harris' Hawks is most intriguing. In a population of Harris' Hawks in the Lower Sonoran Desert of southern Arizona he found that approximately half of the nests under observation were attended by threesomes, with all three adults sharing duties in the care of young. Further, threesomes were more successful than twosomes. The purpose of my study was to describe the reproductive activity of the Harris' Hawk and, more specifically, to determine if segments of Harris' Hawk populations in west Texas exhibited the same unusual breeding behavior observed in populations of southern Arizona.

Study Area and Methods

The present distribution of the Harris' Hawk within west Texas is patchy; it is completely absent in some districts while locally common in others. It frequents the rich mesquite (*Prosopis glandulosa*) savannah around Midland, Texas, near the periphery of its range, and the yucca-cactus-creosote bush deserts of the Trans-Pecos region (Kincaid 1974).

My study area lies mainly in Brewster and Pecos Counties in the Trans-Pecos region of the Chihuahuan Desert. I also found four nests in adjoining Crane County. The first Brewster County, Texas, record of the Harris' Hawk was in 1953 (Dixon and Walmo 1956). The nature of their observations suggest that the species had in fact been present for at least a short time before, but probably not in large numbers. The species has since increased and extended its range in the western part of the state.

Harris' Hawks were essentially limited to the desert brushlands, where mesquite appears in isolated woodlands often mixed with stands of hackberry (*Celtis reticulata*) and desert sumac (*Rhus microphylla*) along the lower drainage areas. The region is further characterized by Spanish-dagger (*Yucca torreyi*) usually with an understory of creosote bush (*Larrea divaricata*). Further north in Crane County the habitat of the Harris' Hawk is characterized by dense mesquite savannah.

The study area was rectangular measuring approximately 39 km by 22 km; however, some parts were not accessible for study.

The mean annual precipitation in the area of the largest hawks population is 38 cm; rain occurs primarily in the summer months. The average annual temperature is 17°C, ranging between −17°C in the winter and 40°C, in the spring and summer months (U.S. Department of Commerce 1968). The elevation is approximately 1126 m, with less than 30 m variation between areas.

This study was conducted between 30 March and 29 July 1975. I determined nesting success by searching for nests by car and on foot. The majority of the nests were found from the road.

Nest site preferences, clutch sizes, fledging success, and nest sizes were recorded. Thirteen nestlings were banded with Fish and Wildlife Service metal bands and with blue consecutively numbered plastic bands on the opposite leg. The long, bare tarsosmetatarsus of the Harris' Hawk facilitated the use of tall bands measuring 25 mm. No adults were banded.

Results

Territories. Nesting pairs of Harris' Hawks appeared to maintain individual nesting territories. I found 19 territories. However, I saw no intraspecific competition between nesting groups. I found only one threesome consisting of two males and one female. These adults occupied a territory and maintained two nests but failed to lay eggs. The two closest nests of other pairs were approximately 1.2 km apart. I saw only one instance of interspecific aggression when a Harris' Hawk was in pursuit of a Marsh Hawk (*Circus cyaneus*). Even though the chase occurred in the general vicinity of a Harris' Hawk nest, I cannot be sure that it was territorial defense. Great Horned Owls (*Bubo virginianus*) commonly nested in the vicinity of Harris' Hawks, but I saw no encounters between the two species. Harris' Hawks were quite attentive to their nesting territories and hunted in the general vicinity of their nests. When a nest failed, the hawks quickly vacated the nesting territory.

Nest Sites. Harris' Hawk nests were usually in low-lying isolated woodlands. Of 19 nests, 5 were in Spanish-daggers and 14 were in trees: 7 in hackberry, 6 in mesquite, and 1 in desert sumac.

The nests were large, bulky platforms constructed of sticks and usually lined with grass. The lining of one nest consisted of lambs' wool. Nest measurements are shown in Table 1.

The Great Horned Owl was the only other common nesting raptor in the study area. The Swainson's Hawk (*Buteo swainsoni*) and Red-tailed Hawk (*Buteo jamaicensis*) nested only on the periphery of the study area, well outside the territory of active Harris' Hawk nests, and did not infiltrate the heart of the Harris' Hawk range.

