SHORT COMMUNICATIONS

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AGE-CLASS DIFFERENCE IN WINTERING DISTRIBUTION OF BROAD-WINGED HAWKS

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ABSTRACT.—The Broad-winged Hawk (*Buteo platypterus*) is one of the most easily observed North American raptors during migration, yet little is known about its distribution during the nonbreeding season. To better understand the winter distribution of Broad-winged Hawks by age, we compiled 2164 Broad-winged Hawk sightings with age data and 25,797 sightings without age data reported to eBird during the nonbreeding period from 2000–2020. The mean latitude of adult birds was significantly farther south than the mean latitude of immatures, with broad overlap in the distribution of both age classes from the United States through South America. The distribution of birds that were not aged overlapped the distribution of both age classes. A higher proportion of immatures was observed in the United States through Central America, with a mean latitude of 15.69°N, whereas adults were concentrated in Central and South America (with a mean latitude of 9.93°N). When only birds wintering south of the United States were analyzed, immatures were still found farther north than adults, although the latitude difference was less. The winter age class distribution for Broad-winged Hawks could result from short-stopping behavior occurring more often in immatures than adults. Further research is needed to understand how geographic, sex, and age class groups may differ in winter distributions and the implications of these patterns. Citizen science data from eBird proved useful in examining broad-scale patterns in Broad-winged Hawk winter distribution and is a valuable resource to scientists evaluating avian distributions.

KEY WORDS: *Broad-winged Hawk*; Buteo platypterus; *age*; *Central America*; *differential migration*; *eBird*; *Neotropical migrant*; *South America*; *wintering.*

DIFERENCIA DE CLASES DE EDAD EN LA DISTRIBUCIÓN DE INVERNADA DE *BUTEO PLATYPTERUS*

RESUMEN.—*Buteo platypterus* es una de las rapaces norteamericanas más fáciles de observar durante la migración, pero se sabe poco sobre su distribución durante la temporada no reproductiva. Para comprender mejor la distribución invernal por edad de esta especie, recopilamos 2164 avistamientos de *B. platypterus* con datos de edad y 25,797 avistamientos sin datos de edad reportados a eBird durante el período no reproductivo de 2000–2020. La latitud media de las aves adultas se ubicó significativamente más al sur que la latitud media de las aves inmaduras, con una amplia superposición en la distribución de ambas clases de edad desde los Estados Unidos hasta América del Sur. La distribución de las aves sin datos de edad se superpuso con la distribución de ambas clases de edad. Se observó una mayor proporción de inmaduros en Estados Unidos y a lo largo de América Central, con una latitud media de 15.69°N, mientras que los

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adultos se concentraron en América Central y del Sur (con una latitud media de 9.93°N). Cuando solo se analizaron las aves que invernaban al sur de los Estados Unidos, los inmaduros aún se encontraron más al norte que los adultos, aunque la diferencia de latitud fue menor. La distribución de clases de edad durante el invierno para *B. platypterus* podría deberse a un comportamiento de parada corta que ocurre con más frecuencia en los inmaduros que en los adultos. Se necesita más investigación para comprender cómo los grupos geográficos, de sexo y de clase de edad pueden diferir en las distribuciones de invierno y las implicaciones de estos patrones. Los datos de ciencia ciudadana de eBird demostraron ser útiles para examinar patrones a gran escala en la distribución invernal de *B. platypterus* y son un recurso valioso para los científicos que evalúan las distribuciones de las aves.

[Traducción del equipo editorial]

INTRODUCTION

Neotropical migrant birds have been the focus of conservation concern and research for several decades (Faaborg et al. 2010). Knowledge of the nonbreeding (hereafter winter) range for a species and how populations disperse within that range is critical to understanding conservation threats and solutions (Newton 2008, Faaborg et al. 2010, Curley et al. 2020). Studies on songbirds such as the American Redstart (*Setophaga ruticilla*; Marra and Holmes 2001) suggest that overwinter survival can vary by habitat and the more dominant age-sex class (i.e., adult males) is found in higher-quality habitats possibly resulting in differential survival by age. Some raptors show differential winter range by sex or age, which could affect survival (e.g., American Kestrel [*Falco sparverius*], Smallwood et al. 2020; Sharp-shinned Hawks [*Accipiter striatus*] and Cooper's Hawks [*A. cooperi*], Goodrich et. al. 2012).

