Forty-five years of Fall Banding at Little Gap Raptor Banding Station, Danielsville, PA: Summary of Captures and Morphological Measurements of Raptors

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ABSTRACT

The Little Gap Raptor Banding Station in Danielsville, PA, is located along the Kittatinny Ridge and has been in operation since 1974. Every fall raptors have been banded there at two locations using baited mist nets and a bow trap. In this study, we summarized birds banded at Little Gap from 1974-2018 by year and species and quantified raptor morphological measurements by sex and age for the ten most commonly captured species using data from 1978-2018. A total of 14,766 individual raptors was banded during the study period with an average of 328 raptors per year. The majority of birds banded were, in descending order: Sharp-shinned Hawk (Accipiter striatus)*, Red-tailed Hawk* (Buteo jamaicensis)*, and Cooper's Hawk* (Accipiter cooperii)*. For all species examined, females were heavier, had longer wings, and had longer tails. This confirms the well-known reversed sexual size dimorphism found in these raptors. By comparison, age-based dimorphism was not as uniform across these ten species. Adults of most species, except Merlin* (Falco columbarius) *and Peregrine Falcon* (Falco peregrinus)*, were heavier than hatch-year birds. Adult Sharp-shinned Hawk, Cooper's Hawk, and Red-tailed Hawk had significantly longer wing chords than hatch-year birds, whereas, hatch-year Sharp-shinned Hawk, Cooper's Hawk, Red-tailed Hawk, and female Peregrine Falcon had longer tails than adult birds. These patterns largely matched those previously documented by age. However, this appears to be the first documentation of adult Red-shouldered Hawks* (Buteo lineatus) *(and American Kestrel* (Falco sparverius) *with a heavier mass than hatch-year birds. Overall, raptors captured at Little Gap tended to match the measurements of birds captured at other eastern or coastal banding stations with a larger body mass and shorter wing chord and tail length than birds captured at inland western and central banding stations.*

INTRODUCTION

Raptors have been banded in the United States and Canada for over 100 years (Robbins 1986). Although some raptors are banded as nestlings, most raptors are captured and banded as adults during migration at stations designed specifically for this purpose (Bildstein and Peterjohn 2012). These banding stations are located strategically along migration corridors that act as a boundary or funnel where large concentrations of migratory birds occur (Bildstein 2006). Despite technological advances in tracking bird movements, banding data still remains the forefront in understanding the details of raptor migration routes and distances (e.g., Goodrich et al. 2012), and has expanded into understanding population demographics. Through the use of banding data and encounter data (when the bird originally banded is re-captured or re-sighted), migration movements can be monitored, better management practices can be implemented on hunted species, and a better understanding of overall avian behavior can be gained (Bildstein and Peterjohn 2012). Thus, banding stations provide critical information about raptor behavior and ecology for conservation efforts.

The Kittatinny Ridge in the eastern United States is an important site for raptor research that involves migration counts and banding. This ridge extends from Pennsylvania through the northwestern corner of New Jersey into New York. The 185 miles that extend across Pennsylvania form the most eastern ridge of the Appalachian Mountains (Goodrich 1999). The ridge forms a leading line of the Atlantic flyway zone used by a large majority of eastern migratory raptors. Due to the large number of migrants utilizing this flyway, the Kittatinny Ridge has been designated an "Important Bird Area" in Pennsylvania and North America (Chipley 1999). Because of this important location, raptors are counted from several hawk watch monitoring stations along the ridge. Hawk Mountain in Kempton, PA, is the most well known of these stations where every fall approximately 18,000 raptors are counted as they migrate south along the ridge (Bildstein 2006). Thus, the Kittatinny Ridge is an ideal area for studying raptor migration. Although raptors have been monitored through observation counts at many sites along the ridge, there have been fewer raptor banding stations here.

Raptor banding during fall migration on the Kittatinny Ridge in Pennsylvania was initiated in the 1950s when Chester Robertson and Jack Holt launched a regular banding operation east of Hawk Mountain. Since that time, the number of stations has ranged from two to seven sites with some operated sporadically by one or two individuals. From the late 1970s through to mid-1990's, at least five stations operated fairly consistently in the Wind Gap, Little Gap, Lehigh Furnace, and Leaser Lake areas in Lehigh County. Two to three occasional sites were operated on the ridge from areas near Shartlesville in Berks County to Harrisburg in Dauphin County. Finally, from 1987 to 1999, another consistently manned site was operated at Tri-county Corners east of Hawk Mountain in Berks County. However, the only site with annual, long-term and consistent weekly coverage is the Little Gap Raptor Banding Station (LG, pers. obs.).

The Little Gap Raptor Banding Station is located along the eastern part of the Kittatinny Ridge in Pennsylvania. Raptors have been banded here annually since 1974. However, there has been minimal analysis of the extensive banding data from this station. Therefore, the objectives of this study were to (1) provide an overview of fall banding at the Little Gap Raptor Banding Station, (2) summarize numbers of raptors banded in fall by year and species, and (3) quantify the morphology of the ten most commonly captured raptor species by sex and age class.