In 1975 rodent populations were determined by trapping censuses to be very high (Pete Gobber pers. comm.), probably because of unusually heavy rainfall the previous summer and fall. Flowering plants appeared in great abundance, some that had not been seen for more than 50 years, according to local ranchers.

Nests of pack rats (*Neotoma* sp.) were abundant near Harris' Hawk nests, at the bases of nest trees or within a few meters of them. The farthest from a nesting tree was 18 m away. Pack rats collected essentially all the castings in the vicinity of hawk nests.

Copulation. Copulation was seen on five occasions. The earliest was on 2 March, the latest on 25 April. The average duration of copulation was 18 seconds, with a range extending from 6 to 30 seconds. I watched copulation by the only threesome twice on the same evening. The female was perched on a telephone pole and was joined by a male. He mounted her for 6 seconds, then perched next to her. Then the second male flew in and perched on an adjacent pole. Both males flushed together and perched in a small tree 45 m north of the pole. At 18:04, 32 minutes later, the female was again perched on the telephone pole and was joined by a male. He mounted her for 5 seconds, then jumped off and perched next to her. He mounted her again, and copulation lasted for 24 seconds. Both males were in the immediate vicinity during copulations and displayed no aggression. I was unable to distinguish between the two males.

Seasonal Timing. There was little synchrony of egg laying among nesting pairs of Harris' Hawks. Eggs were found as early as 30 March and as late as 23 June. Mader (1976b) reported an average incubation period of 35 days in Arizona. A pipping egg that I found on 12 April was therefore presumably laid on 9 March, the earliest date for egg laying in my study area. The latest date for egg laying was estimated to be 1 June. Thus the earliest hatch date would be 13 April and the latest was estimated to be 28 June. However, if the late egg of 1 June had hatched, the latest hatch date would have been approximately 5 July. My earliest date for fledged young was 24 May, and the latest was approximately 29 July. With a longer study, later nesting dates might have been found.

Productivity. Eighteen of the 19 nests were active. They were checked two or more times to determine clutch size. Twenty clutches averaged 2.85 eggs. This average includes a second clutch of two eggs in one nest which had four nearly fledged young when the eggs were laid, and another which successfully renested with three replacement eggs after the first attempt apparently failed.

Nests in which at least one chick was reared to an age of approximately four weeks were considered successful (Mader 1976a). Eight nests (44 percent) were successful and fledged 15 young, averaging 1.87 per successful nest (range 1 to 4). The fledging success was 0.83 young per adult pair.

Causes of nest failure could be determined for only three nests. At one, two addled eggs were found, and within 70 m of the nest I found a female hawk dead from gunshot. At another, with two eggs, there was raccoon (*Procyon lotor*) sign. Even though one egg was left, the nest failed. The third, a yucca nest with four eggs, was knocked down when a pasture was "chained."

Discussion

In southern Arizona Mader (1976a) found that of 50 nests, 23 consisted of threesomes; and of these, 18 (78 percent) were successful. Of 19 Harris' Hawk nests in west Texas, only one consisted of a polyandric trio. Copulations were observed within this threesome, but no eggs were laid.

Differential productivity may influence the number of threesomes in each population. Woolfenden (1975) found in a study on helpers at the nest of Florida Scrub Jays (*Aphelocoma coerulescens*) that a year with high fledging success produced more helpers the next year.

Clutch size was much the same in Arizona and in my Texas study. In Arizona, from 1969 through 1973, 50 nests averaged 2.96 eggs (Mader 1976a). In Texas, 20 clutches in 18 nests averaged 2.85 eggs in 1975.

Production per nest was slightly higher in Texas than in Arizona. Thirty-four successful Arizona nests from 1969-1973 averaged 1.60 chicks per nest (Mader 1976a). In 1975, 8 successful nests in Texas averaged 1.87 chicks per nest.

Total nest success (percentage of nests fledging at least one young) was higher in Arizona. From 1969 through the 1973 nesting seasons, nesting success was 68 percent (Mader 1976a), whereas in Texas for 1975 it was 44 percent. This low occurred in Texas despite the use of napthalene crystals at the base of trees to repel predators, a technique not used in Arizona (Mader pers. comm.).

