J. Field Ornithol., 61(2):201–211

SIZE OF FALL-MIGRANT ACCIPITERS FROM THE GOSHUTE MOUNTAINS OF NEVADA

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Abstract.—Over 5000 Sharp-shinned Hawks (*Accipiter striatus*), Cooper's Hawks (*A. cooperii*), and Northern Goshawks (*A. gentilis*) were trapped and measured during fall migration on the Goshute Mountains of eastern Nevada from 1980 through 1987. Western accipiters, particularly Cooper's Hawks and Northern Goshawks, have significantly different measurements from those of eastern North America. Therefore, regional criteria should be used to identify species and sexes. Previously published criteria reliably identify eastern accipiters. We provide new criteria that accurately identify accipiters from the Rocky Mountains westward. Culmen and hallux-claw lengths separate species and sexes, and may be the most reliable measurements to use year-round. Data from the Goshute Mountains confirm that immature accipiters weigh less and have shorter wings and longer tails than adults. Immature accipiters also have shorter culmens and hallux claws, and age-dimorphism for tarsus width is significant, but the interspecific pattern is mixed. Age-specific sexing criteria account for these differences.

TAMAÑO DE MIGRANTES OTOÑALES (ACCIPITRINAE) DE LAS MONTAÑAS GOSHUTE, NEVADA

Sinopsis.—De 1980–1987 mas de 5000 individuos de *Accipiter striatus, A. gentilis* y *A. cooperii* fueron atrapados y medidos en las Montañas Goshute (Nevada) durante la migración otoñal de estas aves. Los accipiteres del oeste particularmente los Halcones de Cooper y *A. gentilis* resultaron (en medidas) ser diferentes a las aves del este de Norteamerica. Por lo tanto se deben utilizar criterios regionales para identificar estas especies y entre sus sexos. Previo a este trabajo se utilizaron criterios confiables para identificar los Accipitrinae del este. Proveemos nuevos criterios para identificar con presición accipiteres al oeste de las Rocallosas. El largo del culmen y halux-garra permite separar las especies y los sexos, y parecen ser los criterios más confiables a utilizarse a través del año. Los datos obtenidos en las Montañas de Goshute confirman que los inmaduros pesan menos y tienen alas más cortas y rabos más largos que los adultos. Los accipiteres inmaduros tienen además culmen y halux-garra más cortos y el dimorfismo por edad para el ancho del tarso es significativo, pero el patrón interespecífico es mixto. Criterios asociados a la edad-sexo son responsables de estas diferencias.

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Criteria used by researchers to identify and sex Sharp-shinned Hawks, *Accipiter striatus,* Cooper's Hawks, *A. cooperii,* and Northern Goshawks, *A. gentilis,* have been controversial. Measurements recently collected in the Goshute Mountains of Nevada and in the Marin Headlands of California reveal significant east-west size differences, particularly among Cooper's Hawks (Smith et al. 1990; also see Henny et al. 1985). The Canadian Wildlife Service (CWS) and United States Fish and Wildlife Service (USFWS) raptor age-sex key (1980) is commonly used by banders to identify accipiters, but these criteria are largely based on size data from eastern North America (Brown and Amadon 1968; Mueller et al. 1976, 1979, 1981a; Storer 1966; and unpubl. data from Cape May Point, New Jersey). The CWS and USFWS criteria and those presented in Mueller et al. (1976, 1979, 1981a) do not accurately identify some accipiters trapped in western North America. In this manuscript we discuss mensural data collected from over 5000 accipiters trapped during fall migration on the Goshute Mountains of Nevada in 1980–1987, and provide criteria that accurately identify and sex accipiters from the Rocky Mountains westward.

STUDY AREA AND METHODS

The research site.—The Goshute Raptor Migration Research Project site is located at the southern end of the Goshute Mountain range of eastern Nevada (2745 m elev.), 200 km west of Salt Lake City, Utah. The Goshutes form an isolated, 100 kilometer-long, north-south ridge along the west edge of the Great Salt Lake Desert. Pinyon (*Pinus monophylla*) and juniper (*Juniperus osteosperma*) dominate the lower slopes, with white fir (*Abies concolor*) and limber pine (*Pinus flexilis*) dominant at higher elevations. The site and the associated research activities are described in more detail in Hoffman (1985). Trapping, banding, and observing of migrants occurs from late August through late October each year.