METHODS

Study Area and Data Collection

The Little Gap Raptor Banding Station is located on Pennsylvania State Game Lands Number 168 near Danielsville, Northampton County, Pennsylvania (40°47'N, 75°31'W), approximately 26 miles northeast of Hawk Mountain Sanctuary. The station has been operating since 1974; however, measurement data were only available from 1978-2018. The banding station originally consisted of one blind, known as North Blind, but expanded to two blinds, a North and South Blind, in the mid 1970s. The original station was operated by master permittee Tom Mutchler and several volunteers from Hawk Mountain Sanctuary. Tom was responsible for training the original group of banders, which included current master bander Gerald Lahr. Since 1978, any new banders joining the station were trained and mentored by the entire group. Currently, Gerald Lahr holds the master permit for the station and has five other sub-permitees who help run the station during migration. These banders have dedicated approximately 40 hours per week to capturing and banding diurnal raptors during the fall migration period (late August through the end of November) at both North and South blind locations. Occasional banding occurred during spring migration, but these spring efforts have not been systematic or continuous over the full years the station has been in operation.

Raptors were captured at both the North and South blinds using a set of mist nets in a triangular shape with a lure bird placed in the middle and by using a baited bow trap that could be activated from inside the blind (e.g., Bloom et al. 2007). Once captured, all raptors were banded, measured (tail length, wing chord, and body mass), sexed, and aged in accordance with North American Banding Program and the Bird Banding Laboratory (Gustafson et al. 1997). Sexing and aging were based on morphometric size, plumage, as well as eye color. Raptors that could not be reliably sexed were recorded as unknown sex. Although occasional birds were aged to specific age classes (e.g., Second Year or after Second Year birds), these were not frequent enough to allow an analysis at this level of detail. Thus, all adult age classes were treated simply as after HatchYear birds. Complete measurements were not obtained for all birds because an occasional bird lacked one or more measurements. This resulted in slightly different sample sizes for mass, wing chord, and tail analyses. Note: common and scientific names of all raptor species captured at Little Gap are listed in Table 1. (**See Appendix A**)

Analyses

We focused our summary of captures and morphological analyses on birds banded during fall migration because banding efforts were sporadic during spring migration. Yearly and total number of raptors banded were calculated for each species. This summary does not include any foreign site or local site recaptures. We summarized the morphological measurements of all species and quantified the differences by age and sex classes among species with a sample size of at least 40 captures using two-way ANOVA tests. For a few species whose sex could not reliably be identified (i.e., most buteos), we quantified differences only by age class among species using a one-way ANOVA. For Peregrine Falcons, there was a lack of sufficient age class data for males. Therefore, we used a one-way ANOVA with sex and a separate one-way ANOVA to examine the effect of age on females only. Measurement data collected from the recapture of raptors originally banded at Little Gap were excluded as well to ensure that no birds had duplicate measurements to avoid pseudoreplication. All statistical analyses were completed using SPSS version 24.

RESULTS

Banding Summary

A total of 14,766 individuals of 14 different species of raptors were bandeded during the study period with an average of 328 raptors banded per year (Table 1). Sharp-shinned Hawk had the highest total number banded (47% of all birds banded), followed by Red-tailed Hawk, Cooper's Hawk, Northern Goshawk, American Kestrel, and Merlin (Table 1). Each of the other eight species had less than 100 captures. Bald Eagle, Rough-legged Hawk, and Gyrfalcon were rarely captured with only one to four captures each (Table 1). While recaptures of birds originally banded at Little Gap were infrequent, local site recaptures occurred four times for Red-tailed Hawks and twice for Sharp-shinned Hawks.

Morphology Summary

For species where body mass was examined by sex, females of all species were significantly heavier than males (Tables 2, 3). Similarly, age influenced body mass in all species, except Merlin and Peregrine Falcon, with after Hatch-Year birds significantly heavier than hatch-year birds (Tables 2, 3). There was a significant interaction of sex and age on body mass for the three species of accipiters (Table 3), which suggests that after Hatch Year females were disproportionately heavier (Table 2). For species where wing chord was examined by sex, females of all species had significantly longer wing chords than males (Tables 4, 5). However, age only influenced wing chord in Sharp-shinned Hawk, Cooper's Hawk, and Red-tailed Hawk with after-hatch-year birds having significantly longer wing chords than Hatch Year birds (Tables 4, 5). There were no significant interactions between sex and age on wing chord (Table 4). Finally, for species where tail length was examined by sex, females of all species had significantly longer tails than males (Tables 6, 7). Age influenced tail length in Sharp-shinned Hawk, Cooper's Hawk, Red-tailed Hawk, and female Peregrine Falcon with Hatch Year birds having a significantly longer tail than after Hatch Year birds (Tables 6, 7). There was a significant interaction between sex and age on tail length in Sharp-shinned Hawk and Cooper's Hawk (Table 7), which suggests that Hatch Year males had disproportionately longer tails (Table 6).

DISCUSSION

Although more birds are banded at coastal and western banding stations, raptors banded at the Little Gap Raptor Banding Station, in the Appalachian Mountains of Pennsylvania, represent 2% of all raptors counted flying past this site, which makes it comparable to other sites in the eastern and central United States (Table 8). Interestingly, a few western stations capture a much higher proportion of migrating raptors (Table 8), but birds at these sites are likely migrating through open areas with less available prey compared to the heavily forested areas in the east. The number and percent of migrant raptors captured at Little Gap are also noteworthy because other sites likely utilize more blinds and full-time staff. Thus, the Little Gap Raptor Banding Station is an important raptor banding site in the eastern United States and the most active, long-term site in the Appalachian Mountains.