Shifts in Harris' Hawk populations are not well understood. However, there is growing speculation that the sporadic and unevenly distributed rainfall typical of the Trans-Pecos region and its subsequent effect on rodent populations may regulate the patchy distribution and the nesting success of Harris' Hawks in the suitable habitats of west Texas. For example, after some 7 years of drought in my study area the unseasonable and large rainfall of the late summer and fall months of 1974 provided more food for rodents, whose numbers increased markedly, and, subsequently, predator populations increased. Harris' Hawks, not so numerous the previous year, (Grainger Hunt pers. comm.) invaded the area in large numbers.

A similar invasion was recorded in 1971 in Midland and Glasscock Counties, Texas, where 17 active nests were found (Tom Cade pers. comm.). In 1975, not one nesting was found there. This absence of hawks was attributed to decreased rainfall and low rodent populations (Frances Williams pers. comm.).

Such erratic shifts of Harris' Hawk nesting also occur in south Texas (Peter Cragg and F. and F. Hamerstrom pers. comm.) where drought conditions are local and irregular.

In Arizona, where rainfall is also irregular and unevenly distributed, nesting territories are nevertheless occupied regularly. Mader (1976a) suggests that the sporadic and uneven rainfall may result in the scattering of food resources throughout the year in varying localities. He believes that this irregularity, coupled with its effect on prey populations, may indirectly affect Harris' Hawk nesting success, but it seems not to cause the erratic shifts in populations reported for Texas.

Acknowledgments

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Table 1

Harris' Hawk Nest Measurements (N=19).

	Mean	Range
Height	3.4 m	1.6-7.6 m
Diameter	46.6 cm	30.4-68.3 cm
Depth	23.3 cm	17.7-32.9 cm
Lining		
Diameter	23.8 cm	17.7-35.5 cm
Depth	5.3 cm	2.5-10.1 cm

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SNAKE RIVER BIRDS OF PREY RESEARCH PROJECT – 1975 ANNUAL REPORT

The Snake River Birds of Prey Research Project—1975 Annual Report is available from the Bureau of Land Management, Boise District Office, 230 Collins Road, Boise, Idaho 83702. It is a 193-page compendium of the research projects being conducted in the Birds of Prey Natural Area and is recommended to anyone doing ecological studies on western raptors. The bureau would welcome any comments concerning this project. There is no better way to ensure future consideration of raptors in land-use planning than to let the decisonmakers know that ongoing efforts are worthwhile. If you order the annual report, for which there is no charge, why not follow up after you have read it with a letter to Curt Berklund, Director, Bureau of Land Management, 18th and C Streets, N.W., Washington, D.C. 20240

CONFERENCE ON MANAGEMENT TECHNIQUES TO BE HELD AT OXFORD

The British Falconers Club is organizing its second international scientific conference on the subject of "Birds of Prey Management Techniques." The meetings are planned for October 3-5, 1977, and will be held at the Department of Zoology and Wadham College, Oxford. Additional information can be obtained by contacting R. E. Kenward, Department of Zoology, Edward Grey Institute of Field Ornithology, South Parks Road, Oxford OX1 3PS, England.

CORROSION OF BONE BY SOLUTIONS SIMULATING RAPTOR GASTRIC JUICE*

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ABSTRACT. To determine whether falconiforms digest the bones of their prey more thoroughly than strigiforms because of greater gastric acidity in falconiforms, mouse bones were incubated in solutions simulating gastric juice from the two orders. Solutions simulating the gastric juice of falconiforms with a pH of 1.66 corroded bones more extensively than solutions simulating strigiform gastric juice with a pH of 2.35. Pepsin, at concentrations ranging from 0 to 4 mg/ml, also were slightly involved in bone corrosion at both pH's.

Introduction

Previous studies have shown that hawks digest bone more exensively than do owls (Errington 1932, Glading et al. 1943, Clark 1972, Duke et al. 1975). Duke et al. (1975) found that the gastric juices of hawks and owls had approximately equal proteolytic activities, but that hawk gastric juice had a much lower pH than that of owls. They hypothesized that the difference in acidity may account for the greater corrosion of bones that occurs in the stomach of hawks. The purpose of this study was to test this hypothesis.

