RAPTOR RESEARCH

Volume 10

Number 4

Winter 1976

Raptor Research Foundation, Inc.
Provo, Utah, U.S.A.

RAPTOR RESEARCH Winter 1976

Volume 10, Number 4, Pages 97-128

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SCIENTIFIC PAPERS

RAPTOR RESEARCH

Published Quarterly by the Raptor Research Foundation, Inc.

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RAPTOR ENERGETICS: A REVIEW

by
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Ecological energetics, as a discipline, has grown rapidly in recent years. In the broadest sense, it is the study of energy transfers within an ecosystem; however, most research involves only the determination of energy requirements for various categories of activity for a range of organisms. Much interest has focused on thermoregulatory adaptations by endotherms to desert and arctic environments (Schmidt-Nielsen 1964, Scholander 1955, Scholander et al. 1950 a, b, and c, and Irving et al. 1955).

This review is not intended to deal with the enormous volume of literature on endotherm or even avian energetics. I will confine the discussion to work which has examined energy transfers involving raptorial species (orders Falconiformes and Strigiformes). These are heterogeneous orders of birds with regard to size, behavior, and habitat, making them interesting but difficult groups to work with both in the laboratory and in the field.

The ease with which such standard data as body temperature, oxygen consumption, carbon dioxide production, food consumption, and excreta production can be collected varies considerably with the species. Thus technical problems account, in part, for the deficiency in our understanding of raptor energetics which will become apparent in this review. Since 1927 only 28 species have been studied by 20 workers with sample sizes ranging from 1 to 29 (table 1). Ignoring the largest study, the upper limit drops to 10. These facts point to a serious problem with the data base: small sample sizes. Most studies consider only minimum energy requirements (under quite variable conditions) and, sometimes, metabolic rate responses to several environmental temperatures. Very few studies have focused on specific ecological adaptations or the energetic costs associated with factors such as flight, growth, incubation, or molt.

Review of Methods Employed

In his monograph on ecological energetics, Gessaman (1974) provides an extensive and complete review of methods employed in this discipline. These methods will be mentioned only briefly here.

Food Consumption. By measuring the amount of food consumed and excreta produced, the energy metabolized by an animal can be estimated if constant weight of the animal over the period of measurement is assumed. Such data also permit the calculation of digestive efficiency which is of ecological interest.

Respiratory Gas Exchange. The rate at which an animal uses oxygen or produces carbon dioxide is an indirect estimate of metabolic rate. Given both these measurements simultaneously, we may calculate the respiratory quotient which is an indication of the proportion of protein, carbohydrate, and fat that is being metabolized, provided uric acid content of excreta is also known. Such information permits a more accurate estimate of heat production (metabolic rate) than does oxygen consumption or carbon dioxide production alone.

Review of Results

This review is divided into three parts. The first deals with the relationship between body weight and metabolic rate. The second discusses work dealing with the energy cost of productive work (e.g., flight). The third reviews studies which examined responses to varying ambient temperatures and other environmental variables.

Body Size and Metabolic Rate. The relationship between body size and metabolic rate for endotherms has received considerable attention beginning with the work of Brody (1942), Klieber (1961), and Scholander et al. (1950 a, b, and c). This work, for birds, has been reviewed thoroughly in *Avian Energetics* by Calder (1974).

Considerable discussion has surrounded the question of how best to describe (mathematically) the relationship which take the general form: $M = aW^b$, where M is metabolic rate, W is body mass, a is constant, and the exponent b describes the effect of size (Lasiewski and Dawson 1967, 1969; Zar 1968, 1970). The pertinent formulas with respect to raptors were presented by Zar (1968).

The regression formula for standard metabolic rate on body weight was determined empirically based on five species of falconiforms ranging in weight from 0.108 kg to 10.320 kg. The equivalent equation for strigiforms was based on 6 species over a weight range from 0.0377 kg to 1.450 kg. Collins et al. (in prep.) have calculated a revised equation with the addition of new data.

More data will undoubtedly improve the accuracy of these regression equations although the interesting problem will be to uncover the causes of significant inter- and intraspecific deviations from the regression line.

Energy Costs of Productive Work. With respect to the energetic cost of productive work, nothing has been published except for the works of Tucker (1970, 1971, and 1973) and Pennycuick (1968) on the cost of flight. Pennycuick's work is primarily theoretical but includes some observations on African vultures. The empirical work of Tucker was carried out on nonraptorial species.

Tucker (1974:306) presents an approximation formula: $P_i = (6.43 \times 10^{-3}\,h + 94.15)\ m^{0.974}$ which may be used to calculate the power requirements of flight given a number of assumptions concerning the bird's mass, altitude of flight, airspeed, wind conditions, wingspan, and basal metabolic rate. In this formula h = altitude, m = mass (of bird), P_i = power output (watts). For a complete discussion of the effect of these factors see Tucker's review in Paynter (1974).

I have included this material relating to nonraptorial species because the equation developed by Tucker and Pennycuick can be applied with reasonable confidence in the development of energetic models from field data. Bartholomew (in Paynter 1974:329) sums it up nicely, "Knowing these things, any one of us . . . can, by using the tertiary formulae, get values as accurate or more accurate than one could obtain by direct physiological measurement."

Response to Climatological Factors. **Cold Environments.** Data for metabolic rates at controlled temperatures outside the thermoneutral zone are available for only five species (Ligon 1969, Coulombe 1970, Gessaman 1972). These data, all for owls, are summarized in figure 1.

The values given for the lower critical temperature are of particular ecological interest. They are commonly accepted as an indication of an animal's tolerance of cold and reflect the insulative quality of the plumage (Scholander et al. 1950 c). This relationship is readily observed in figure 1, which shows a much lower critical temperature and a shallower slope for the Snowy Owl (*Nyctea scandiaca*) than for the other four species. There are no comparable data for falconiforms.

Hot Environments. At ambient temperatures approaching or exceeding normal body temperature, an animal is faced with the problem of dissipating excess heat and/or reducing the absorption of heat from the environment. This can be accomplished both behaviorally and physiologically.

Panting is commonly used by raptors under heat stress. It has the effect of moving relatively large quantities of air over the moist respiratory surfaces thereby removing water vapor. Since water has a high heat of vaporization, it is an effective mechanism for heat dissipation, providing the animal can efficiently replace the lost water and maintain proper blood gas concentrations. Panting also adds to the heat burden because of the associated muscular activity.

Ligon (1969) and Coulombe (1970) have reported respiratory water loss (RWL) for three species of owls (*Athene cunicularia, Otus trichopsis,* and *Micrathene whitneyi*). These data show a rapid and substantial rise in RWL commencing at an ambient temperature approximately equal to body temperature. The sharp jump in RWL was associated with the onset of gular fluttering in owls (a mechanism unavailable to the falconiforms). Here again no data on RWL are available for the falconiforms.

Countercurrent vascularizaton in appendages has been demonstrated for a variety of endotherms (e.g., Irving and Krog 1955, Scholander et al. 1950). Bartholomew and Cade (1957) have reported the only study of this mechanism in raptors. They demonstrated in American Kestrels (*Falco sparvarius*) a rise in tarsal temperature associated with increasing ambient temperature, thereby reducing the gradients between tarsal and core temperature, and ambient and tarsal temperature. As ambient temperature approached normal body temperature, so also did tarsal temperature, and this corresponded to a rise in body temperature. Presumably, the rise in tarsal temperature was caused by increased blood flow due to vasodilation (Bartholomew and Cade 1957). A similar response has been demonstrated in several large falcons (Mosher and White 1978).

Sun Bathing. Several avian studies have pointed out the value of sunbathing as a supplement to endogenous heat production (Hamilton and Heppner 1967, Lustick 1969). Other studies have discussed the relationship of a spread-wing posture observed in Ciconidae (Kahl 1971) and raptors (Cade 1973). While sunbathing apparently provides a supplementary source of heat under some conditions, the spread-wing posture of some raptors appears not to be correlated with control of body temperature (Cade 1973).

Circadian Rhythms in Metabolic Rate. Daily cycles in metabolic rate and body temperature have been recorded for raptors associated with their nocturnal or diurnal habits (Bartholomew and Cade 1957, Graber 1962, Coulombe 1970, Gatehouse and Markham 1970).

The most striking of these studies compared two species of owls with a small falcon (Gatehouse and Markham 1970). The owls had higher nighttime standard metabolic rates (SMR), and the falcon had a higher daytime SMR. Such variation in SMR has not always been considered in studies which report this parameter.

Other Factors Affecting Metabolic Rate. There may be sexual differences in metabolic rate unrelated to differences in body size. Although female Broad-winged Hawks (*Buteo platypterus*) are about 15 percent heavier than males, they have the same weight specific metabolic rate (Mosher and Matray 1974).