The five most commonly banded migratory raptor species at Little Gap were, in descending order of abundance: Sharp-shinned Hawk, Red-tailed Hawk, Cooper's Hawk, Northern Goshawk, and American Kestrel (Table 1). Other inland banding stations, such as those in the western United States and in Duluth, MN, have a similar group of most commonly banded species with the Sharp-shinned Hawk as the most frequently captured (Evans et al. 2012, HawkWatch International 2018). This is not surprising because Sharp-shinned Hawks are one of the most abundant species counted at hawk watches in the United States (Goodrich and Smith 2008) and their small size facilitates capturing them in mist-nets. By contrast, coastal banding stations at Cape May, NJ, and in coastal California band the Cooper's Hawk most frequently (Cape May Raptor Banding Project 2019, McInnis 2019). This is most notable at Cape May where the ten-year banding average for Cooper's Hawk is almost double that of Sharp-shinned Hawk. These high numbers of Cooper's Hawk captured are perplexing because more Sharp-shinned Hawk than Cooper's Hawk are counted flying over both of these sites (Goodrich and Smith 2008). At least at Cape May, specific habitat features near the blinds appear to bias captures toward Cooper's Hawks (P. Napier, Cape May Raptor Banding Project pers. comm.). Nevertheless, Sharp-shinned Hawks historically have been the most commonly banded raptor in the United States and Canada (Robbins 1986).

As expected, we confirmed the well-known pattern of reversed sexual size dimorphism (Snyder and Wiley 1976) in all species of raptors examined. Females of all species were heavier and had longer wings and tails. These differences match those that have been previously documented for Northern Harriers (Bildstein and Hamerstrom 1980, Palmer 1988a), the three species of accipiters (Mueller et al. 1976, 1979, 1981), and the three species of falcons (Clark 1985, Smallwood and Bird 2002, White et al. 2002). Most buteos were not able to be sexed and other species, e.g., eagles, had too few captures to examine for sex-based size dimorphism. Although the benefits of reversed sexual dimorphism in raptors remain equivocal, small size in males likely makes them more agile to either improve efficiency of capturing small prey or competitiveness in obtaining territories, whereas large size in females likely allows them to produce more/larger eggs or to better compete for good mates (Pérez-Camacho et al. 2015).

We also found age-based dimorphism in many of these raptor species, but these trends were not as uniform as the sex-based differences. Adult Northern Harriers and adults of the three accipiter species were heavier than hatch-year birds and adult Sharp-shinned Hawk and Cooper's Hawk had longer wings and shorter tails than hatch-year birds. For all three accipiter species, mass differences by age were larger in females than males (Tables 2, 3). Similarly, differences in tail length by age were larger in males than females in Sharp-shinned Hawk and Cooper's Hawk. Previous researchers have documented the same broad trends by age in Norther Harrier (Bildstein and Hamerstrom 1980, Palmer 1988a), Sharp-shinned Hawk (Mueller et. al. 1979, Hoffman et al. 1990) and Cooper's Hawk (Mueller et al. 1981, Hoffman et al. 1990). Mueller et al. (1981) suggested that the heavier mass and longer wings of adult accipiters make them more rapid and powerful fliers, which may give them an advantage in attacking prey and in intraspecific interactions. By contrast, the lighter mass and longer tails of juvenile accipiters may make them more agile and efficient fliers, which would benefit these birds while learning to capture prey (Mueller et al. 1979).

Interestingly, Mueller et al. (1976) found that Northern Goshawks followed the same trend as other accipiters where adults were heavier with longer wings and shorter tails. Our Northern Goshawk results differed from Mueller's (1976) with a lack of significant differences in wing chord and tail length, although we found a slight trend toward longer tails in hatch-year birds. Hoffman et al. (1990) also found no age difference in wing chord in Northern Goshawks. The lack of uniformity among trends for goshawks may be due to the relatively small sample sizes by age class for this species compared to the robust sample sizes for the other two accipiters.

Similarly, all the buteos we examined show some evidence of age-based size dimorphism. Adults of all three buteo species were heavier than hatch-year birds. However, only Red-tailed Hawk showed differences in other measurements by age. Adult Red-tailed Hawks had longer wings and shorter tails than hatch-year birds. Our results match previous comparisons by age completely for Red-tailed Hawks (Palmer 1988b, Schoenebeck et al. 2014). For Broad-winged Hawk, migrant adults from Minnesota showed the same trends as Little Gap birds in mass and wing chord, but hatch-year birds from Minnesota also had longer tails (Goodrich et al. 2014). Surprisingly, we found no past analyses of Red-shouldered Hawk measurements by age class for comparison. Thus, our results appear to be the first to document heavier adults than hatch-year Red-shouldered Hawks.