Methods

To simulate gastric juices of falconiforms and strigiforms, two liters of Avian Ringer's solution were treated in the following manner. Using concentrated hydrochloric acid, one liter was adjusted to pH 1.66 and the second liter to pH 2.35, the mean pH's of samples of gastric juice collected preprandially from several species of hawks and owls, respectively (Duke et al. 1975). Solutions containing 4 mg/ml of bovine pepsin were prepared from aliquots of the Ringer's solutions, and the aliquots were readjusted to their respective pH's. This concentration of pepsin approximates the proteolytic activity of raptor gastric juice (Duke et al. 1975). Aliquots of these latter solutions were then diluted to a concentration of 2 mg/ml of pepsin using the Ringer's solutions with pH's of 1.66 and 2.35. This procedure provided three solutions at each pH containing (1) 4 mg/ml of pepsin, (2) 2 mg/ml of pepsin, and (3) no pepsin. Five experiments were performed using the latter two solutions, and six experiments were run using the solution containing 4 mg/ml of pepsin (table 1).

In each experiment, bones from 3 adult laboratory mice (*Mus musculus*), cleaned of tissue by a dermestid beetle colony, were used. The cleaned bones were washed in cold water, oven-dried, and divided into 2 groups: group A contained 1 femur, 1 scapula, 2 ribs, 2 each of caudal and lumbar vertebrae, and 1 tibia fibula; group B contained 1 humerus, one-half mandible, 1 os coxae, 2 ribs, and 2 each of caudal and lumbar vertebrae. Each group of bones was weighed on a numbered, preweighed filter paper, and bone weight was calculated. In order to minimize differences in degree of digestion due to variation in bone size and shape, bones from each group were added to duplicate, numbered 100 ml aliquots of each of the six solutions (table 1), and the solutions were incubated for 4 hours in a heated waterbath at 39°C (the approximate body temperature of hawks and owls as determined in our laboratory). After incubation, the remaining bones in each group were collected on their corresponding numbered filter papers (see above) by filtration. Filter paper and bones were dried at 60°F overnight and weighed. The weight of the paper plus bone was subtracted from their initial weight after drying to estimate the amount digested.

To determine if incubation or the presence of bones in the solution may have altered the proteolytic activity of the solutions with 4 mg/ml of pepsin, proteolytic activity was determined in the solutions at each pH (1) before incubation or the addition of bones, (2) after 4 hours of incubation with no bones added to the solution, and (3) after addition of bones and 4 hours of incubation at 39°C. The release of tyrosine from hemoglobin upon addition of hemoglobin to the simulated gastric juice solutions was used as a measure of proteolytic activity of the pepsin in the solutions. Tyrosine release was determined by a modified colorimetric method (Duke et al. 1975).

Results and Discussion

Solutions of pH 1.66 corroded bones significantly more than solutions of pH 2.35 (table 1) at all pepsin concentrations. Pepsin appeared to have a slight effect on bone corrosion at either pH.

Proteolytic activity was slightly greater in solutions at pH 1.66 than in solutions at pH 2.35 (table 2). Four hours of incubation and the presence of bones in solution each appeared to decrease the proteolytic activity of the solutions.

The results of these studies support the hypothesis that the lower pH of gastric juice is principally responsible for greater bone corrosion in falconiform stomachs than in strigiform stomachs (Duke et al. 1975). The proteolytic activity of the simulated gastric juice solution apparently was also slightly involved in bone corrosion.

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TABLE 1
Effect of pH or pepsin on digestion of bone.

Contents/100 ml Bone Group	Pepsin (mg)	pH	Bone loss (%)*
A	0	1.66	70.7 ± 10.7 (5)
A	”	2.35	25.2 ± 14.7 (5)
B	”	1.66	64.8 ± 14.8 (5)
B	”	2.35	24.5 ± 8.7 (5)
A	200	1.66	81.9 ± 10.7 (5)
A	””	2.35	32.6 ± 18.3 (5)
B	””	1.66	75.6 ± 10.1 (5)
B	””	2.35	34.0 ± 11.0 (5)
A	400	1.66	81.8 ± 10.5 (6)
A	”	2.35	37.0 ± 19.8 (6)
B	”	1.66	80.8 ± 11.4 (6)
B	”	2.35	32.9 ± 14.1 (6)

* Mean ± S. D. with number of experiments in parentheses.