Wind is a significant factor in an animal's thermal environment and can have a considerable impact on the rate of heat loss. Gessaman (1974) is the only worker to report the effects of wind velocity on metabolic rate for a raptor. He found oxygen consumption of Snowy Owls to be a linear function of the square root of airspeed at -20° and -30° C.

Plumage color, unrelated to absorption of radiant energy, may also be related to metabolic rate. Red phase Screech Owls have higher metabolic rates at low ambient temperatures than do gray phase birds (Mosher and Henny 1976). This difference may be due to differences in plumage conductance.

Future Research Directions

This review has been undertaken for the purpose of pointing out gaps in our knowledge of raptor energetics and to encourage research designed to close these gaps.

Basic data are needed in the following areas: (1) energy cost for productive work, especially molt, incubation, growth, and flight; (2) metabolic response to wind and humidity; (3) seasonal metabolic acclimation; (4) energetic efficiencies—metabolized energy/gross energy intake and efficiency of prey capture, i.e., energy value of captured prey/energy cost of hunting; and (5) sexual differences, unrelated to body weight, in metabolic responses.

Besides these basic data, there are several other problems of broader ecological interest. The thermal environment of the nest is crucial to the young and can affect adults by requiring a greater investment of energy in the form of brooding or shading behavior. Direction of exposure of cliff nests is one factor controlling their thermal environment (Mosher and White 1976). A detailed study including nest temperature, radiation regimen, reflectivity of nest background, and nest success would be significant. How the desert-nesting Ferruginous Hawk (*Buteo regalis*) is adapted to the extremes of temperature it faces would be an equally interesting problem. The solution is likely to be both behavioral and physiological. For example, there may be a relationship between respiratory water loss and the relatively large gapes of the Ferruginous Hawk (Niel Woffinden pers. comm).

Differences in plumage coloration may be correlated with differences in thermal conductances (Mosher and Henny 1976). In addition, there may be regional metabolic adaptations to environmental variation within species as reflected by plumage variation (Blem 1974). Study of plumage thermal conductance is a reasonable starting point.

The ecological importance of predators in community function is generally accepted. A knowledge of their energy requirements and the avenues and efficiencies of energy utilization is equally important.

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A CHEAP METHOD OF DIVIDING LARGE PENS FOR BREEDING RAPTORS

by
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If you wish to separate a pair of birds over winter or to divide a large pen into smaller ones, we found that inexpensive canvas panels were excellent for this purpose.

The panels can be cut to size and nailed to the ceiling, floor, and walls with narrow strips of plywood and small nails. Small, weighted flaps covered the feed holes, and two 20-inch-long zippers were sewn about 2 feet apart as a door for each pen. These doors were used for changing bath water and entering pens.

These panels are inexpensive and fast to assemble and take down. They can be reused numerous times and are easy to wash and store when not in use. They can be left up as permanent partitions or put up and removed as required.

We have used these panels to winter female Peregrines and Merlins with very satisfactory results.

TABLE 1

SUMMARY OF RAPTOR ENERGETICS STUDIES

Species	N	Methods	Factors Studied										Reference
			T	W	F	M	I	BS	C	S	G	Other	
Buteo jamaicensis	5	Food Con.									*		Olendorff 1971
Buteo swainsoni	4	″									*		″
Buteo regalis	5	″									*		″
Buteo platypterus	7	Food Bal.						*				Sex, EE	Mosher & Matray 1974
Accipiter gentilis	1	Food Con.										EE	Fevold & Craighead 1958
Aquila chrysaetos	3	Food Con.										EE	″
Falco sparverius	3	O_2/CO_2							*				Gatehouse & Markham 1970
″	10	Temp.	*										Bartholomew & Cade 1957
″	–	O_2 & D_2O18	*									HR	Gessaman unpubl.
Accipiter nisus												SMR	Giaja & Males 1928
Falco mexicanus	2	Lin. M.									*		Fowler 1931
Falco peregrinus	8	Temp.	*										Mosher & White unpubl.

Table 1 cont.

Species	N	Methods	T	W	F	M	I	BS	C	S	G	Other	Reference
			Factors Studied										
Geranoaetus melanoleucus												SMR	Benedict & Fox 1927
Gypaetus barbatus												SMR	″
Vultur gryphus												SMR	″
Aegolius acadicus	1	O_2/CO_2							*				Gatehouse & Markham 1970
″	2	O_2 & Temp.	*					*				RWL	Ligon 1969
″	2	Food Bal. & O_2							*	*	*	EE	Graber 1962
″			*				*					SMR	Collins 1963
Otus asio	1	O_2/CO_2							*				Gatehouse & Markham 1970
Otus asio	2	O_2 & Temp.	*					*				RWL	Ligon 1969
Otus tricopsis	3	″	*					*				″	″
Glaucidium gnoma	3	O_2 & Temp.	*					*				RWL	Ligon 1969
Micrathene whitneyi	3	″	*					*				″	″
Asio flammeus	1	Food Bal. & O_2							*	*	*	EE	Graber 1962
Asio otus	1	″							*	*	*	EE	″
Athene cunicularia	29	O_2 & Temp.	*						*			RWL & SR	Coulombe 1970

Table 1 cont.

Species	N	Methods	T	W	F	M	I	BS	C	S	G	Other	Reference
			Factors Studied										
Otus flammeolus	2	O_2										RWL	Mosher & Woffinden unpubl.
Nyctea scandiaca	4	O_2/CO_2 & Food Bal.	*	*								Insul.	Gessaman 1972
Bubo virginianus												SMR	Benedict & Fox 1927
Strix aluco												SMR	Herzog 1930
Tyto alba		O_2 Food Bal.	*					*				EE, Insul	Johnson 1974
Surnia ulula	1	O_2	*					*				SMR	Johnson & Collins 1975
Glaucidium cuculoides	1	O_2	*					*				SMR	"

[1]Note the following abbreviations: T-temperature, W-wind, F-flight, M-molt, I-incubation, BS-body size, C-circadien rhythms, S-seasonal rhythms, G-growth, SMR-standard metabolic rate, RWL-respiratory water loss, EE-existence energy, SR-surface radiation, Insul.—insulation, HR-heart rate, Food Cons.-food consumption, Food Bal.-food balance calorimetry, Temp.-temperature measurement, Lin M.-linear measurements.

BALLOT FOR ELECTION OF BOARD OF DIRECTORS

The ballot is included as a separate item in this mailing. Please note that ballots are to be returned to the secretary, Dr. Don Johnson. Although the return deadline is given as July 1, ballots will be accepted up to the end of August, owing to the late mailing. Please vote!

NEW EDITOR OF RAPTOR RESEARCH

After several years of faithful service, Dr. Richard Olendorff (aka "Butch") has asked to be relieved of the editorial burden. Dr. Clayton White of the Department of Zoology, Brigham Young University, has agreed to serve as the new editor, effective immediately. On behalf of the board of directors and membership, we extend our sincere appreciation to Butch and our best wishes to Clay for a successful tenure as editor.