Falcons did not show as many differences in body measurements by age class as previous groups of raptors. We found that only adult American Kestrels were heavier than hatch-year birds and only hatch-year female Peregrine Falcons had longer tails than adults. There appear to be no prior direct comparisons of American Kestrel body measurements by age class, although Palmer (1988b) noted that juveniles are not measurably different from adults in size. Thus, our analysis appears the first to show that adult kestrels are heavier than hatch-year birds. We found a non-significant trend toward heavier mass in adult Merlins that matches the trend found in Merlins banded at Cape May (Clark 1985). Adult female Merlins from Cape May also had longer wings which doesn't match our results. Merlins captured in coastal Cape May may be from a different geographic origin than Merlins captured in the Appalachian Mountains at Little Gap, similar to patterns found for Sharp-shinned Hawk (Goodrich and Smith 2008), which might explain the different size trend. Alternatively, Clark's (1985) sample size for Merlins was much larger than ours and may explain the lack of a significant trends in wing chord by age for Little Gap birds. However, Temple's (1972) measurements of Merlin museum specimens by subspecies showed little difference in wing chord by age, but no statistical comparisons were made. We also found no difference in tail length, but no other study compared tail length by age for Merlins. Finally, Peregrine Falcon body size also has not been studied by age, although White et al. (2002) stated that juveniles have 1% longer wings and 4 to 5% longer tails (dependent upon sex) than adults, which matches the trends we found for female Peregrine Falcons. However, it is important to note that birds captured at Little Gap are likely a mix of several different gene pools that were used in reintroduction efforts in the eastern United States and might not be directly comparable birds of a single subspecies or genetic origin (White et al. 2002).

A variety of factors including migration patterns, wintering locations, and breeding grounds have been known to influence the morphology of migratory raptors. For example, species with a large geographic range can vary in size in different parts of their range. The five most commonly captured species in our study (Sharp-shinned Hawk, Cooper's Hawk, Northern Goshawk, Red-tailed Hawk, and American Kestrel) have been examined for geographic variation in body measurements during fall migration at several sites (i.e., west coast, inland west, central, and east coast) across the United States (Smith et al. 1990, Pearlstine and Thompson 2004). Overall, coastal migrant raptors tended to have a larger body mass with a shorter wing chord and tail length than their inland and central counterparts (Smith et al. 1990, Pearlstine and Thompson 2004). Cooper's Hawk was the exception to this pattern with heavier and larger birds in the east (Pearlstine and Thompson 2004), but in proportion to their weight, western birds had longer wings and tails (Smith et al. 1990). In general, these differences result in lighter wing loading, which may be related to longer fall migratory flight distance of western birds (Pearlstine and Thompson 2004).

Raptors banded at Little Gap mostly followed these broad regional trends in mass and body size with most measurements similar to birds from Cape May, NJ. Where comparisons were available, all bird species banded at Little Gap were heavier than birds from western sites and Sharp-shinned Hawks and Cooper's Hawks were also heavier than birds from the central United States (Table 2, Smith et al. 1990, Pearlstine and Thompson 2004). However, Northern Goshawks from Little Gap were lighter than central flyway birds (Smith et al. 1990). This is not surprising because goshawks captured at the central flyway site in Wisconsin are more likely from northern latitudes (e.g., Brinker and Erdman 1985) and have larger bodies. The wing chord of Little Gap birds, except Cooper's Hawks, tended to be smaller than western and central birds and mostly were similar to Cape May birds (Table 4, Smith et al. 1990, Pearlstine and Thompson 2004).

Trends in tail length of Little Gap birds were not as clear cut. The tails of raptors caught at Little Gap tended to be shorter than inland western birds but longer than all other sites (Table 6, Smith et al. 1990, Pearlstine and Thompson 2004). However, Northern Goshawks from Little Gap did not follow any clear trend in tail length. Hatch Year Little Gap birds had longer tails than central flyway birds but shorter tails than inland western birds, whereas adult Little Gap birds had longer tails than central and western birds (Table 6, Smith et al. 1990). Cooper's Hawks from Little Gap had longer wings and tails similar to those from Cape May as compared to all other sites (Table 6, Smith et al. 1990, Pearlstine and Thompson 2004) suggesting that eastern birds are larger, which contradicts the trends for most other raptors.

The location of the Little Gap Raptor banding station along the Kittatinny Ridge creates an ideal location for capturing migrating raptors. The long-term banding effort at Little Gap has provided a substantial data set for studying migratory raptor morphology. The Sharp-shinned Hawk was the most commonly captured raptor during migration (47 % of all captures), followed in descending order by Red-tailed Hawks and Cooper's Hawks. We confirmed the well-known trend for reversed sexual dimorphism in mass and body size for the 10 species of raptors examined. In addition, we documented age-based dimorphism occurs in many raptors, but trends were not as uniform for individual measurements as for sex-based differences. Nevertheless, most adult raptors were heavier, had longer wing chords, and shorter tails than hatch-year raptors. These results matched many previously documented trends, but our results appear to be the first to document age-based mass differences in Red-shouldered Hawk and American Kestrel. Finally, raptors banded at Little Gap mostly followed the general geographic trends in body size, with a few exceptions, where eastern and coastal birds are heavier with shorter wings and tails than western and central birds.

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Appendix A follows, Table 1 thru Table 8, Pages 9 - 18.

Appendix A

Table 1. Total captures by year for each of the fourteen species of migratory raptors[1] captured in fall at the Little Gap Raptor Banding Station in Danielsville, Pennsylvania from 1974-2018.