The Broad-winged Hawk (*Buteo platypterus*) is a small forest-nesting hawk that breeds in eastern and central North America and west through western Canada, and winters from southern Mexico to the northern half of South America (Goodrich et al. 2020). Some populations of Broad-winged Hawks appear to be declining in eastern North America (Farmer et al. 2008; Oleyar et al. 2021) and although the species is relatively well studied within its breeding range, much is still unknown about its wintering ecology. In winter, Broad-winged Hawks regularly occur south to Bolivia, Peru, Venezuela, and southern Brazil (Meller and Bencke 2012, Willrich and Joenck 2019, Goodrich et al. 2020, McCabe et al. 2020), and occasionally in Argentina (Monllor and Chiurla 2020). Recent analyses suggest Broad-winged Hawks may be increasing as a wintering bird in South America (Kilpp et al. 2018). The increase could be related to the breeding range expansion in Alberta and British Columbia (Phinney 2015, Goodrich et al. 2020). Studies of tagged birds suggest that different breeding populations may migrate to different parts of the winter range (Haines et al. 2003, Capitolo et al. 2020, McCabe et al. 2020). Because satellite-tracking studies have primarily focused on adult females, further research is needed to clarify possible age-sex class migration connectivity patterns in this species.

Different age classes of some avian species may winter at different latitudes, although this is not well studied in raptors (Bildstein 2006, Newton 2008). Adults wintered farther north than immatures in Sharp-shinned Hawks, Cooper's Hawks (Hoffman et al. 2002, Goodrich et al. 2012), and Eurasian Kestrels (*Falco tinnunculus*; Kjellén 1994). In contrast, immature birds wintered farther north than adults in the Slate-colored Junco (*Junco hyemalis*; Ketterson and Nolan 1983) and a few European songbirds (Newton 2008), but this has not been reported widely among raptors (Kerlinger 1989, Bildstein 2006). In a satellite-tracking study of three immature and 12 adult Broad-winged Hawks tagged on their breeding grounds in Pennsylvania and Alberta, immatures wintered farther north, though this was a small sample size (McCabe et al. 2020). If winter range differs by age class in the Broad-winged Hawk, immatures could encounter different threats than adults, with implications for the species' survival and conservation.

In the last two decades, birdwatchers have logged millions of bird sightings in the international database eBird (Sullivan et. al. 2009, Sullivan et al. 2014). Because records are carefully vetted by regional editors, eBird data has proven useful in informing conservation science, particularly in understanding avian distribution and movement ecology (Aceves-Bueno et al. 2017, Coxen et al. 2017). One advantage of using citizen-science data such as eBird data is that it provides a more geographically extensive sample than can be found in scientist-led surveys (Sullivan et al. 2009). Researchers often use filters to correct eBird data for possible biases before analyses (Sullivan et al. 2014, Sullivan et al. 2017, Steen et al. 2019). Concerns with eBird data include that the absence of a record does not necessarily represent absence of the species (Sullivan et al. 2014), and possible sampling or observer biases (Steen et al. 2019). However, eBird data that is filtered or culled has been shown to accurately represent species distribution as well as regional population trends (Aceves-Bueno et al. 2017, Walker and Taylor 2017, Steen et al. 2019).

Here, we filtered eBird data (eBird 2021) to examine the wintering latitudes of adult and immature Broad-winged Hawks. As eBird data is available from all regions of the known winter range of the Broad-winged Hawk (Kilpp et al.

2018, Goodrich et. al 2020), we surmised eBird data would provide a robust sample of aged birds to evaluate broad-scale age-class distribution patterns. We hypothesized that immature Broad-winged Hawks winter farther north than adults as was observed by McCabe et al. (2020), as they are less experienced and less energetically prepared for long-distance Neotropical migration.