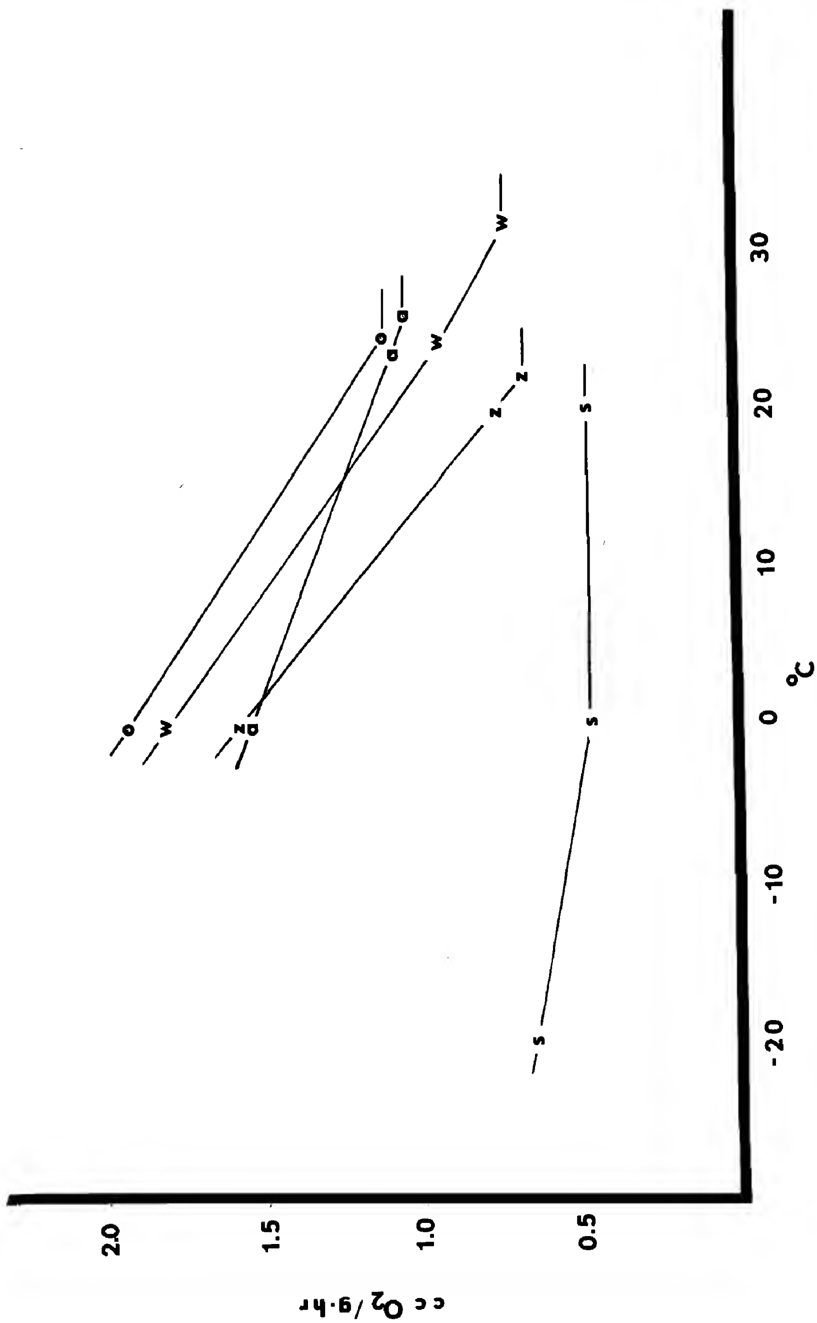

Figure 1. Oxygen consumption response of several owls to decreasing ambient temperatures (Ligon 1969, Gessaman 1972, and Coulombe 1970). The symbols are as follows: o-*Athene cunicularia*, w-*Otus trichopsis*, x-*Otus asio* c., a-*Aegolius acadicus*, and s-*Nyctea scandiaca*.

HIGH INCIDENCE OF SNAKES IN THE DIET OF NESTING RED-TAILED HAWKS

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The summer food of Red-tailed Hawks (*Buteo jamaicensis*) usually consists of ground squirrels, lagomorphs, and/or upland game birds (Craighead and Craighead 1969, Seidensticker 1970, Gates 1972, Smith and Murphy 1973, McInvaille and Keith 1974), although Fitch et al. (1946), Beebe (1974), and Kochert (1975) indicate that Red-tailed Hawks prey on reptiles for summer food along the Pacific Coast and in the Western deserts. This paper presents quantitative data for one nesting season on the food habits of Red-tailed Hawks along the Columbia River in north-central Washington, particlarly with regard to the high occurrence of snakes in their diet.

Study Area and Methods

Field studies were conducted from 14 July 1974 through 1 August 1975 on 6669 ha paralleling a 72 km stretch of the Columbia River between Chief Joseph and Grand Coulee dams. The vegetation is characteristic of the Upper Sonoran Life Zone with sagebrush (*Artemisia* spp.) and cheat grass (*Bromus tectorum*) the principal plants. Scattered stands of coniferous and deciduous trees occur infrequently.

Six active Red-tailed Hawk nests were visited every 3 days for identification of prey remains. Average weights of mammalian and avian prey species were determined from specimens at the Burke Memorial Washington State Museum, University of Washington, Seattle, and from Poole (1938) and Christensen (1970). Weights of reptiles were obtained from Walter English of the Seattle Woodland Park Zoo.

Results and Discussion

Mammals (table 1) constituted 40.6 percent of the individual prey items found in Red-tailed Hawk nests. Birds made up 18.1 percent of the diet, four species of snakes comprised 41.3 percent of all prey items. On a biomass basis, snakes were the principal prey item, making up 49.2 percent of the total. Mammals and birds comprised 32.9 and 17.8 percent, respectively. Snakes were evenly represented in all nests. Apparently, this is the highest recorded percentage of reptiles in the diet of a Red-tailed Hawk population.

Olendorff (1973) suggests that snakes are not a preferred food item of the Red-tailed Hawk in south central Washington. Beebe (1974) states that whenever ground squirrels are available, they are a favored food during the breeding season. No species of ground squirrel occurs on the study area. Two species of lagomorphs (*Sylvilagus nuttalli* and *Lepus californicus*) occur but were present in very low numbers (Erickson et al 1977). Pocket gophers (*Thomomys talpoies*) were present only in limited numbers during the study. They are available to Red-tailed Hawks for only a short time when the young leave their natal burrows (Ingles 1965). Small mammal trapping on representative habitat types on the study area gave 0.05 mammals per trap night of effort (1,654 trap nights), indicating a very low small mammal population (Erickson et al. op cit.).

Without a multi-year study and an accurate idea of reptile populations, it is impossible to assert that this high level of reptiles in the Red-tailed Hawk summer diet is a usual occurrence. It may be a response to a periodic decline in rabbit and other small mammal populations. Nevertheless, this study illustrates that Red-tailed Hawks will rely heavily on snakes as suitable prey under certain conditions.

Acknowledgments

This study was supported by the U.S. Army Corps of Engineers. It would not have been possible without the Colville Confederated Tribes who generously made their land and facilities available. R. R. Olendorff, C. W. Servheen, D. R. Paulson, G. Munger, and J. B. Athearn were kind enough to read drafts of this manuscript and offer helpful criticisms.

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TABLE 1

FOOD REMAINS FOUND IN RED-TAILED HAWK NESTS ALONG THE COLUMBIA RIVER, 1 MAY-18 JUNE 1975.

Food Species	No. Indv.	Percent Indv.	Approx. Biomass (gm)	Percent Biomass
Mammals				
Mountain cottontail (*Sylvilagus nuttalli*)	14	9.3	8400.0	25.9
Northern pocket gopher (*Thomomys talpoides*)	16	10.6	1633.6	5.0
Great Basin pocket mouse (*Perognathus parvus*)	8	5.3	132.8	.4
Western harvest mouse (*Reithrodontomys megalotis*)	1	.7	13.3	tr.
Deer mouse (*Peromyscus maniculatus*)	1	.7	21.1	.1
Sagebrush vole (*Lagurus curtatus*)	14	9.3	267.4	.8
Mountain vole (*Microtus montanus*)	4	2.7	227.2	.7
House mouse (*Mus musculus*)	1	.7	10.2	tr.
Unidentified mammals	2	1.3	–	–
Subtotal	61	40.6	10705.6	32.9
Birds				
California quail (*Lophortyx californicus*)	3	2.0	486.0	1.5
Chukar (*Alectoris graeca*)	4	2.7	2284.0	7.0
Ring-necked pheasant (*Phasianus colchicus*)	1	.7	1304.0	4.0
Common flicker (*Colaptes auratus*)	2	1.3	378.0	1.2
Cliff swallow (young) (*Petrochelidon pyrrhonota*)	2	1.3	30.0	.1
Black-billed magpie (*Pica pica*)	4	2.7	692.0	2.1

Table 1 cont.

Food Species	No. Indv.	Percent Indv.	Approx. Biomass (gm)	Percent Biomass
Western meadowlark (*Sturnella neglecta*)	4	2.7	580.0	1.8
Vesper sparrow (*Pooecetes gramineus*)	1	.7	27.0	.1
Unidentified birds	6	4.0	–	–
Subtotal	27	18.1	5781.0	17.8
Reptiles				
Yellow-bellied racer (*Coluber constrictor*)	32	21.3	5456.0	16.8
Gopher snake (*Pituophis melanoleucus*)	27	18.0	10044.0	30.9
Garter snake (*Thamnophis* sp.)	1	.7	141.8	.4
Western rattlesnake (*Crotalus viridis*)	2	1.3	341.0	1.1
Subtotal	62	41.3	15982.8	49.2
Total	150	100.0	32469.4	99.9

1977 ANNUAL MEETING—PRELIMINARY ANNOUNCEMENT

The annual meeting of the Raptor Research Foundation will be held in Tempe, Arizona, on November 11, 12, and 13 (not in Canada as tentatively announced at the Ithaca meeting). Sessions will be held in the Student Union Building at Arizona State University, with accommodation headquarters at the nearby Howard Johnson's Motor Lodge (225 E. Apache Blvd., Tempe, AZ 85281). Local committee chairman is John Russo of Arizona Game and Fish Department, with Dr. Robert Ohmart of ASU as co-chairman. Dr. David Ellis will serve as program chairman. Paper sessions will be held on Friday, Saturday, and Sunday mornings, with workshops, panels, and discussion groups on Friday and Saturday afternoons. An optional field trip to Harris Hawk country on Sunday afternoon is being planned by the local committee. Because of the limited time for paper presentations, it may not be possible to accept all manuscripts that are submitted. Anyone desiring to present a paper should send the manuscript (or an abstract) to Dr. David Ellis, Box 95A-1, Sasabe Star Rt., Tucson AZ 85736. Further details regarding the meetings will be circulated in the near future.