Year	GOEA	NOHA	SSHA	COHA	NOGO	BAEA	RSHA	BWHA	RTHA	RLHA	AMKE	MERL	GYRF	PEFA	Total
1974	0	0	6	1	1	0	0	0	19	0	0	0	0	0	27
1975	0	0	9	1	6	0	0	2	22	0	0	0	0	0	40
1976	0	1	62	8	6	0	1	0	33	0	1	0	0	1	113
1977	0	0	295	14	8	0	1	1	79	0	4	0	0	0	402
1978	0	0	55	1	2	0	0	3	24	0	0	0	0	0	85
1979	0	1	67	6	2	0	1	0	30	0	1	0	0	0	108
1980	0	6	40	10	7	0	3	4	95	0	0	0	0	0	165
1981	1	1	153	24	21	0	4	4	140	0	4	0	0	0	352
1982	0	0	80	16	16	0	2	0	67	0	0	0	0	0	181
1983	0	0	112	25	11	0	2	3	63	0	0	0	0	0	216
1984	0	0	96	18	7	0	1	5	42	0	0	0	0	0	169
1985	0	0	98	17	12	0	0	1	67	0	1	0	0	0	196
1986	0	2	116	7	6	0	1	2	92	0	1	0	0	0	227
1987	0	0	266	46	4	0	2	2	70	0	6	1	0	0	397
1988	0	4	167	26	7	0	2	0	101	1	1	1	0	0	310
1989	0	1	188	39	2	0	2	1	106	0	5	1	0	1	346
1990	0	3	308	74	23	0	1	5	150	0	2	2	0	3	571
1991	1	2	352	64	14	0	1	4	117	0	6	4	0	3	568
1992	0	0	203	42	3	0	0	6	121	0	2	3	0	3	383
1993	1	4	172	43	21	0	0	0	142	0	7	1	0	0	391

Table 1. (Continued) Total captures by year for each of the fourteen species of migratory raptors[1] captured in fall at theLittle Gap Raptor Banding Station in Danielsville, Pennsylvania from 1974-2018.

Year	GOEA	NOHA	SSHA	COHA	NOGO	BAEA	RSHA	BWHA	RTHA	RLHA	AMKE	MERL	GYRF	PEFA	Total
1994	1	1	191	49	7	0	0	0	156	0	10	0	0	0	415
1995	2	2	112	44	23	0	1	2	286	0	2	1	0	1	476
1996	1	0	77	38	7	0	0	0	74	0	4	0	0	2	203
1997	1	4	225	59	16	0	2	6	165	0	11	5	0	3	497
1998	2	1	136	69	1	0	1	2	154	0	1	2	0	2	371
1999	0	1	172	69	48	0	3	3	378	0	4	7	0	2	687
2000	1	0	123	49	3	0	0	0	106	0	2	2	0	2	288
2001	0	2	173	43	17	0	4	0	180	0	8	6	0	0	433
2002	0	0	128	38	7	0	5	4	184	0	1	2	0	1	370
2003	0	3	171	53	6	0	2	3	181	1	6	3	0	4	433
2004	2	1	122	31	8	0	2	1	114	0	4	5	0	2	292
2005	0	1	76	43	7	0	2	0	87	0	1	4	0	0	221
2006	1	0	102	38	3	0	0	2	111	0	2	6	0	1	266
2007	1	0	149	27	8	0	2	7	118	0	2	3	0	0	317
2008	0	1	136	24	3	0	1	0	100	0	1	4	1	0	271
2009	1	0	145	35	8	0	2	2	65	0	1	3	0	0	262
2010	0	1	207	49	16	0	4	6	147	0	0	6	0	1	437
2011	1	4	347	75	1	0	3	7	133	0	3	9	0	3	586
2012	1	0	314	59	10	0	2	0	188	0	5	0	0	4	583
2013	1	3	173	37	1	0	0	0	106	0	2	0	0	1	324
2014	0	2	229	55	4	0	11	0	167	0	2	0	0	2	472
2015	0	1	173	76	2	1	1	2	49	0	6	14	0	0	325

Table 1. (Continued) Total captures by year for each of the fourteen species of migratory raptors[1] captured in fall at theLittle Gap Raptor Banding Station in Danielsville, Pennsylvania from 1974-2018.

Year	GOEA	NOHA	SSHA	COHA	NOGO	BAEA	RSHA	BWHA	RTHA	RLHA	AMKE	MERL	GYRF	PEFA	Total
2016	2	1	117	40	8	0	4	7	179	1	0	8	0	1	368
2017	1	2	113	48	1	0	2	4	54	1	3	9	0	2	240
2018	0	0	180	57	8	0	5	1	125	0	3	2	0	1	382
Total	22	56	6936	1687	402	1	83	102	5187	4	125	114	1	46	14766
Mean	0.49	1.24	154.13	37.49	8.93	0.02	1.84	2.27	115.27	0.09	2.78	2.53	0.02	1.02	328.13
SE	0.10	0.22	12.30	3.15	1.28	0.02	0.29	0.34	10.16	0.04	0.41	0.48	0.02	0.18	22.55

[1] GOEA = Golden Eagle (*Aquila chrysaetos*), NOHA = Northern Harrier (*Circus cyaneus*), SSHA = Sharp-shinned Hawk (*Accipiter striatus*), COHA = Cooper's Hawk (*Accipiter cooperii*), NOGO = Northern Goshawk (*Accipiter gentilis*), BAEA = Bald Eagle (*Haliaeetus leucocephalus*), RSHA = Red-shouldered Hawk (*Buteo lineatus*), BWHA = Broad-winged Hawk (*Buteo platypterus*), RTHA = Red-tailed Hawk (*Buteo jamaicensis*), RLHA = Rough-legged Hawk (*Buteo lagopus*), AMKE = American Kestrel (*Falco sparverius*), MERL = Merlin (*Falco columbarius*), GYRF = Gyrfalcon (*Falco rusticolus*), PEFA = Peregrine Falcon (*Falco peregrinus*).