TABLE 2
Effects of incubation and/or digestion on
Proteolytic activity of simulated raptor gastric juice
solutions containing 4 mg/ml of pepsin.

Treatment	mg/ml of tyrosine released* pH 1.66	pH 2.35
not incubated; no bones added	4.13 (2)**	4.43 (2)
4 hr. of incubation; no bones added	3.21 (2)	2.67 (2)
4 hr. of incubation; bones added	2.73 (2)	1.96 (2)

* see text.
** mean with number of samples tested in parentheses.

DECK-FEATHER MOLT IN BALD AND GOLDEN EAGLES IN RELATION TO FEATHER MOUNTING OF RADIO TRANSMITTERS

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Introduction

Of the many techniques being used for mounting radio transmitters on raptorial birds, one that seems to minimize disturbance to bird behavior, plumage, and movements is the tail-feather mount. Several types of tail mounts are in use, including drilling the feather shaft, tying the transmitter in place, and cementing the transmitter to the shaft.

There is some question as to the amount of weight that can be attached to a feather without causing it to drop out prematurely. In order to prevent such feather loss, some investigators attach one transmitter to be on center tail (deck) feathers, thus reducing the load on each feather. There are inherent drawbacks, including reduced mobility of the deck feathers when the bird fans or closes its tail and the possibility of molting these two feathers at different times.

Since transmitters mounted on tail feathers are lost when the feather is molted, knowledge of the molt sequence of these feathers is essential so that the life of the transmitter on the bird can be estimated. This paper presents the results of preliminary studies on deck-feather molt in Bald Eagles (*Haliaeetus leucocephalus*) and Golden Eagles (*Aquila chrysaetos*).

Methods

All work was done on captive eagles: two Golden Eagles of known age and five Bald Eagles tentatively aged using plumage characteristics and beak, cere, and eye color according to Southern (1964, 1967) and Servheen (1975). The yearly succession of plumages in the Bald Eagles studied followed Southern's age classes over a two-year period (e.g., third year to fourth, fourth year to fifth, etc.).

Molt was studied by wrapping a numbered plastic adhesive strip (W. H. Brady Co. Perma-Code wire markers) around the base of each feather shaft while the feathers were still on the eagle. Mews were checked daily; feathers were collected and recorded as to exact day of molt by noting the feather number.

The Golden Eagles were fed road-killed deer, rats, rabbits, and chickens. Bald Eagles were fed salmon, chickens, and rabbits. The Golden Eagles were manned and exercised on a creance or were flown free. The Bald Eagles were injured when they arrived at the holding facility but were not undergoing treatment during the research. The Bald Eagles were kept together in a flight cage and were not handled. All birds were kept outside and were subject to the natural climate and photo-period of Missoula, Montana (approx. 46° 50' latitude), for the Golden Eagle work, and Seattle, Washington (approx. 47° 30' latitude), for the Bald Eagle work.

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Assumptions

Extrapolation of molt timing from captive birds to wild birds is limited by several assumptions. A deficiency or reduction in food supply can disrupt the timing of a molt sequence or interrupt an ongoing molt (Payne 1972). All birds used in this work were fed what I considered an adequate diet in amount and nutritional content.

Captive birds may shed feathers abnormally after disturbance or handling (Payne 1972). Such feather loss, characterized as "fright molt," is quite striking with many feathers being dropped at once soon after the disturbance. I have never observed such feather loss in eagles, and I doubt that it occurs in them under most handling conditions.

Another factor is the effect of sex hormones on the timing of molt. Experimental work and observations on the timing of reproduction and molt indicate that sex hormones have an inhibitory effect on molt (Payne 1972). Thus, nonbreeding captive adults would be expected to molt sooner than wild or captive breeding adults. This expectation is yet to be verified in eagles, however. In this study, hormonal delay of molt was probably not a factor in any of the subadult birds because they would not normally be reproductively active.

Results and Discussion

Data on molt timing of deck feathers for Golden and Bald Eagles are presented in tables 1 and 2, respectively. Jollie's (1947) data on Golden Eagles are included with my results for comparison.

TABLE 1
Timing of molt of Golden Eagle deck feathers

	1 year female	2 year male	1 year[1] female	2 year[1] female
Right	15 July	13 Aug	3 May	7 June
Left	30 Aug	14 May[2] (2 yrs)	7 June	11 Aug

[1] From Jollie (1947). This is the same bird in both years.