Measurements.—Unflattened wing chord, standard and uropygial tail length, exposed culmen length, hallux claw length, tarsus length and width, and weight were recorded for each migrant. Uropygial tail length was measured with a ruler from the caudal base of the uropygial gland to the tip of the longest rectrix. Standard tail length was measured by sliding a ruler between the center rectrices to their point of insertion, and sighting across the tip of longest rectrix. Wing chord was measured with a standard wing chord ruler. Tail lengths and wing chord were recorded to the nearest 1 mm. Other measurements were taken according to Baldwin et al. (1931) and recorded to the nearest 0.1 mm using dial calipers. Weight was recorded from a triple beam balance to the nearest 0.1 g; only weights for hawks with empty crops were analyzed. Tarsus width measurements were collected only in 1987. Other 1987 data were for Northern Goshawks.

When personnel/hawk ratios were low, fewer measurements were taken to reduce the time each hawk was held captive. Sample sizes for

each measurement varied accordingly. From one to three trapping and processing blinds were operated throughout each season, and measurements were made by many different individuals, primarily volunteers. Although each person was carefully trained to maximize uniformity of technique, some variation was unavoidable.

Species identification, aging, and sexing.—Species were identified using relative size and plumage characteristics (Clark and Wheeler 1987, Smith 1988a). The measurement criteria discussed below could also be used. Hawks were aged according to plumage characteristics described in Mueller et al. (1976, 1979, 1981a) and were separated into four age groups: hatching-year, second-year, after-hatching-year or adults of unknown age, and after-second-year. However, means for the three adult age groups rarely differed significantly, so for this presentation only two age groups were recognized: hatching-year (HY) or immature hawks with all brown plumage, and after-hatching-year (AHY) or adults more than one year old with mostly gray plumage.

The sex of each hawk was subjectively determined from relative size and plumage characteristics (Smith 1988a). However, because these subjective criteria are fallible, we carefully examined stem-leaf and normal probability plots (Wilkinson 1986) of each variable, with hawks separated by age and their subjectively determined sex. We then decided whether any individual was consistently aberrant (i.e., for more than one variable) when classified in this way. If so, we assumed an error had been made and the individual was assigned to the alternate sex. Few hawks (<1%) were reclassified by this method. If a hawk was unusual for one measurement, but all other measurements fell within the normal range for its sex, we assumed a recording error had been made and the aberrant value was deleted from further analyses. The resulting distributions (for each measurement, for each species-sex-age group) closely resembled normal curves. Summary statistics were calculated from the adjusted data using SYSTAT (Wilkinson 1986). The *t*-test was used to compare contrasting means and identify significant ($P < 0.05$) age and sex dimorphism. Sexing criteria for each age group were then calculated according to Mueller et al. (1976). The confidence levels associated with these criteria were derived from Rohlf and Sokal (1981), and reflect the percentage of the total normal population that will be included within the calculated limits.

RESULTS AND DISCUSSION

Measurements.—We found that uropygial tail length was less subject to measurement error and more reliable for differentiating the sexes than the standard tail length measurement. Therefore we discuss only uropygial tail length in this paper; however, we included summary statistics in Table 1 to facilitate regional comparisons (Smith et al. 1990). Similarly, tarsus measurements did not differentiate the species or sexes, but were useful in regional comparisons (Smith et al. 1990) and age dimorphism

TABLE 1. Measurements of accipiters trapped on the Goshute Mountains of Nevada from 1980–1987.[a]