Cooper's Hawk
Comstock studios George West

Table 2. Mean body mass (g) ± SE by sex and age class for raptors banded at the Little Gap Raptor Banding Station during autumn migration from 1978-2018.

		Hatch-Year		After-Hatch-Year		Unknown	
Species	**Sex**	**Mean ± SE**	**n**	**Mean ± SE**	**n**	**Mean ± SE**	**n**
Golden Eagle	Female			4350.00	1		
	Male	3209.50 ± 330.50	2	2850.00	1		
	Unknown	3315.00 ± 185.00	2				
Northern Harrier	Female	460.05 ± 15.69	19	546.57 ± 13.49	7		
	Male	334.78 ± 6.35	18	382.75 ± 12.31	4		
	Unknown	427.25 ± 35.13	4				
Sharp-shinned Hawk	Female	172.28 ± 0.24	3221	179.09 ± 0.54	689		
	Male	100.85 ± 0.16	2318	104.09 ± 0.47	255		
	Unknown						
Cooper's Hawk	Female	516.13 ± 1.90	625	555.07 ± 2.35	468		
	Male	342.64 ± 1.88	325	360.77 ± 2.20	222		
	Unknown	328.00	1				
Northern Goshawk	Female	929.28 ± 15.10	95	1020.86 ± 17.63	29		
	Male	772.53 ± 5.00	186	806.39 ± 15.48	33		
	Unknown	779.86 ± 10.89	21	794.00 ± 103.97	3		
Red-shouldered Hawk	Female						
	Male						
	Unknown	644.92 ± 9.36	74	762.29 ± 42.22	7		
Broad-winged Hawk	Female						
	Male						
	Unknown	379.33 ± 6.64	79	456.53 ± 8.94	17		
Red-tailed Hawk	Female	1103.60 ± 55.46	5	1142.50 ± 30.17	4		
	Male	808.64 ± 27.11	11				
	Unknown	1002.01 ± 2.59	4036	1089.16 ± 5.66	892		
Rough-legged Hawk	Female	862.67 ± 41.16	3				
	Male						
	Unknown	590.00	1				
American Kestrel	Female	114.55 ± 1.50	33	117.58 ± 2.79	12	114.67 ± 5.78	3
	Male	103.95 ± 1.21	58	114.46 ± 3.48	13		
	Unknown						
Merlin	Female	206.75 ± 4.45	36	219.50 ± 5.34	10		
	Male	155.43 ± 2.78	51	163.08 ± 6.46	12		
	Unknown	202.67 ± 4.06	3				
Gyrfalcon	Female	1640.00	1				
	Male						
	Unknown						
Peregrine Falcon	Female	802.22 ± 25.90	20	847.71 ± 35.49	7		
	Male	548.06 ± 10.67	14				
	Unknown	887.00	1	920.00	1		

Table 3. Two-way ANOVA results evaluating the influences of sex and age on body mass (g) measurements for raptors banded at the Little Gap Raptor Banding Station during autumn migration from 1978-2018.

Species	F	df	P
Northern Harrier			
Sex	69.22	1, 44	<0.001
Age	14.98	1, 44	<0.001
Sex*Age	1.23	1, 44	0.273
Sharp-shinned Hawk			
Sex	25527.24	1, 6479	<0.001
Age	120.02	1, 6479	<0.001
Sex*Age	15.17	1, 6479	<0.001
Cooper's Hawk			
Sex	6069.45	1, 1636	<0.001
Age	146.18	1, 1636	<0.001
Sex*Age	19.41	1, 1636	<0.001
Northern Goshawk			
Sex	170.17	1, 339	<0.001
Age	19.43	1, 339	<0.001
Sex*Age	4.11	1, 339	0.043
Red-shouldered Hawk[1]			
Age	12.69	1, 79	0.001
Broad-winged Hawk[1]			
Age	26.68	1, 94	<0.001
Red-tailed Hawk[1]			
Age	206.55	1, 4946	<0.001
American Kestrel			
Sex	10.00	1, 112	0.002
Age	9.75	1, 112	0.002
Sex*Age	2.97	1, 112	0.088
Merlin			
Sex	100.11	1, 105	<0.001
Age	3.59	1, 105	0.061
Sex*Age	0.22	1, 105	0.637
Peregrine Falcon[2]			
Sex	91.56	1, 39	<0.001
Age	0.93	1, 23	0.345

[1] For buteos that could not be sexed, we quantified differences only by age using a only one-way ANOVA

[2] Peregrine Falcons lacked sufficent age data for males, so a one-way ANOVA was used to quantify sex differences. A separate one-way ANOVA was used to examine the effect of age on females only.

Table 4. Mean wing chord (mm) ± SE by sex and age class for raptors banded at the Little Gap Raptor Banding Station during autumn migration from 1978-2018.