METHODS

Because eBird was launched in 2002, we accessed records of Broad-winged Hawk sightings from 2002–2020 using both the eBird Species Maps tool and by downloading all Broad-winged Hawk records (Sullivan et al. 2009, eBird 2021). We used the Map tool to examine photographs and comments with sightings where provided. Prior to analysis, we culled checklists to include only checklists from October–March in South America, and from November–February in areas north of South America. Timing was selected based on known movements reported in two satellite-tracking studies (Haines et al. 2003, McCabe et al. 2020). We also excluded any checklists from the Caribbean where Broad-winged Hawks are resident (Goodrich et al. 2020) and selected only complete, non-duplicate checklists (e.g., Walker and Taylor 2017). We eliminated any individual sightings of more than three birds assuming they might represent migrants and we eliminated potential duplicate sightings of same-aged birds from the same location and year. Although immature birds are more difficult to identify and may be less likely to be reported due to observer uncertainty, we assumed that the probability of reporting an immature or an adult did not vary across latitude and that all data reports were carefully vetted by eBird editors. Because eBird is largely used by experienced birders (Sullivan et al. 2017) we believe this assumption is reasonable. We also assumed that all records within the study period were of wintering birds, not migrants. Locations of each bird were mapped in ArcGIS 10.3 (ESRI 2011) and analyzed with the SYSTAT 13.1 statistical package (SYSTAT 2009).

Prior to analyses of latitude by age, we evaluated the proportion of birds that were aged by eBird observers across the winter range by 10° latitude blocks to ascertain whether the proportion aged varied substantially by latitude and thus could affect the results. Proportions were compared using a chi-square test for entire range and for the core range (i.e., from 10°S to 30°N). Then, latitude of wintering birds was analyzed as the response variable with age class (adult, immature, or unknown age) as the predictor using generalized linear models (GLMs) with $\alpha < 0.05$ and using identity link function with a normal distribution ($x\beta = \mu$).

To assess whether the latitude of aged birds shifted across years of the study, we broke the study period into two periods and analyzed the proportion aged per study period and conducted a two-way GLM comparing latitude for adults and immatures within two study periods, 2002–2010 and 2011–2020.

Finally, because winter records seemed to show a clumped pattern in the United States and Canada, we analyzed latitude by age for all data and then for all data excluding the United States and Canada.

RESULTS

Range-wide and Core Area Analyses and Distribution. A total of 27,961 complete eBird checklists contained a Broad-winged Hawk sighting during the winter period. Checklists reporting age data, or with photographic evidence of age, totaled 2164 records (7.7% of all winter records from 2002–2020). The proportion of Broad-winged Hawk eBird winter records with age data increased between early and late periods of the study from 6.2% aged prior to 2010 to 7.9% after 2010 ($x^2 = 7.28$, $P < 0.007$, df $= 1$).

The proportion aged by 10° latitude blocks across the winter range varied significantly as well, with greater proportions aged at the extremes of the winter distributional range (e.g., 40.5% of sightings above 40°N latitude [$n = 131$] and 41.9% below 10°S latitude [$n = 36$] were aged; $x^2 = 543.08$, df = 5, $P < 0.001$). In the core part of the winter range (10°S to 30°N latitude) the proportion aged per 10° block varied from 6.6% to 9.8% of sightings per block, with sample size per block ranging from 327 to 14,578 sightings). Because the proportions aged varied only by $\leq$3.2% between different blocks within the core winter range, and because the sample size was much lower for blocks at the tails of distribution, we concluded the variation in proportion aged would not substantially affect our analysis of winter distribution by age.

The mean latitude of all winter sightings of immatures was significantly farther north than adult sightings, lying approximately in southern Mexico or northern Guatemala, whereas the adult mean latitude was in central Costa Rica ($F = 1847.65$, df = 1, $P \leq 0.001$; Fig. 1, 2a, Supplemental Material Table S1). Unknown age sightings had a similar mean latitude to adults, lying in southern Costa Rica (9.47°N ± 7.13°; Fig. 2a). Despite the difference in mean latitude by age, there was overlap between the two age classes throughout most of the winter range (Fig. 1, 2a).

The mean latitude of adult and immatures did not differ between the early ($\leq$2010) and late study periods (2011–2020; $F = 2.64$, df $= 1$, $P > 0.1$).