[2] This feather was not molted after one year but was molted after two years.

TABLE 2
Timing of molt of Bald Eagle deck feathers

	3 year female	4 year male	4 year male	5 year male	6 year male
Right	16 Sept	30 July	1 Aug	...[1]	8 June
Left	12 June	13 June	...[1]	22 Sept	...[1]

[1] No data. Eagle was removed from the experiment before the feather was dropped.

These results indicate a wide variation in the timing of deck feather molt. For example, Jollie's (1947) data on the molt of a year-old female were vastly different from my observations on a bird of the same age and sex. Apparently, the specific date when a feather is dropped is determined primarily by local factors and/or individual variation.

The only pattern that emerged from the Golden Eagle data is that the right deck feather was always molted before the left, and the period between the molting of the two feathers was never less than 35 days. Thus, the left deck may be better for transmitter mounting because of its later molt. It also appears that any old deck feather on a Golden Eagle is unsafe for transmitter mounting between 1 May and 31 August because of the danger of the feather's being dropped during that period.

For the two Bald Eagles that did molt both deck feathers before being removed from the study, the left feather was molted before the right, just the opposite of Golden Eagles. Further work is in progress to determine whether this pattern is characteristic of Bald Eagles. The period between the molting of the two deck feathers was not less than 47 days in the Bald Eagles. Because of the variation in timing observed in the three other Bald Eagles, however, this time interval between the molt of deck feathers can be regarded as only a preliminary figure.

On the basis of both the Bald Eagle and the Golden Eagle data, the conclusion is that the mounting of a transmitter on both deck feathers simultaneously could be detrimental to the eagle. The natural timing of deck feather molt in eagles appears to be such that both feathers are not missing at the same time. This is possibly an adaptation to avoid the reduced maneuverability that would result from a large gap in the tail if both deck feathers were missing. If a transmitter is attached to both deck feathers and one is molted, the result may be the loss of the remaining feather because of excessive weight and stress on its follicle. If the remaining feather is not lost, the molted feather that remains in position could damage or inhibit the growth of the new feather. Such damage could reduce the maneuverability of the eagle, especially when combined with a loose feather in the tail held in place only by the transmitter. Reduced maneuverability could affect the prey-catching ability of the eagle and might, under some conditions, reduce its potential for survival.

Acknowledgments

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RANGLE

by
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ABSTRACT. The historical background of the use of rangle by raptors is outlined and compared with the use of gastroliths by certain other carnivores, such as seals. Some possible functions of gastroliths are summarized. Observations of rangle stones in wild New Zealand Falcons (*Falco novaeseelandiae*) are described. The relevance of rangle to modern raptor management techniques is discussed.

Introduction

The use of rangle by raptors has long been established in falconry circles. The origin of this knowledge is not clear, but it probably derives from observations of captive birds because some captive falcons will voluntarily pick up stones of the appropriate size and swallow them. Latham (1615) fed 16 rangle stones to a Peregrine (*Falco peregrinus*). She cast them the next day. When the stones were washed and replaced near the falcon's block, she swallowed about a dozen of them every day for a month. Harting (1898) observed a similar occurrence in a captive Peregrine tiercel. He also believed that Merlins (*Falco columbarius*) which ate their food on fine gravel had a more healthy and lively appearance than those which ate their food on turf.

The function of rangle has not been fully investigated, but falconers (e.g., Michell 1900, Blaine 1936) generally agree that it stirs up grease and mucus lining the anterior digestive tract as far as the gizzard. My observations indicate that some of the mucus is cast up on the stones, and some is loosened and passes through the gut, discoloring the mutes and giving them an oily appearance for a day or two. It appears that the stones loosen mucus more effectively than any pellet-forming material because they are heavier and can grind together. Blaine considered that pebbles about 20 mm in diameter are suitable for a female Peregrine. Smaller smooth stones down to about 4 mm were considered best for a male Merlin. He suggested using rangle for 7-10 days, occasionally missing a day, on fat hawks after the molt, on taking up from hack, or when the bird is dull and sluggish. He also stipulated that rangle should be given only when the hawk is empty of casting. Falconers from the dry Eastern countries make no reference to rangle. It may well be that desert falcons, constantly swallowing sand and grit with their food, seldom require supplementary stones.