		Hatch-Year		After-Hatch-Year		Unknown	
Species	**Sex**	**Mean ± SE**	**n**	**Mean ± SE**	**n**	**Mean ± SE**	**n**
Golden Eagle	Female	805.00	1	685.50 ± 34.50	2		
	Male	600.22 ± 4.58	9	598.33 ± 6.94	3		
	Unknown	619.57 ± 13.83	7				
Northern Harrier	Female	377.38 ± 1.65	21	377.43 ± 3.65	7		
	Male	330.84 ± 6.42	19	339.00 ± 4.66	4		
	Unknown	351.00 ± 8.69	4				
Sharp-shinned Hawk	Female	200.42 ± 0.09	3265	202.17 ± 0.19	695		
	Male	168.23 ± 0.08	2343	170.21 ± 0.25	257		
	Unknown						
Cooper's Hawk	Female	264.61 ± 0.28	629	267.45 ± 0.38	475		
	Male	232.20 ± 0.31	330	236.21 ± 0.43	227		
	Unknown	147.00	1				
Northern Goshawk	Female	344.58 ± 1.14	97	346.06 ± 1.32	31		
	Male	318.55 ± 0.83	194	317.54 ± 1.28	35		
	Unknown	325.29 ± 1.43	21	322.67 ± 10.27	3		
Bald Eagle	Female						
	Male						
	Unknown	630.00	1				
Red-shouldered Hawk	Female						
	Male						
	Unknown	330.34 ± 1.59	74	331.71 ± 4.02	7		
Broad-winged Hawk	Female						
	Male						
	Unknown	276.36 ± 1.96	80	281.79 ± 2.47	19		
Red-tailed Hawk	Female	400.25 ± 2.58	8	395.50 ± 5.19	4		
	Male	351.46 ± 2.05	13				
	Unknown	375.61 ± 0.27	4101	380.23 ± 0.57	907		
Rough-legged Hawk	Female	433.00 ± 1.53	3				
	Male						
	Unknown	400.00	1				
American Kestrel	Female	192.47 ± 0.97	34	188.58 ± 1.83	12	191.00 ± 3.21	3
	Male	184.12 ± 0.73	58	185.00 ± 1.22	13		
	Unknown						
Merlin	Female	211.06 ± 0.74	36	211.20 ± 1.73	10		
	Male	192.31 ± 0.78	52	193.67 ± 1.73	12		
	Unknown	205.25 ± 2.14	4				
Gyrfalcon	Female	400.00	1				
	Male						
	Unknown						
Peregrine Falcon	Female	361.78 ± 1.65	18	357.85 ± 2.05	7		
	Male	314.72 ± 1.99	16				
	Unknown	367.00	1	334.00	1		

Table 5. Two-way ANOVA results evaluating the influences of sex and age on wing chord (mm) measurements for raptors banded at the Little Gap Raptor Banding Station during autumn migration from 1978-2018.

Species	F	df	P
Northern Harrier			
Sex	42.87	1, 47	<0.001
Age	0.40	1, 47	0.530
Sex*Age	0.39	1, 47	0.535
Sharp-shinned Hawk			
Sex	31608.92	1, 6556	<0.001
Age	106.56	1, 6556	<0.001
Sex*Age	0.371	1, 6556	0.542
Cooper's Hawk			
Sex	7183.12	1, 1657	<0.001
Age	82.86	1, 1657	<0.001
Sex*Age	2.47	1, 1657	<0.116
Northern Goshawk			
Sex	331.72	1, 353	<0.001
Age	0.03	1, 353	0.873
Sex*Age	0.69	1, 353	0.405
Red-shouldered Hawk[1]			
Age	0.07	1, 79	0.797
Broad-winged Hawk[1]			
Age	1.66	1, 97	0.201
Red-tailed Hawk[1]			
Age	54.99	1, 5031	<0.001
American Kestrel			
Sex	22.31	1, 113	<0.001
Age	1.42	1, 113	0.236
Sex*Age	3.56	1, 113	0.062
Merlin			
Sex	204.84	1, 106	<0.001
Age	0.35	1, 106	0.554
Sex*Age	0.23	1, 106	0.633
Peregrine Falcon[2]			
Sex	393.84	1, 41	<0.001
Age	1.77	1, 23	0.197

[1] For buteos that could not be sexed, we quantified differences only by age using a only one-way ANOVA.

[2] Peregrine Falcons lacked sufficent age data for males, so a one-way ANOVA was used to quantify sex differences. A separate one-way ANOVA was used to examine the effect of age on females only.

Table 6. Mean tail length (mm) ± SE by sex and age class for raptors banded at the Little Gap Raptor Banding Station during autumn migration from 1978-2018.