Measure	Age	Sharp-shinned Hawk		Cooper's Hawk		Northern Goshawk	
		Male	Female	Male	Female	Male	Female
Weight (g)	HY	96.3 ± 7.08[b] 71.7–127.5[c] 714[d]	159.8 ± 10.64 127.2–193.6 427	268.7 ± 21.69 215.0–335.2 183	398.6 ± 36.17 305.8–499.7 310	748.1 ± 45.51 673.5–826.9 26 *	941.9 ± 77.68 800.0–1079.3 48 NS
	AHY	101.7 ± 6.28 86.1–121.8 175	170.5 ± 10.50 143.5–198.8 298	281.0 ± 19.06 230.0–340.8 177	439.2 ± 34.58 348.8–541.3 416	797.3 ± 47.29 723.0–876.4 8	966.9 ± 69.32 866.1–1107.5 20
Wing chord (mm)	HY	171.1 ± 3.62 161–181 901	203.8 ± 4.32 190–218 860	223.6 ± 5.27 209–238 317 **	253.5 ± 6.03 238–269 444	324.8 ± 8.05 303–337 37 NS	357.7 ± 9.06 340–376 57 NS
	AHY	174.0 ± 3.59 164–183 264	205.7 ± 4.33 195–218 524	224.7 ± 5.26 209–238 287	256.1 ± 6.00 238–271 545	327.0 ± 6.63 313–335 15	356.6 ± 7.75 340–377 31
Standard tail length (mm)	HY	136.4 ± 4.28 123–148 475 *	161.3 ± 5.05 146–177 537	189.9 ± 6.41 171–205 194	214.4 ± 7.04 200–230 286	243.2 ± 8.10 223–255 20	280.7 ± 8.24 263–295 40
	AHY	134.4 ± 4.40 124–145 94	160.2 ± 5.32 145–175 204	181.3 ± 6.68 166–199 128	209.3 ± 6.56 195–225 285	226.9 ± 11.15 212–241 7	269.3 ± 5.45 259–277 12
Uropygial tail length (mm)	HY	145.3 ± 4.09 135–157 806 *	172.0 ± 4.96 154–190 767	202.0 ± 5.25 190–217 294	228.8 ± 6.48 212–246 409	257.5 ± 7.99 238–274 36	296.4 ± 7.23 282–313 52
	AHY	144.7 ± 4.25 133–154 253	170.6 ± 4.84 159–184 485	195.0 ± 5.75 181–210 249	223.7 ± 6.25 208–243 523	245.7 ± 8.34 232–263 15	284.5 ± 6.96 274–306 31
Culmen length (mm)	HY	9.8 ± 0.39 8.5–11.2 478	11.9 ± 0.45 10.6–13.2 505	14.8 ± 0.51 13.5–16.3 246	17.4 ± 0.62 15.8–19.3 374	20.9 ± 0.66 19.5–22.5 33	23.4 ± 0.74 21.7–24.9 53

TABLE 1. Continued.

Measure	Age	Sharp-shinned Hawk		Cooper's Hawk		Northern Goshawk	
		Male	Female	Male	Female	Male	Female
	AHY	10.1 ± 0.43	12.6 ± 0.48	15.3 ± 0.58	18.3 ± 0.70	21.9 ± 0.49	24.3 ± 0.74
		9.2–11.3	11.2–13.9	13.7–16.9	16.5–20.4	20.8–22.4	23.0–25.5
		154	272	212	447	11	23
Hallux claw length (mm)	HY	11.3 ± 0.45	14.4 ± 0.53	18.8 ± 0.71	22.2 ± 0.80	27.4 ± 0.86	30.8 ± 0.92
		10.0–12.5	12.6–16.0	17.0–20.7	20.0–25.0	25.9–29.2	28.6–32.9
		484	504	250	389	33	53
						NS	NS
	AHY	11.6 ± 0.43	14.8 ± 0.52	19.1 ± 0.73	22.9 ± 0.90	27.7 ± 0.88	31.2 ± 1.22
		10.5–12.8	13.3–16.2	17.3–21.6	19.8–25.5	26.0–28.6	29.5–33.1
		153	267	220	467	11	23
Tarsus width (mm)	HY	3.5 ± 0.22	4.4 ± 0.29	5.5 ± 0.28	6.7 ± 0.30		
		2.9–4.0	3.6–5.1	4.9–6.2	5.9–7.4		
		185	152	90	73	8.2 ± 0.36[e]	9.5 ± 0.45[e]
		*	NS	*	*	7.8–8.9	8.5–10.1
	AHY	3.4 ± 0.28	4.4 ± 0.32	5.6 ± 0.37	6.8 ± 0.42	10	15
		2.8–4.0	3.5–5.0	4.8–6.4	5.8–7.8		
		99	163	45	102		
Tarsus length (mm)	ALL[f]	50.2 ± 1.66	56.6 ± 2.09	62.3 ± 2.34	68.3 ± 2.52	74.0 ± 2.83	78.9 ± 2.40
		45.7–54.6	47.4–63.0	55.2–69.2	62.0–74.9	69.0–79.7	74.5–84.6
		501	664	470	838	45	69

[a] All HY/AHY (within a sex) and male/female (within an age) means differ significantly (t-test, $P < 0.001$), unless indicated by NS (nonsignificant $P > 0.05$), * (significant $P < 0.05$), or ** (significant $P < 0.01$).
[b] Mean ± SD.
[c] Range.
[d] n.
[e] Insufficient sample sizes precluded separation of age groups.
[f] There were no significant age differences ($P > 0.05$).

for tarsus width was significant. Again, we included summary statistics to provide a single, comprehensive reference for measurements of Goshute migrants.