Falconers of old Europe were aware of the main facts concerning rangle, but most modern falconers have ceased to use it, being unfamiliar with its administration and effect. Latham's (1615:23) well-known adage is seldom adhered to:

Wash'd meat and stones maketh a hawk to flie,
But great casting and long fasting maketh her to die.

Although the use of rangle in captive raptors is well documented, I have been unable to find any scientific references to its use by wild raptors. Stones, or gastroliths, have been found in the gizzards of nesting cormorants (*Phalocrocorax* spp.) and divers (*Gavia* spp.), but the function of stones in these species has not been investigated. It is possible that the gastroliths perform the same function as rangle in raptors.

Many workers have observed gastroliths in various seals, sea lions, and crocodiles and have conjectured on the significance of the stones. Fleming (1953) described how gastroliths were cast up by sea lions (*Zalophus hookeri*), often accompanied by indigestible food remains. Substantial deposits of gastroliths, some from distant sources, have thus accumulated on the Snares and Auckland Islands. Dr. Falla (pers. comm.) observed that gastroliths cast up by the New Zealand fur seal (*Arctocephalus forsteri*) were occasionally covered with a layer of mucus, sometimes in considerable quantities. It appears that seals and sea lions retain the stones much longer than do raptors, perhaps for several weeks. However, Schroeder (1935) noted that large numbers of pebbles were removed from the floor of zoo tanks by sea lions and seals soon after feeding, and a few hours later the stones reappeared in their former abundance on the tank floor, apparently having been regurgitated after the food had been digested.

Emery (1941) summarized some of the theories about the function of gastroliths in seals and sea lions:

1. The stones may serve as ballast to aid in diving.
2. They may act as "gastric chewing gum" to prevent atrophy of the male's stomach during the long period of fasting.
3. They may crush worms infesting the stomach or alleviate ulcers.
4. They may triturate (grind up) food particles.

The last theory, trituration, appears to be the most valid one for seals. Gizzard stones have long been known to be used for trituration by herbivorous birds, but it seems unlikely that raptors swallow stones for this reason. Sharp sand is an old remedy for the treatment of intestinal worms in raptors.

Field Observations

Recently I have been involved in a study of the New Zealand Falcon (*Falco novaeseelandiae*). In the 1974 breeding season I examined plucking posts near about 10 nests, searching for prey remains, castings, mutes, and molted feathers. I mentally rejected any nonbiological material. Then, early in the 1975 breeding season, I came across a classic case of rangle: about nine small pebbles on the top of a rock used as a perch by the falcons. After the discovery, rangle was included in my "searching image," and I found numerous examples, always in association with falcon perches.

Female New Zealand Falcons, weighing 450-660 g, produce rangle stones about 15 mm diameter, weighing 17-20 g per group (figure 1A, B). Stones of this size are not easily blown away and appear to remain for considerable periods. One or two examples had lichen growing on them. Males, weighing 260-350 g, produce smaller stones, about 7 mm diameter (figure 1C) and weighing about 8-10 g per group. These stones are more easily lost, and the only examples found in the wild were some that had fallen onto moss. The stones were readily recognizable because they were all water-worn to some extent, thus contrasting strongly with the rough, fragmented surface of the perch rock (figure 1E). Often, too, they were of a different color from the rocks nearby. All examples were found on plucking or hunting perches in the open. Most roosts had a vertical drop below, and rangle would be lost; similarly rangle cast onto vegetation is quickly lost.

Pellet Analysis

Analysis of about 600 pellets to date has not revealed any significant quantity of rangle. Each of two pellets contained about 15-19 small stones (figure 1D), but they were considerably smaller than true rangle stones and could well have been in the gizzard of prey.

It seems likely that wild falcons take stones only after they have cast all pellet-forming material. For example, a crop resulting from an early morning kill could be digested and the pellet cast by evening, while there was still sufficient daylight for the falcon to obtain rangle from a creek. My experiments in supplying rangle to trained falcons have always confirmed Blaine's description, but I have not risked feeding casting and rangle together.