		Hatch-Year		After-Hatch-Year		Unknown	
Species	**Sex**	**Mean ± SE**	**n**	**Mean ± SE**	**n**	**Mean ± SE**	**n**
Golden Eagle	Female	370.00	1	368.00 ± 12.00	2		
	Male	332.63 ± 5.68	8	359.00 ± 5.00	3		
	Unknown	341.86 ± 9.69	7				
Northern Harrier	Female	251.00 ± 2.24	21	244.57 ± 5.13	7		
	Male	217.37 ± 2.29	19	212.00 ± 4.32	4		
	Unknown	225.25 ± 7.86	4				
Sharp-shinned Hawk	Female	161.45 ± 0.13	3264	161.05 ± 0.29	695		
	Male	136.11 ± 013	2341	134.39 ± 0.41	257		
	Unknown						
Cooper's Hawk	Female	224.28 ± 0.43	629	220.57 ± 067	475		
	Male	200.13 ± 0.64	329	192.03 ± 0.85	228		
	Unknown	203.00	1				
Northern Goshawk	Female	275.60 ± 1.56	97	272.29 ± 1.94	31		
	Male	241.95 ± 1.32	194	237.31 ± 1.64	35		
	Unknown	257.71 ± 1.00	21	251.67 ± 4.37	3		
Bald Eagle	Female						
	Male						
	Unknown	275.00	1				
Red-shouldered Hawk	Female						
	Male						
	Unknown	218.31 ± 1.43	74	213.71 ± 3.63	7		
Broad-winged Hawk	Female						
	Male						
	Unknown	171.31 ± 1.29	80	169.32 ± 2.79	19		
Red-tailed Hawk	Female	257.00 ± 4.12	8	248.75 ± 3.75	4		
	Male	235.62 ± 2.04	13				
	Unknown	227.93 ± 0.23	4097	218.91 ± 0.48	908		
Rough-legged Hawk	Female	242.00 ± 4.04	3				
	Male						
	Unknown	212.00	1				
American Kestrel	Female	123.21 ± 1.00	34	121.75 ± 1.99	12	126.00 ± 1.15	10
	Male	119.55 ± 0.67	58	118.69 ± 2.19	13		
	Unknown						
Merlin	Female	129.97 ± 1.81	36	130.10 ± 1.26	10		
	Male	118.88 ± 0.90	51	120.00 ± 1.90	12		
	Unknown	121.00 ± 3.44	4				
Gyrfalcon	Female	242.00	1				
	Male						
	Unknown						
Peregrine Falcon	Female	185.00 ± 1.85	18	172.57 ± 1.99	7		
	Male	158.06 ± 1.61	17				
	Unknown	186.00	1	197.00	1		

Table 7. Two-way ANOVA results evaluating the influences of sex and age on tail length (mm) measurements for raptors banded at the Little Gap Raptor Banding Station during autumn migration from 1978-2018.

Species	F	df	P
Northern Harrier			
Sex	79.96	1, 47	<0.001
Age	2.54	1, 47	0.118
Sex*Age	0.02	1, 47	0.887
Sharp-shinned Hawk			
Sex	8832.68	1, 6553	<0.001
Age	14.71	1, 6553	<0.001
Sex*Age	5.71	1, 6553	0.017
Cooper's Hawk			
Sex	1615.70	1, 1657	<0.001
Age	81.39	1, 1657	<0.001
Sex*Age	11.21	1, 1657	0.001
Northern Goshawk			
Sex	229.45	1, 353	<0.001
Age	3.08	1, 353	0.080
Sex*Age	0.09	1, 353	0.769
Red-shouldered Hawk[1]			
Age	0.92	1, 79	0.340
Broad-winged Hawk[1]			
Age	0.45	1, 97	0.504
Red-tailed Hawk[1]			
Age	278.43	1, 5028	<0.001
American Kestrel			
Sex	6.34	1, 113	0.013
Age	0.75	1, 113	0.387
Sex*Age	0.05	1, 113	0.823
Merlin			
Sex	29.85	1, 105	<0.001
Age	0.10	1, 105	0.749
Sex*Age	0.07	1, 105	0.799
Peregrine Falcon[2]			
Sex	82.54	1, 40	<0.001
Age	14.75	1, 23	0.001

[1] For buteos that could not be sexed, we quantified differences only by age using a only one-way ANOVA.

[2] Peregrine Falcons lacked sufficent age data for males, so a one-way ANOVA was used to quantify sex differences. A separate one-way ANOVA was used to examine the effect of age on females only.

Table 8. A comparison of the number of diurnal raptors banded per year as a proportion of raptors counted at hawk watches for several long-term raptor banding stations in the United States.

Banding Station	Location	# banded/year	# counted/year[1]	% banded	Reference
Cape May Raptor Banding Project	Cape May, NJ	2322	45591	5.1	Cape May Raptor Banding Project 2019
Little Gap Raptor Banding Station	Danielsville, PA	328	16241	2.0	This study
Hawk Ridge Bird Observatory	Duluth, MN	2008	89957	2.2	Evans et al. 2012
Manzano Mountains Hawkwatch	Manzano Mountains, NM	816	5391	15.1	Oleyar and Watson 2018a
Goshute Raptor Migration Research Project	Goshute Mountains, NV	1764	16615	10.6	Oleyar and Watson 2018b
Bonney Butte Hawkwatch	Bonney Butte, OR	303	2908	10.4	Oleyar and Watson 2018c
Chelan Ridge Hawkwatch	Chelan, WA	527	1813	29.1	Oleyar and Watson 2018d
Golden Gate Raptor Observatory	Marin Headlands, CA	1192	29256	4.1	McInnis 2019

[1] Average number of diurnal raptors counted at each hawk watch site from Goodrich and Smith (2008).

Gerald Lahr
Red-tailed Hawk