PROGRESS TOWARD TRACKING MIGRATING RAPTORS BY SATELLITE

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ABSTRACT. The ultimate objective of this radiotracking research is to track and monitor migrating birds by satellite. It is envisioned as only a part of a much broader program of satellite biological and ecological data collection (Wolff, Cote, and Paint-er 1975). The future need and demand for satellite tracking and monitoring of birds will very likely be focused on waterfowl and ocean birds, but large raptors, such as the Bald Eagle (*Haliaeetus leucocephalus*) and Golden Eagle (*Aquila chrysaetos*), provide ideal subjects for initial experiments. Current efforts are directed toward conducting successful feasibility experiments with these birds. Some specific objectives include equipment development and testing, animal-instrument interphase or attachment methods, evaluation of various feasibility tracking experiments with raptors, and suggestions for expediting a future program.

History of Satellite Animal Tracking

The first organized attempt to consider the feasibility and to examine the potential of satellites for tracking and monitoring wild animals was a conference sponsored jointly by the Smithsonian Institution, the American Institute of Biological Sciences (AIBS), and the National Aeronautics and Space Administration (NASA) in May 1966. In 1969 the National Academy of Sciences assembled a panel of scientists to look anew at the foundation of space biology. Wildlife behavior and ecological relationships were part of the agenda. Recommendations were made for a program for satellite tracking of free-ranging animals. One result of this meeting was a cooperative program in which an elk (*Cervus canadensis*) was tracked and monitored by the Nimbus-3 satellite (Craighead, Craighead, Cote, and Buechner 1972). This feasibility experiment was quickly followed by another to monitor a black bear's (*Ursus americanus*) winter den (Craighead, Craighead, and Varney 1971).

Subsequently, various meetings led to workshops on wildlife monitoring by satellite. A NASA/AIBS Santa Clara conference on wildlife monitoring was held 24-27 April 1973 at the Ames Research Center, Moffett Field, California. It was followed by a Santa Cruz workshop in September 1973. The purpose of these meetings and the subsequent report was "to show the importance of our wildlife resources and to show that their management, conservation and rational use are national goals, based on laws, treaties, and agreements binding between the United States and other countries as well as upon agencies of the State and Federal levels" (1973 Santa Cruz Report).

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The report stresses that state and federal agencies have established programs for which information is needed on habitat, censusing, movement, location, physiology, and behavior of animals and their populations.

Further impetus was given to animal satellite tracking and monitoring by the Easton, Maryland, workshop on Satellite Data Collection User Requirements held 18-20 May 1975.

The biology panel recommended (1) that NASA offer the community its services for liaison and information dissemination; (2) that a common data processing and standardization effort be established; (3) that NASA institute a program to develop and standardize in situ sensors; (4) that NASA support the development of recoverable packages; and (5) that NASA consider the Santa Cruz report on wildlife movement and tracking systems (Wolff et al. 1975).

Equipment Development and Testing

The 1973 Santa Cruz Report treated the application of technology to various satellite tracking programs. Two systems, RAMS and Omega/OPLE, were selected by consensus as having the greatest capability and best specifications for locating and monitoring animals and their environments. The needs of users were analyzed in terms of the required degree of equipment (transmitter) miniaturization, type of packaging, and harness required. The aim was a package needing little or no modification when fastened to the smallest (feasible) as well as the largest animal to be studied.

Attachment difficulties, which vary from species to species, can be sharply reduced by microminiaturization of the gear attached to the animal. The smaller the gear, the greater the number of species to which it can be effectively applied. Microminiaturization was based on two typical sizes of birds: large waterfowl (ducks, geese, swans), large raptors (birds of prey), and small passerines. The transmitter power, life, size, and weight are critical factors. Typical weight allowances are:

Waterfowl and Raptors	*Passerines*
100–200 g	10 g

It is estimated that electronics units manufactured under normal assembly techniques would weigh in the 200-g class. Miniaturization could achieve 80 g in a 28-cc volume in the immediate future without major effort. A subsequent step in microminiaturization can be expected to reduce this to 12 g in about 2 cc. Estimates of battery and antenna weights to be added to the above run from 40 to 1,000 g depending upon communication requirements. The total weight range is now 52 to 1,200 g. The development of the Nimbus-F/RAMS DCP one-watt transmitter weighing 56 g and compatible with Nimbus satellite frequencies (401 MHz) has been an ef fort to expedite the program and to follow the recommendations of the Santa Cruz report.

It was developed for the investigator and is being tested (Varney and Pope 1974). The work was sponsored jointly by the National Geographic Society and NASA's Ames Research Center through contracts with the Environmental Research Institute. This random access measurement system uses the Doppler location technique (G. Balmino et al. 1968). The random system transmits at predetermined intervals as compared with an ordered system, such as IRLS which responds to an interrogation from the satellite. It permits large-scale experiments at low cost using simple data collection equipment. The platforms transmit a one-second message to the satellite at random times at the rate of once per minute. The satellite records a Doppler frequency measurement and a time lag and formats the received data. This information is stored aboard the satellite for readout over the Fairbanks, Alaska, ground station and transmission to Goddard [Goddard Space Flight Center, Greenbelt, Md.] for processing. At Goddard the position location coordinates of each platform are computed, and the data is transmitted to the investigators.

The smallest available battery pack capable of operating the RAMS—compatible transmitter weighs 33 g. Operating life of the 33-g lithium battery pack would be 3.2 months or about 2.5 days/g. As mentioned, the weight of the demonstration transmitter is 56 g. The package thus weighs in the neighborhood of 100 g (56 + 33 + 10). It could be carried by a Golden Eagle, but further weight reduction is desirable for most objectives and is necessary for a comprehensive program of bird tracking. It appears that it can be reduced to about 60 g: transmitter to 20 g, battery pack to 33 g, antenna and harness to 5 plus g. This would be well within the weight-carrying capability of many migratory birds.

Briefly, the systems operate in the following fashion. Each instrumented bird carries a transmitter that transmits a constant frequency. The signals received by the Doppler equipment aboard the satellite contain the Doppler frequency shift caused by the motion of the satellite. The received frequency at the satellite varies as the satellite passes near the instrumented animal. The shape of the signal received at the satellite, combined with the known orbit of the satellite, defines two lines on the surface of the earth that run parallel to the track or orbit of the satellite. The instrumented animal is located on one of these two lines. The time at which the signal received at the satellite changes most rapidly occurs when the satellite is close to the transmitter. At this time, a plane normal to the orbit of the satellite is defined. The intersection of this plane and the surface of the earth produces a line which bisects the orbit lines and on which the transmitter or electronic animal package is located. The instrumented animal (bird) must be at one of these two intersections. These intersections are normally several hundred miles apart on the surface of the earth. Knowledge of the previous position of the animal can be used to eliminate one of the intersections (G. Balmino et al. 1968). Two fixes on locations can be made every 24 hours.

The RAMS system aboard the Nimbus-5 satellite can accommodate up to 1000 platforms per orbit. The received data is stored aboard the satellite for readout every 108 minutes (orbital period). Eight data acquisition channels allow for simultaneous reception of up to eight transmissions (Cote, DuBose, and Coates 1973).

Animal Instrument Interphase

The Santa Cruz report emphasizes that "the attachment of an electronic package to an animal is basic to acquiring position/location and other pertinent information. Any foreign object attached to an animal must be done with care so as not to introduce a physiologically or behaviorally unacceptable variant as such aberrations will degrade the value of any data acquired."

In order to test and evaluate various transmitter attachment methods, a combination 148 MHz and 462 MHz bird telemetry system was acquired and put into operation. Basically, it consisted of a 148 MHz system (Beaty 1972) with a UHF to VHF converter on the UHF antenna. The miniaturized transmitters weighed 2.8 g.

Four approaches to instrumenting or harnessing were tried: transmitter attachment to the tarsus (tarsometatarsus), attachment to the rectrices or tail feathers, the backpack harness (Dunstan 1972), and the backsack attachment. Each of the four methods has advantages for some species of birds, and one may be favored over the other depending on objectives.