Species identification.—Sharp-shinned Hawks from the Goshutes—with empty crops—weighed less than 200 g; Cooper's Hawks weighed between 200 and 600 g; goshawks weighed more than 600 g (Table 1). However, these criteria should only be used during fall months, because weight may vary seasonally (Henny et al. 1985). Unlike migrants from Cedar Grove, Wisconsin (Mueller et al. 1979, 1981a), wing chord measurements from the Goshutes overlapped between Sharp-shinned and Cooper's hawks (see comment in Clark and Wheeler 1987, p. 40). However, 97% (586 of 604) of the male Cooper's Hawks measured at least 215 mm, whereas over 98% (1367 of 1384) of the female Sharp-shinned Hawks measured less than 215 mm. Wing chord easily separated Cooper's Hawks (<275 mm) from goshawks (>300 mm), and culmen and hallux claw lengths generally separated all the species on the Goshutes (see Table 1).

Weight, wing chord, and standard tail length measurements of fall migrants from Cedar Grove did not overlap between the species (Mueller et al. 1976, 1979, 1981a). Among Goshute migrants, however, only weight and hallux claw length did not overlap between female Sharp-shinned and male Cooper's hawks, and tail and tarsus measurements overlapped between female Cooper's Hawks and male goshawks (Table 1). Measurement error might have caused some of the added variation in the Goshute data; the coefficient of variation (SD/mean) for measurements taken at Cedar Grove was consistently less than for Goshute measurements. However, this was true for weight (less subject to measurement error) as well as for wing chord and tail length, suggesting there might have been more natural variation in the Goshute samples.

The Goshute migrants may originate from a larger and more diverse area than the Cedar Grove migrants. The Goshute project site is situated more than 300 km south of Cedar Grove and probably draws from a larger segment of the northern breeding population. In addition, the diversity of potential nesting habitats available to accipiters north of the Goshute flyway is much higher than is available north of Cedar Grove. The former range from the xeric, open forests of the northern Great Basin, through the moist forests of the northern Rocky Mountains, to the mesic and dense, temperate rainforests of the Pacific Northwest. Ecologically-adaptive variation in size or proportions may therefore be greater among the breeding populations that use the Goshute migration corridor.

Age-related size variation.—Immature Sharp-shinned and Cooper's hawks weigh significantly less and have shorter wings, but longer tails than adults (Table 1; Mueller et al. 1979, 1981a). Generally, the same is true for goshawks (Table 1; Mueller et al. 1976), but wing chord in females may be an exception among Goshute migrants (larger samples will be necessary to confirm either a regional trend or statistical anomaly). These adaptations may reduce the energetic cost of flight and enhance maneuverability for young hawks as they learn to hunt (Amadon 1980;

Mueller et al. 1976, 1981b). Immature accipiters of all species-sex groups from the Goshutes also had shorter culmens and hallux claws than adults (Table 1). Delayed growth of these structures may help reduce the weight of young accipiters, or may help minimize drag and make flight easier. Immature Golden Eagles (*Aquila chrysaetos*) also have shorter culmens and hallux claws than adults (Bartolotti 1984).

Age dimorphism for tarsus length was insignificant in all cases, a logical result since elongation of bird bones is a determinant process completed around fledging time (Brown and Amadon 1968). Insufficient sample sizes for tarsus width precluded analyses of age-dimorphism among goshawks. Otherwise, adult male Sharp-shinned Hawks averaged significantly narrower tarsi, whereas adult Cooper's Hawks of both sexes averaged significantly wider tarsi. Averill (1920) documented a negative correlation between migration distance and foot/leg size among certain passerines. Post-juvenile selection for lighter, drag-reducing feet and legs may be stronger among Sharp-shinned Hawks, particularly males, since they regularly migrate the longest distances (Bent 1937, Brown and Amadon 1968). The larger species tend to take more mammalian and ground-dwelling prey (Reynolds and Meslow 1984, Storer 1966, Snyder and Wiley 1976). Post-juvenile selection for thicker, stouter tarsi may therefore be more pronounced among Cooper's Hawks and goshawks to accommodate higher impact attacks and the handling of stronger prey.