Discussion

The factors which stimulate wild falcons to take rangle would be very difficult to elucidate in the field. Certainly the stones selected by a particular bird are remarkably uniform. Also, the frequency with which wild falcons make use of rangle is not known. In the pairs studied, the adults were present on territory all year for periods of many years, so it is difficult to evaluate how often they cast rangle. As far as I can tell, a haggard female of a pair of aviary birds has used rangle at least twice in the last twelve months.

One thing does seem certain: aviary birds, especially captive breeding stock, cannot fail to benefit from having appropriate stones available to them at all times. Leading an inactive, well-fed existence, they have rangle requirements almost certainly higher than those of wild birds. There have been cases of captive hawks dying from diets containing too high a fat content, such as adult pig meat or fat moorhens (*Gallinula chloropus*); a few timely doses of rangle could perhaps have saved these hawks. Rangle may also have a place in preventive therapy of foot troubles in lethargic and sluggish raptors.

I would be most grateful for any observations or information on rangle, especially in wild raptors.

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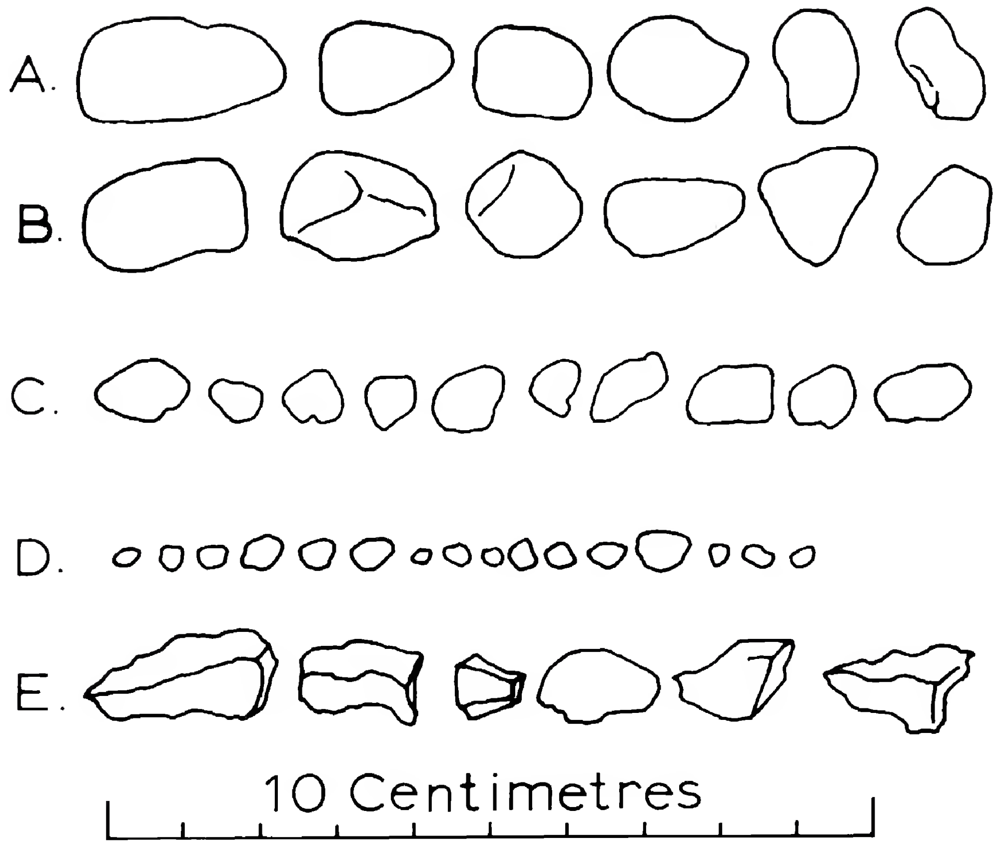

Figure 1. Rangle from New Zealand Falcons.
A. Female rangle. Sweet Stream pair, Marlborough. 1975
B. Female rangle. Byron Creek pair, Marlborough. 1975.
C. Male rangle. Byron Creek pair, Marlborough. 1975.
D. Stones found in a casting. Waikene Hills, Kaikoura. 1974.
E. Control: typical rock chips. Byron Creek area, Marlborough. 1975.

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