Tail-feather Attachment. The tail-feather attachment falls off when the bird molts—both an advantage and a liability. Its operational life is limited to periods between molts, and its use is not feasible just prior to molting. Sooner or later the transmitter is dropped, and the bird is free of any encumbrance—a decided asset.

For the tail attachment a 4.3 g lithium battery (2.80 volts) was glued to the 2.8 g miniature transmitter using fast drying epoxy. Two strands of heavy dental floss (720 inches to the spool) were tied around the transmitter and knotted so as to leave eight loose ends or four ties. These were used to secure the transmitter to the two inner tail feathers. Two square knots were tied around the shaft of each feather—one above the other. The transmitter rested against the ventral surfaces of the feather shafts, and the knots were tied on the dorsal side. Prior to being placed on a bird, the transmitter dental floss wrapping and battery were covered with several coats of epoxy. While the more permanent tail attachment was being secured, either the bird was hooded or its head and eyes were covered with a stocking. This had a calming effect and minimized struggling. In some cases the task was made easier by lightly binding the bird's wings to its sides using several wrappings of cheesecloth or towel. With the bird immobilized, the transmitter was quickly tied to the two central tail feathers about 4 cm below the point of feather insertion. Each tie on both the ventral and dorsal side of the feather was epoxied—a precaution found necessary to prevent slippage. The antenna was tied to the shaft of one tail feather about 5 cm from the end of the feather. This knot also was coated with epoxy to prevent breaking or untying when picked at by the bird. The antenna length was as near ¼ wavelength as feasible but varied with the subject. Shortening the antenna length reduced operating range in proportion to the reduction. The antenna extended between 2.5 and 12.5 cm beyond the end of the tail. The whip antennas varied from 24 to 30 cm in length.

Tarsal Attachment. The tarsal attachment was prepared by cutting an unoiled pattern of leather to fit the species of bird to be instrumented. The transmitter with attached battery was epoxied to the leather. Two snaps permitted rapid attachment or removal. When the transmitter was to be kept on the bird for an extended period of time, a drop of epoxy was placed on each snap. The tarsal transmitter assembly was readily snapped on the subject's leg while the bird was sitting on the gloved hand. Hooding the hawks simplified the task.

Backpack Harness. The backpack harness as designed by Dunstan (1972), a modification of earlier such attachments, was used on Ravens (*Corvus corax*) and Golden Eagles. The transmitter, power source, and transmitting antenna were either embedded in perm dental acrylic (Hygienic Dental Mfg. Co., Akron, Ohio) or sealed in layers of epoxy to waterproof them and to prevent breakage. Neck and body straps of tubular teflon were used to form the harness. The present weight of a satellite transmitter package is in the neighborhood of 100 g. It seemed logical that weights ranging between 100-200 g could best be carried by a bird when attached to the back. The maximum package weight used on a Raven was 45 g. A wild Golden Eagle successfully carried a 180-g modified package while nesting.

Backsack Harness. Radio packages prepared as backpacks were sewn within a "backsack" made of ATV-16 Fabric (Cooley, Inc., Pawtucket, Rhode Island) or Saflag fabric (Safety Flag Co. of America, Pawtucket, Rhode Island). The backsack reduces the possibility of transmitter antenna breakage and also serves as a color marker during and after batter failure. A 59-cm neck strap and a 64-cm body strap made of 1-or 1.4-cm wide tubular teflon (ribbon style 8476, Bally Ribbon Mills, Bally, Pennsylvania) were centered and embedded into the ventral surface of the package. The straps formed a harness for use on either Bald Eagles or Golden Eagles.

The back package was placed on the material for the sack and sewn in place along the sack edges and across the harness straps with heavy dacron thread. The transmitter antenna was sewn in place (evenly spaced if more than one transmitter was used) between the material. A nylon tape no. 7407 Mil-T-5038E, Type III (Bally Ribbon Mills), was sewn along the edge of the backsack to minimize fraying and separation.

When placed on the eagle, the two ends of the neck staps were passed around the body in front of the wings, and the ends of the body straps were passed around in back of the wings. The four ends were joined at the midline of the breast. Straps and harness fit were adjusted to allow for growth of nestlings and molt and body size changes in full-grown eagles. Straps were joined with various suture material for short-term use and with pop rivets for long-term use.

The total length of the backsack was 41 cm, and the width of the portion covering the antenna(s) was 5.3 cm. The total length of the backsack varies with the length of the transmitting antenna, which is related to the transmission frequency. The 222 MHz transmitters used in this study had 30.4-cm antennas. The size of the anterior portion of the sack covering the power source varied in width from 9.5 to 10.5 cm depending on the size of the batteries used.

The weight of the backsack was related to the type of batteries used and ranged from 60 to 180 g. The theoretical transmitter lifetimes for this study were from 14 to 33 months. Some actual lifetimes are still to be determined as the work on some birds continues.

The use of solar cells to recharge transmitter batteries has been increasing and is being perfected. Solar panels kept the batteries recharged on the IRLS equipment used to track an elk (Craighead et al. 1972). They have been used successfully on turkeys (*Meleagris gallopavo*) and mule deer (*Odocoileus hemionus*) (Patton, Beaty, and Smith 1971). The antenna sheath used to prevent antenna breakage by Golden Eagles (Dunstan 1976) could readily be used to house solar cells for recharging of satellite-transmitter batteries thus assuring longer life at reduced weights.

Radio transmitter backsacks were placed on two adult female Golden Eagles, four nestling Golden Eagles, and four nestling Bald Eagles. All birds carried the backsacks well, and neither the young nor the adults showed concern for the presence of the backsack. The marked adult female Golden Eagles continued to kill prey and feed young after tagging. Golden Eagle nestlings with backsacks were fed by unmarked adults at the same rate as prior to tagging, and the adults showed no unusual behavior in relation to tagged nestlings. The Golden Eagle nestlings fledged and dispersed from the parental ranges well within the time ranges for the same activities of other unmarked young. The tagged nestling Bald Eagles were fed regularly by the unmarked parents and also fledged and dispersed from the home ranges within the time limits for other unmarked young in the study areas. The backsacks used on the adult Golden Eagles were green and those used on the nestling Bald Eagles and Golden Eagles were yellow.

Occasionally the adults and young preened the antenna portion of the sacks and the harness straps. During these preening bouts the antennas were not sharply bent, and the force of pulling was absorbed by the entire harness. The distal portion of the sack, including the antenna, sometimes slipped from the middle of the back to either side along the flank, but most of the time the sack remained toward the middle of the bird's back. The scapular feathers often covered a portion of the proximal (anterior) portion of the sack, but the distal half of the sack was visible.

Three marked eagles (two of which were marked under BLM contract 525 CO-CT 5-1013) were later captured and appeared to show no adverse affects from the tagging. One fledgling Golden Eagle wore a backsack for 11 weeks before being recaptured. A second recaptured Golden Eagle had worn a backsack for 53 days after fledging. Neither bird showed any damage to skin, feathers, or the backsack. However, both were in poor physical condition when captured. One had a case of *Trichomonas gallinae* and had lost considerable weight. The second had lost considerable weight, apparently from lack of food, but was not diseased. One nestling Bald Eagle marked with a backsack with no transmitter on 23 July 1974 was found shot in Iowa in December 1974, 624 km from the Minnesota nest site. The feathers, skin, and backsack of this bird were undamaged when examined.

Evidence indicates that the radio transmitter backsack works well on nestling, fledgling, and adult eagles. Antenna breakage is minimized, and, after the transmitter power source fails, the backsack acts as a color marker for long-term use. More than one transmitter with separate antennas can be placed in a backsack. The use of two transmitters will become important when monitoring both location and physiological parameters, such as core temperature and EKG, becomes practical. It is also possible to place a long-range, short-term transmitter for satellite tracking in combination with a shorter-range, longer-term transmitter for location from the ground in the same backsack. This combination would facilitate global location via satellite during migration, followed by short-distance ground observations for behavioral and recap ture studies.

Of the four attachments tested, the backpack and backsack harnesses appear to be the first choices for satellite feasibility experiments using the present RAMS DCP transmitter. With the RAMS transmitter, a 33-g lithium cell would provide an operating lifetime of 3.2 months (Varney and Pope 1974). An eight-month lifetime is a reasonable goal to obtain optimum results. A 99-g lithium battery pack would provide eight months of operating time. The backsack has the drawback that it is not readily dropped when the package is no longer functioning. Using materials that disintegrate (e.g., when exposed to sunshine) should permit ultimate release. This is an area for continued research.