Sexing criteria.—The sex of all Goshute Sharp-shinned Hawks was unambiguously determined using either wing chord or hallux claw length (Table 2). Weight and uropygial tail length were as reliable for separating the adults. In other cases, culmen length, weight, and uropygial tail length were associated with confidence levels of at least 98.8% and could be used as secondary criteria. The same measurements proved useful for sexing Cooper's Hawks, but the associated confidence levels were generally lower and classification errors more frequent (Table 3). Wing chord was consistently the most reliable discriminator (confidence level >99% for both age groups; 3 of 5 ambiguous cases fell on the dividing line), but weight proved the best criterion for sexing adults. Other criteria resulted in between 4 and 14 classification errors per sex-age group, with confidence levels of at least 97.5%. Mueller et al. (1981a) also found that weight and wing chord were better measurements than tail length for sexing Cooper's Hawks.

Tail length was associated with the highest confidence levels for sexing both Goshute (Table 4) and Wisconsin goshawks (Mueller et al. 1976), wing chord generally ranking second. Culmen length and hallux claw length also resulted in error-free classifications of Goshute adults, but were associated with lower confidence levels and were less reliable for sexing immature birds. Weight could be used also as an additional criterion, but the zone of overlap was significant. Goshawk sample sizes from the Goshutes were often small (<30), particularly for adults; we therefore recommend that these criteria be used with caution until additional data are collected. It is clear, however, that east-west size dif-

TABLE 2. Sexing criteria for Sharp-shinned Hawks from the Rocky Mountains westward.

Measurement	Age	Division: male less than; female more than	Confidence level (%)	Incorrectly : correctly identified	Observed overlap
Weight (g)	HY	121.7	>99.9	3:1138	127.2–127.5
	AHY	127.4	100	0:473	—
Wing chord (mm)	HY	186	100	0:1761	—
	AHY	188	>99.9	0:788	—
Uropygial tail length (mm)	HY	158	99.7	4:1569	154–157
	AHY	157	99.6	0:738	—
Culmen length (mm)	HY	10.8	98.8	11:972	10.6–11.2
	AHY	11.3	99.4	3:423	11.2–11.3
Hallux claw length (mm)	HY	12.6	99.8	0:988	—
	AHY	13.0	>99.9	0:430	—

ferences are significant (Smith et al. 1990) and that published criteria are inadequate for identifying some western goshawks.

CONCLUSIONS AND RECOMMENDATIONS

Since east-west size differences are pronounced among fall-migrant Cooper's Hawks and Northern Goshawks (Smith et al. 1990), sexing and species identification criteria must account for regional size differences. We suggest that the criteria presented here be used from the Rocky Mountains westward, and that the CWS and USFWS (1980) raptor age-sex key and the criteria provided in Mueller et al. (1976, 1979, 1981a) be used in eastern North America. Size variation among Sharp-shinned Hawks is less pronounced (Smith et al. 1990) and regional criteria are therefore of less concern. Banders also should remember that coastal and inland migrants differ in size (Smith et al. 1990), but such differences

TABLE 3. Sexing criteria for Cooper's Hawks from the Rocky Mountains westward.

Measurement	Age	Division: male less than; female more than	Confidence level (%)	Incorrectly : correctly identified	Observed overlap
Weight (g)	HY	317.4	97.6	4:489	305.8–335.2
	AHY	337.2	99.7	0:589	—
Wing chord (mm)	HY	238	99.2	4:757	238
	AHY	239	99.5	1:831	238
Uropygial tail length (mm)	HY	214	97.7	7:696	212–217
	AHY	209	98.3	7:765	208–210
Culmen length (mm)	HY	16.0	97.9	9:611	15.8–16.3
	AHY	16.7	98.1	7:652	16.5–16.9
Hallux claw length (mm)	HY	20.4	97.6	12:627	20.0–20.7
	AHY	20.8	98.0	14:673	19.8–21.6

TABLE 4. Sexing criteria for Northern Goshawks from the Rocky Mountains westward.

Measurement	Age	Division: male less than; female more than	Confidence level (%)	Incorrectly: correctly identified	Observed overlap
Weight (g)	HY	819.7	88.4	7:67	800.0–826.9
	AHY	866.1	85.3	2:26	866.1–876.4
Wing chord (mm)	HY	340	94.5	0:94	—
	AHY	341	96.1	0:46	—
Uropygial tail length (mm)	HY	278	99.0	0:88	—
	AHY	267	98.9	0:46	—
Culmen length (mm)	HY	22.1	92.7	3:83	21.7–22.5
	AHY	22.9	94.9	0:34	—
Hallux claw length (mm)	HY	29.0	94.3	3:83	28.6–29.2
	AHY	29.2	90.5	0:34	—

should rarely complicate identification. In addition, resident Cooper's Hawks from Arizona and New Mexico may average larger—contrary to Bergmann's Rule—or at least have longer wings and tails than their northern relatives (Brian Millsap, pers. comm.). Larger overall size would be adaptive for securing larger, ground-dwelling prey which may be more prevalent in the desert Southwest, and also would facilitate water conservation and evaporative cooling (James 1970). Proportionately longer wings and tails would be adaptive for exploiting the open woodlands of the desert Southwest (Smith et al. 1990). Regardless, until more data are accumulated banders working in this area should use these and other identification criteria with caution.