The tail attachment proved to be quite suitable for Ravens and raptors. However, this package weighed under 10 g—transmitter 2.8 g, battery 4.3 g, harness less than 2 g. With the maximum amount of miniaturization available from present advanced technology, the RAMS transmitter could be reduced to 20 g and could conceivably be used to track Golden and Bald Eagles using the tail feather attachment. The tail assembly was received well by all subjects. After a little initial preening, the transmitter was largely ignored and had no noticeable effects on flight performance. The tarsal attachment proved largely unsuccessful for raptors as the birds often bent, twisted, and even completely broke off the whip antennas. It was quite useful and convenient for instrumenting birds for periods of tracking lasting only a few days. It should prove more useful for waterfowl, but winter use with freezing conditions would definitely present problems.

Possible Feasibility Experiments

Although further equipment development and testing will be required, we have now reached a point where we can consider various feasibility experiments with the Nimbus Satellite using a large instrumented raptor as the subject. The approximate 100-g weight of the RAMS transmitter, battery pack, and harness are well within the weight-carrying capacity demonstrated for Golden or Bald Eagles. The current weight precludes all but the backpack attachment, but this does not appear to offer any real deterrents. Whether a Bald or Golden Eagle is selected may well depend upon the time of year when experiments can be undertaken. Timing will be dependent upon a number of factors, one of which will be successful completion of fixed-position transmitter tests. Ideally, the experiment not only should demonstrate the feasibility of satellite tracking, but also should provide information not hitherto available. Three possible experiments are described briefly below.

1. The tracking of a mature or an immature Golden or Bald Eagle of the year (fledgling) from a far northern nesting site would probably provide a distant flight over a relatively short period of time.

2. Adult eagles of either species trapped and instrumented at concentration sites should provide migratory or dispersal data, but movements might be limited as compared to fall or spring migratory flights. Examples of such possibilities include instrumenting adult Bald Eagles at winter concentrations in Alaska (Seward or Juneau) or in Washington (Skagit River). Migratory patterns of these west coast eagles are not well known and lend themselves to discovery through satellite tracking (Buechner et al. 1971). Immature Golden Eagles, such as those concentrating in spring at lambing areas in Montana, could be readily trapped and instrumented. Doing so might provide information on a raptor-prey problem of economic significance. Movement might be extensive or relatively restricted, but data could be obtained on where such birds come from and where they go when they disperse.

3. Golden eagles, either young or adult, instrumented at the Snake River Birds of Prey Natural Area (Idaho) would provide information not now available on eagle migration and movement out of this intensively studied area.

When further miniaturization of the present RAMS transmitter is accomplished, other projects will be feasible, such as plotting the migratory routes of Peregrine Falcons nesting in the far north. Nesting populations of Peregrines in Alaska are definitely on the decline; chlorinated hydrocarbon pesticides picked up in wintering areas are implicated (White and Cade 1971). Some remedial measures might be possible if wintering grounds in South America could be pinpointed by satellite tracking.

Conclusion

We have treated here only the satellite tracking of birds and have limited our presentation largely to raptors. However, migratory movements can be correlated with daily weather maps and habitat delineation and evaluation can and will accompany movement studies using satellite tracking. Stopover or resting areas of migrating birds can be evaluated at to habitat preference and type. So can nesting and wintering areas. The Lansat multi-spectral imagery or U2 photographs, when accompanied by ground truth, can also be used for this purpose (Craighead 1976). Accompanying censuses of nesting and wintering concentrations is a possibility. Such information is in great demand. Further advances in technology may be needed for censuses, but once such a goal is set, progress toward achieving it will accelerate.

Acknowledgments

Previous research was supported by National Geographic Society Grant 1189 and NASA Order A-91082 A. Early work was aimed at producing a prototype transmitter capable of communicating with a Nimbus satellite and light and small enough to be carried by a large bird. Current research is being conducted under National Geographic Society grant 1636, Continued Research toward Tracking Migrating Raptors by Satellite, and a NASA-Ames Grant NSG-2157, "Assessment of Needs for Satellite Tracking of Birds and Suggestions for Expediting a Program." The authors also wish to acknowledge the collaboration and help of Joel R. Varney, Roger L. Pope, Paul Sebesta, David P. Mindell, James Berthrong, and Jana Craighead.

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RELATIVE ABUNDANCE OF NESTING RAPTORS IN SOUTHERN IDAHO

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ABSTRACT. During 1975-76 raptor surveys were conducted on 12,473 km^2 of Great Basin desert in Idaho for the purpose of incorporating raptor baseline data and management programs into land-use plans. Over 970 occupied raptor nests of 18 species were located in the Bureau of Land Management planning units. Prairie Falcons (*Falco mexicaus*) were the most numerous large raptors. Raven (*Corvus corax*)—Prairie Falcon ratios changed with alterations in land use patterns. Ravens increased in desert lands that were converted to agriculture, crested wheatgrass, or cheatgrass pastures. Comparisons of numbers of raptor nests per 100 km^2 in different areas indicate that the Snake River Birds of Prey Natural Area has exceptionally high raptor populations (217.0 occupied raptor nests per 100 km^2). All other areas surveyed averaged only 7.8 occupied raptor nests per 100 km^2.

Introduction

Since 1975 the Bureau of Land Management (BLM) has contracted for and undertaken raptor surveys on the public lands it administers in Idaho. The primary purposes of the surveys are to inventory raptor nesting habitat and to establish nesting densities. Such baseline data are incorporated into the bureau's land-use-planning and decision-making processes. Data resulting from these surveys are also used to fulfill

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seven major objectives as follows:

1. *Comply with the Endangered Species Act of 1973.* The surveys are undertaken to determine the presence or absence of Peregrine Falcons (*Falco peregrinus*) to ensure that no land actions are proposed which would adversely affect this species or its critical habitat. In addition, the surveys involve rechecking historic Peregrine sites suitable for reintroduction.

2. *Identify nesting and hunting areas utilized by sensitive raptor species.* Sensitive raptors are those which could become threatened or endangered in the foreseeable future. Currently they include Bald Eagles (*Haliaeetus leucocephalus*), Ferruginous Hawks (*Buteo regalis*), Ospreys (*Pandion haliaetus*), Prairie Falcons (*Falco mexicanus*), Merlins (*Falco columbarius*), Spotted Owls (*Strix occidentalis*), Burrowing Owls (*Athene cunicularia*), possibly one or more eastern species, and several peripheral species. Identification and management of sensitive species is consistent with the intent of the Endangered Species Act in that habitats and numbers of nesting birds should not be diminished to a point that listing them as threatened or endangered becomes necessary.

3. *Identify important raptor wintering areas.* Bald Eagles, Gyrfalcons (*Falco rusticolus*), and Rough-legged Hawks (*Buteo lagopus*) are the major species considered in this effort in southern Idaho. All these species winter in specific habitats on BLM-administered lands in southern Idaho. It is important to maintain these wintering areas, which are often neglected by both researchers and land managers; much more effort has been and is focused on nesting habitats.

4. *Identify high density or key raptor areas.* Baseline data on key or crucial areas can provide justification for placing proper constraints on agricultural development; powerline corridors; power-plant siting; mineral exploration; livestock grazing; off-road vehicle use; and development of roads, campgrounds, and trails. High densities of nesting raptors may indicate especially high environmental quality, a resource value recognized in multiple-use land-management-planning and decision-making processes.

5. *Establish criteria for buffer zones to protect raptor nesting sites.* Protection for raptors is a matter of great importance both to land managers and to the general public. Without acceptable quantifiable criteria based on field studies such as those reported in this paper, the public's advocacy for more thorough consideration of raptors and other predatory animals by land managers will be largely ineffective.

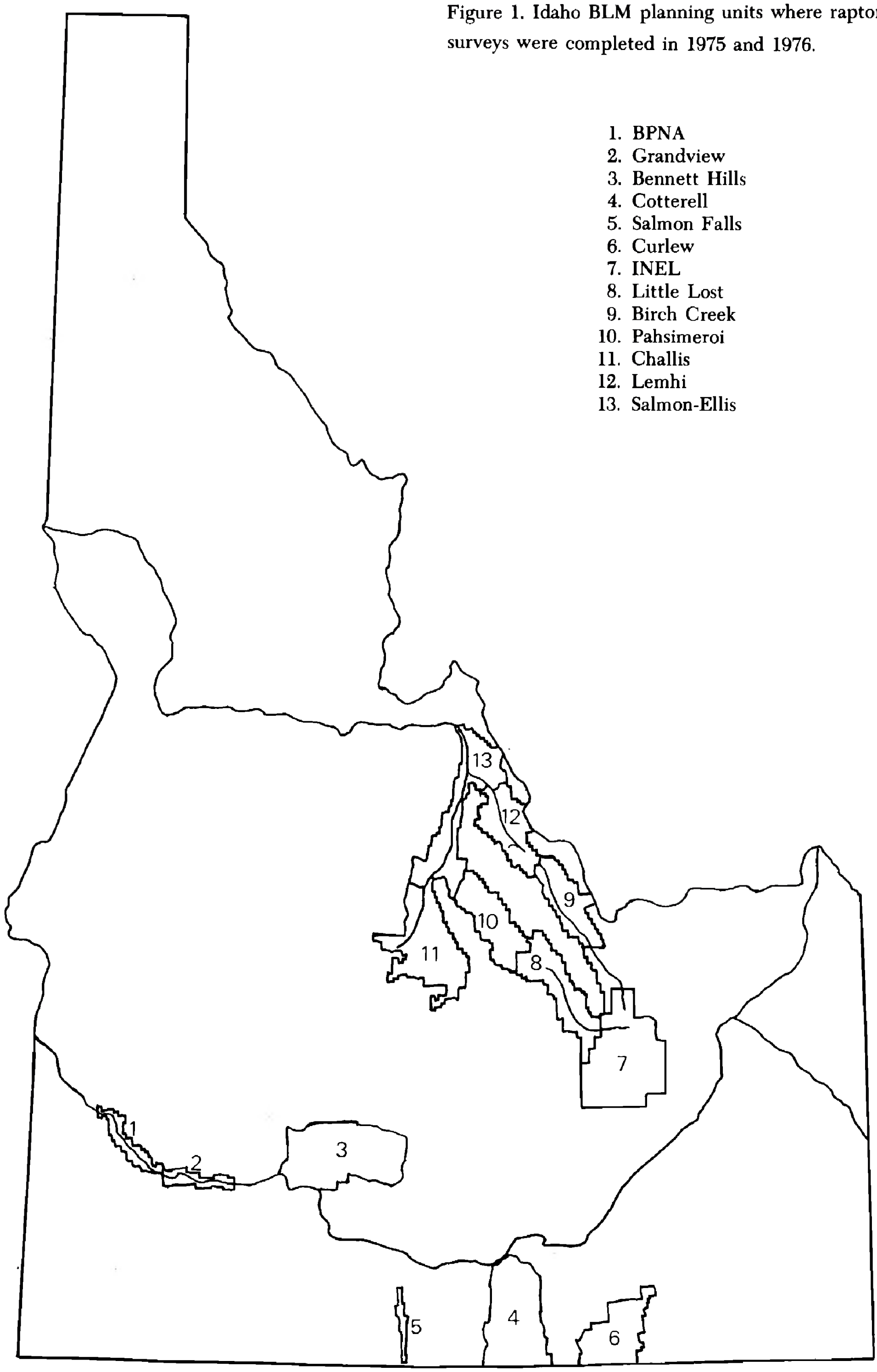
6. *Identify areas that may be suitable for raptor nesting structures or other management.* Raptor management should be conducted only when and if it is needed. As with wildlife management of any kind, there must be a thorough analysis of the advantages and disadvantages of a particular management action, such as providing raptor perching and nesting structures where the birds have not been able to perch or nest in the past. This analysis requires data of the type being collected by the BLM and reported here.

7. *Establish baseline data on raptor nesting populations.* Comparison of data to follow in this report to future survey data may give an indication of general wildlife habitat condition and/or stability. Raptor densities are proportional to the availability of suitable nesting sites and prey. Therefore, significant change in raptor nesting composition and/or density may be an indicator of prey species composition and abundance, as well as a rough measure of habitat conditions.

Figure 1 is a synthesis of raptor nesting surveys conducted on thirteen BLM planning units in Idaho during 1975-76. Focus is on efficiency of surveying methods, comparative raptor density and species diversity, and identification of nesting habitat.

Figure 1. Idaho BLM planning units where raptor surveys were completed in 1975 and 1976.

1. BPNA
2. Grandview
3. Bennett Hills
4. Cotterell
5. Salmon Falls
6. Curlew
7. INEL
8. Little Lost
9. Birch Creek
10. Pahsimeroi
11. Challis
12. Lemhi
13. Salmon-Ellis



Survey Area

Southern Idaho deserts lie within the Upper Sonoran or "cool desert" region of the United States (Odum 1959). Beginning in the mountain valleys of the Little Lost and Birch Creek valleys to the north and Raft River-Salmon Falls Creek to the south, streams here flow into the vast expanse of the Snake River plain. The plain is bisected by the sickle-curve shape of the Snake River. Within the canyons of the Snake and its tributaries are found numerous concentrations of nesting raptors.

Two other valley systems which have been surveyed integrate with the Birch Creek and Little Lost valleys in low, topographically gentle passes to form the Lemhi and Pahsimeroi rivers flowing north into the Salmon River. Altitude varies from 705 m at the Snake River Birds of Prey Natural Area (BPNA) to 2194 m at the Gilmore Summit, Birch Creek. Annual precipitation ranges from 20 cm to 65 cm, much of it occurring as snow in winter. Annual temperatures range from –32° C in January to 38° C in July.

Vegetation in the Snake and upper Salmon River drainages is characteristic of the northern desert shrub biome comprising three altitudinal delineations (Cronquist et al. 1972). The Shadscale (*Atriplex confertifolia*) Zone occurs in saline valley soils. In association with shadscale, greasewood (*Sarcobatus vermiculatus*) is found around recently flooded mud flats and in dry streambeds. Big sage (*Artemisia tridentata*), which occurs in the second major zone, the Sage Zone, is often found as a monotypic stand. Other dominant shrubs in this zone may include black sage (*Artemisia nova*) and rabbitbrush (*Chrysothamnus nauseous*). Utah juniper (*Juniperus osteosperma*) and, at higher elevations, mountain mahogany (*Cercocarpus ledifolius*) occur in the third major zone, the Juniper Zone. Extensive crested wheatgrass (*Agropyron cristatum*) seedings (486,235 ha) for livestock are found throughout the Snake and Salmon River drainages. Agricultural crops include alfalfa (*medicago sativa*), cereal grains, and tubers. Most of the farms are located in the Sage Zone.

Methods

Three survey methods were utilized in various combinations. Ground surveys were conducted on foot and with vehicles. Fixed-wing and rotary-wing aircraft were used in the most inaccessible areas.

Our primary focus was locating nest sites of large raptors, but whenever possible nest sites of small raptors were noted. Nest sites were plotted on U.S. Geological Survey 7.5-minute (1:250,000) quadrangle maps. Nests were located prior to, during, and after the breeding season. When possible, data were collected on the species, number, sex, and age of the raptors present at the nesting sites.

Results and Discussion

Data from raptor inventories can be affected by the time of year, resolution of maps, and experience of personnel. Where manpower and funding permit, a combination of fixed-wing and rotary-wing air surveys and ground surveys yields the most complete data. Comparative results of these survey methods are found in table 1. Rotorcraft are the most efficient tools; however, all three methods have limitations (White and Sherrod 1974). The optimal period for conducting surveys was mid-April through June. Nest sites were easier to locate during this period because of the presence of adults in or near the nest. Young were readily observable and were counted during the surveys, and nest desertion was kept to a minimum (Fyfe and Olendorff 1976).

Table 1. Number of raptor nests found by using ground, fixed wing, and rotary-wing survey methods (G—ground survey; F-W—fixed wing; R-W—rotary wing).

Location (planning unit)	Survey method	Season	Raptor nests/month	Survey
BPNA	G	6 Feb-July	49	Kochert et al. 1976
Grandview	G	6 Feb-July	27	Kochert et al. 1976
Bennett Hills	G, F-W, R-W	2 May-June	72	Snow 1976
Little Lost	G	3 May-July	30	Renn 1976
Salmon Falls	G	5 Feb-June	8	Trost 1976
INEL	G	5 Mar-July	9	Craig 1976
Curlew	G	6 Feb-July	7	Howard 1976
Salmon-Ellis	F-W, R-W	1 May	58	Howard 1976
Lemhi	F-W, R-W	1 May	30	Howard 1976
Cotterell	G	6 Feb-July	7	Howard 1976
Pahsimeroi	F-W, R-W	1 May	18	Howard 1976
Birch Creek	G	3 May-July	5	Renn 1976
Challis	G, F-W, R-W	1 August	11	Platt 1976

Within the thirteen BLM planning units, 972 occupied raptor nests were found during surveys conducted in 1975-76 (table 2). Many more inactive nest sites of large raptors were located on the thirteen planning units. Some were probably alternate nests, but others may have been unused because of the low density of black-tailed jackrabbits (*Lepus californicus*) (Kochert et al. 1975). For example, in 1975 in the Curlew Planning Unit, twelve nesting attempts were made by Ferruginous Hawks, a species that relies heavily on jackrabbits in many areas of the West (Howard 1975, Woffinden 1975). Eighteen successful nests were located in the same area in 1972, a year of high jackrabbit density (Howard 1975).