The identification of species and sexes should always be based on several measurements. Feather wear can significantly alter wing and tail measurements (Smith 1988b), and in fall and especially winter aberrantly thin hawks, particularly young ones, are sometimes encountered. Accurate determinations then depend on examination of additional measurements. Claws and beaks, where wear is generally balanced by growth, should remain approximately the same length throughout the year. Since culmen and hallux-claw lengths generally distinguish the species and sexes of western accipiters, they may be the best measurements to use consistently. We encourage banders to gather more of these measurements to facilitate additional comparisons. Degree of sexual size dimorphism is inversely correlated with size among accipiters (Mueller et al. 1981a, Snyder and Wiley 1976, Storer 1966, and evident in Table 1), except that Goshawks are more sexually dimorphic than Cooper's Hawks for tail length (Mueller et al. 1981a, and evident in Table 1). Thus, it is particularly important to examine several measurements when sexing goshawks.

Finally, age dimorphism can be significant among accipiters and, although the differences are not always great, sexing criteria should reflect the differences.

ACKNOWLEDGMENTS

The U.S. Bureau of Land Management, Elko District, provided helicopter support for the Goshute Project each year. We are especially indebted to Kurt Ballantyne and Roy Price for their unflagging support and assistance. Financial support for the project from 1983–1985 was provided by a grant from EARTHWATCH and the Center for Field Research. In 1987, the project was funded by the Western Foundation for Raptor Conservation, Inc., through individual contributions and grants from: National Fish and Wildlife Foundation, George Whittell-Nevada Environmental Fund, Lahontan and Red Rock Audubon Societies, and the Hawk Migration Association of North America. We also extend our deepest thanks to the many volunteers who contributed time and energy to the project. Earlier drafts of this manuscript were reviewed by Keith Dixon, Ivan Palmblad, Donald Sisson, Patricia Kennedy, Ken Meyer, Mike Collopy, Buzz Hull, Allen Fish, Brian Millsap, Ruthe Smith, Sidney Gauthreaux, Jr., and C. Stuart Houston. We thank them for their advice and assistance.

This paper is Contribution No. 7 of the Western Foundation for Raptor Conservation, Inc., and is a redraft of half of the first chapter of JPS's MS Thesis.

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Received 15 Dec. 1988; accepted 24 Oct. 1989.

NOTES AND NEWS

HAWK MOUNTAIN–ZEISS RAPTOR RESEARCH AWARD

The HAWK MOUNTAIN SANCTUARY ASSOCIATION jointly awarded the 1990 Hawk Mountain-Zeiss Raptor Research Award to Eduardo E. Iñigo Elias at the University of Florida and Karen L. Wiebe at the University of Saskatchewan. Iñigo's project is entitled "Effects of forest fragmentation on a tropical raptor community in the biosphere reserve of "Montes Azules" in the Lacandona region of Chiapas, Mexico" and Wiebe is studying "The effect of food supply on reproductive decisions and success in the American Kestrel."

The Hawk Mountain Sanctuary Association is now accepting applications for its fourteenth annual award to support student research on birds of prey. Support for this award is provided by Carl Zeiss Optical, Inc. Up to $2000 in funds are available and will be awarded to one or two recipients. To apply, a student applicant should submit a brief description of his or her research program (five pages maximum), a *curriculum vitae*, a budget summary including other funding anticipated, and two letters of recommendation to DR. JAMES C. BEDNARZ, *Hawk Mountain Sanctuary Association, Rte. 2, Kempton, Pennsylvania 19529, USA*. The deadline for applications is **15 November 1990**. The Association's board of directors will make a final decision in February 1991. Only undergraduate and graduate students in degree-granting institutions are eligible to apply. The awards will be granted on the basis of the project's potential to improve understanding of raptor biology and its ultimate relevance to the conservation of raptor populations. Applications from anywhere in the world will be considered.