Comparison of the various planning units was made possible by caluculating the number of raptors per 100 km^2 (table 2). Data indicate that the BPNA has exceptionally high raptor populations, 217.0 occupied raptor nests per 100 km^2. Two major requirements for nesting raptors are present in and around the BPNA: an abundant prey base and 64 km of potential nesting cliffs. Though the Challis Unit showed the lowest raptor populations (1.0/100 km^2), these data are not a true reflection of the area, which was not surveyed until August 1975. Extrapolations were made as to raptor occupancy (Platt 1976).

Table 2. Number of occupied raptor nests per 100 km² in 13 planning units in southern Idaho, 1975-76.

Planning unit	Year	Size (km²)	No. of nests	No. of nests/ 100 km²
BPNA	1976	135	294	217.8
Grandview	1976	117	163	139.3
Bennett Hills	1976	1,147	145	12.6
Little Lost	1976	1,235	91	7.4
Salmon Falls	1975	83	58	69.9
INEL	1975	2,315	44	1.9
Curlew	1975	1,212	42	3.5
Salmon-Ellis	1976	1,352	40	3.0
Lemhi	1976	671	30	4.5
Cotterell	1975	1,585	22	1.4
Pahsimeroi	1976	878	18	2.1
Birch Creek	1976	593	14	2.4
Challis	1974	1,114	11	1.0
Totals		12,473	972	7.8

The mean number of 7.8 occupied nests/100 km² in southern Idaho is reduced to 3.7 when the BPNA and Grandview, a proposed extension of the BPNA, are excluded from the calculations (table 3). Comparison was made of the BPNA-Grandview extension to other southern Idaho planning units and study areas in Colorado (Olendorff 1975), Washington (Olendorff 1973), and Utah (Smith and Murphy 1973). Study areas in these states show a similarity in nesting density when compared to southern and north central Idaho. However, these surveys were done prior to 1975, so no direct comparison should be made. They do provide some comparative measurements of nesting densities and reflect the uniqueness of the BPNA and its proposed extension with regard to raptor productivity.

Table 3. Comparative density of raptor nests per 100 km² within the western United States.

Location	Size km²	No. of raptor nests	No. of nests/100 km²
BPNA-GV, Idaho	252	456	181.0
Southern Idaho	12,437	464	3.7
Hanford, Washington	1,036	44	4.2
Pawnee, Colorado	2,590	159	6.1
Cedar Valley, Utah	207	$\bar{x}$ = 35	16.9

Analysis of species composition indicates that the Prairie Falcon is the most numerous large raptor (table 4). Of 972 occupied nest sites, 268 (27.6 percent) were of Prairie Falcons. However, only 70 of these nests were found in eleven of the planning units; the remaining 198 (72.4 percent of the Prairie Falcons) were found in the BPNA-Grandview area. The BPNA-Grandview area may have the highest density of nesting Prairie Falcons in North America (Ogden 1972).

Table 4. Species composition of raptors found nesting in southern Idaho, 1975-76.

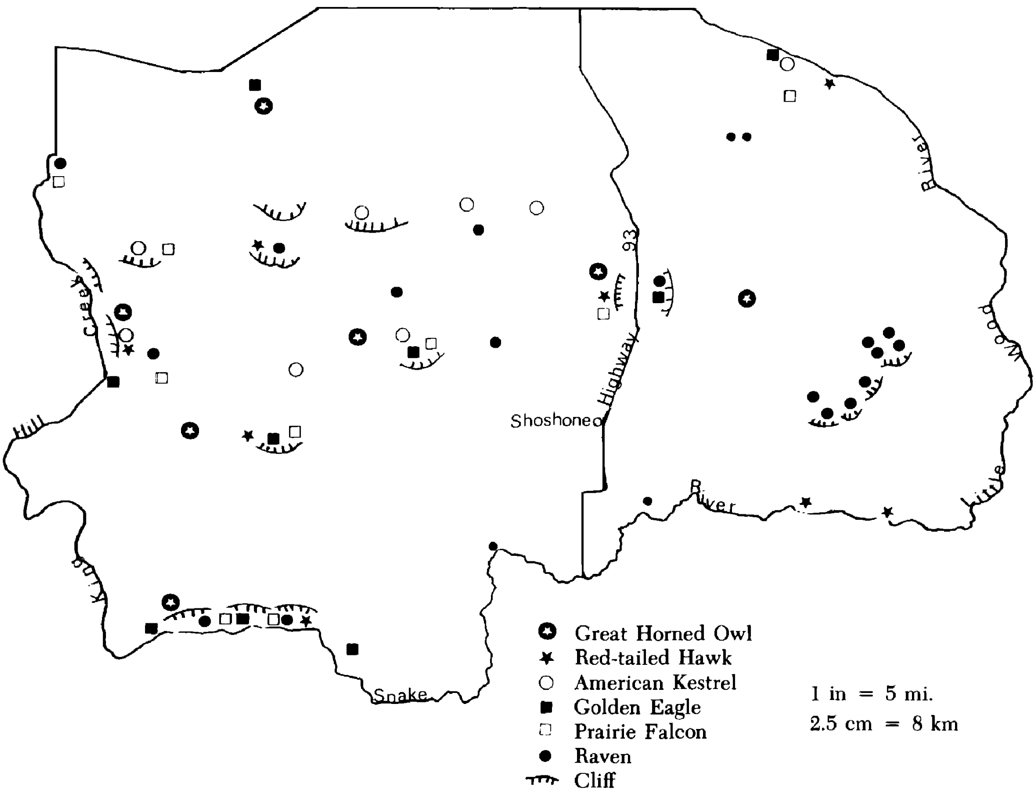
Species	Number	Percent
Golden Eagle (*Aquila chrysretos*)	101	10.4
Peregrine Falcon (*Falco peregrinus*)	1	0.1
Prairie Falcon (*Falco mexicanus*)	268	27.6
Merlin (*Falco columbarius*)	1	0.1
American Kestrel (*Falco sparverius*)	105	10.8
Ferruginous Hawk (*Buteo regalis*)	34	3.5
Red-tailed Hawk (*Buteo jamaicensis*)	140	14.4
Swainson's Hawk (*Buteo swainsoni*)	16	1.6.
Sharp-shinned Hawk (*Accipiter striatus*)	1	0.1
Marsh Hawk (*Circus cyaneus*)	37	3.8
Great Horned Owl (*Bubo virginianus*)	51	5.2
Long-eared Owl (*Asio otus*)	7	0.7
Short-eared Owl (*Asio flamneus*)	6	0.6
Screech Owl (*Otus asio*)	3	0.3
Barn Owl (*Tyto alba*)	15	1.5
Burrowing Owl (*Speotyto cunicularia*)	40	4.1
Raven (*Corvus corax*)	138	14.2
Turkey Vulture (*Cathartes aura*)	8	0.8
Total of 18 species	972	99.8

Red-tailed Hawks (*Buteo jamaicensis*) were the second most abundant raptor, comprising 14.4 percent, and were found in every planning unit. This fact seems to reflect the nesting versatility of this species.

Ravens (*Corvus corax*) were the third most numerous raptor (14.2 percent) if one assumes, as did the Craigheads (1956), that Ravens function as a raptor in an ecological framework. There seems to be a relationsip between undisturbed habitat (i.e., areas not treated extensively with crested wheatgrass) and the ratio of nesting Ravens and Prairie Falcons. From the combined surveys Ravens represented 14.2 percent of the nesting raptors, and Prairie Falcons represented 27.6 percent. This pattern—more Prairie Falcons than Ravens—held true in most of the western planning units. In areas where farming was intensive or where an abundance of cheatgrass or crested wheatgrass was found, Ravens equaled or reversed the ratio.

The dependence of nesting patterns on substrate becomes evident when a composite is developed from a survey. For example, in the Bennett Planning Unit, nests showed a distribution along canyons and rock outcrops (fig. 2). Only a few nests were discovered in trees and on power poles, and none were on the ground. Some clumping of nests was found, probably because of prominent rock outcrops, or simply, under other circumstances, because the canyon rock was the only nesting substrate available. When nesting distributions are analyzed in this way, the land manager has better justification for protecting nest sites with buffer zones or other management considerations.

Figure 2. Raptor nest sites in the Bennett Hills Planning Unit.



Acknowledgments

We gratefully acknowledge the assistance of the BLM district office managers and their staffs while we were conducting these surveys. We also thank those persons who contributed unpublished data and field expertise. They include the following: Dr. Charles Trost, Michael Kochert, Al Bammann, Scott Sawby, Tom Smith, John Doremus, Mike Delate, Carol Snow, and Sue Young.

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