Distribution in United States and Canada. Sightings of wintering Broad-winged Hawks in the United States and Canada ($n = 401$ and $n = 23$, respectively) were clustered in four subregions, the Gulf of Mexico coast (Louisiana and Texas), Florida, Atlantic coast, and Pacific coast, with Florida having the highest concentration of wintering birds ($n = 242$; Fig. 1). Most Broad-winged Hawk sightings in the United States and Canada were of immatures (69.6%). As a result, the distribution of all immature sightings across the entire winter range show two peak clusters, one near 10

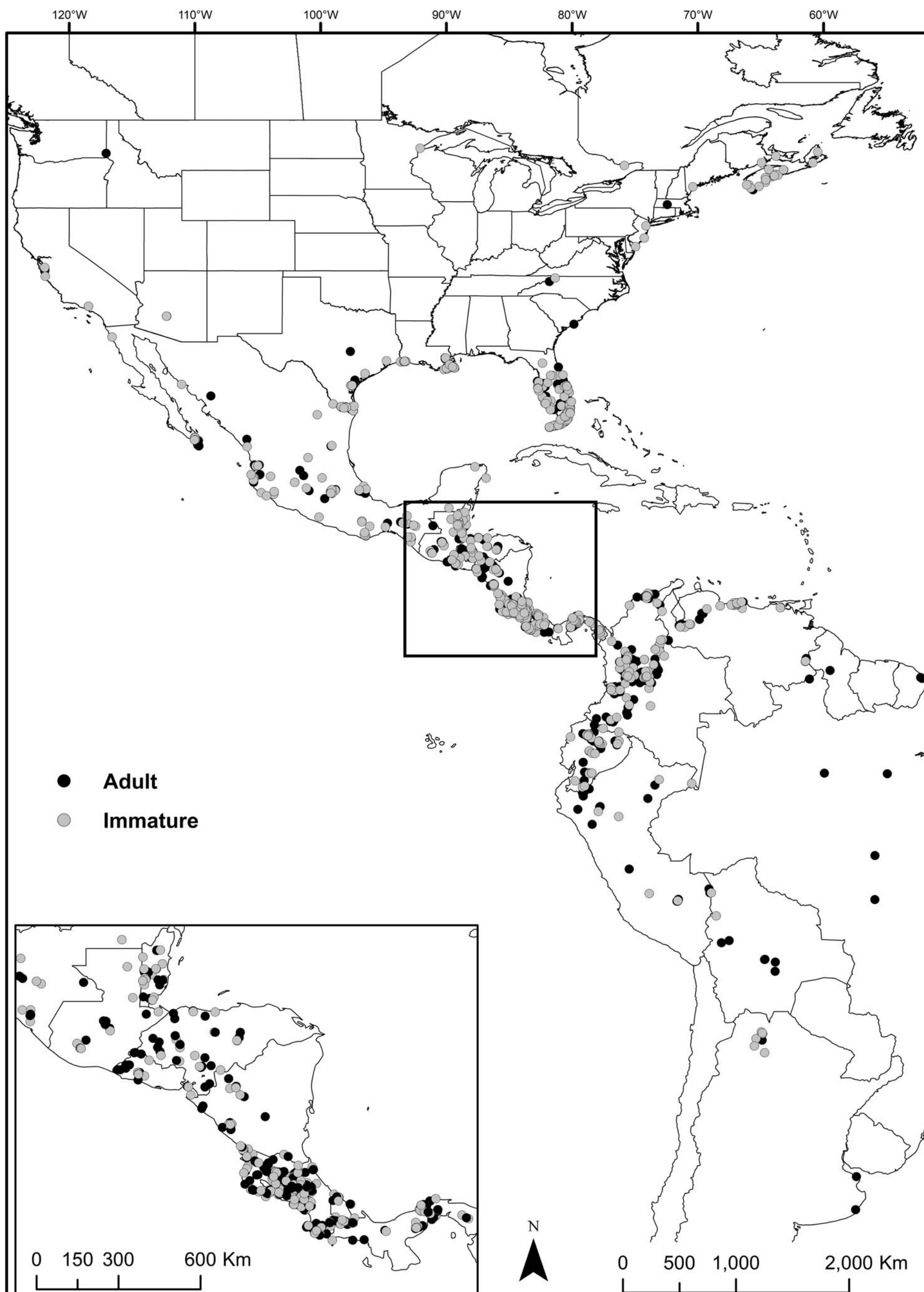

Figure 1. Distribution of eBird sightings of adult and immature Broad-winged Hawks (*Buteo platypterus*) across North, Central and South America, during the winter period, 2002–2020, $n = 2164$ sightings. Inset map shows detailed sightings from southern Mexico/northern Guatemala (~18°) through most of Panama (~7°).

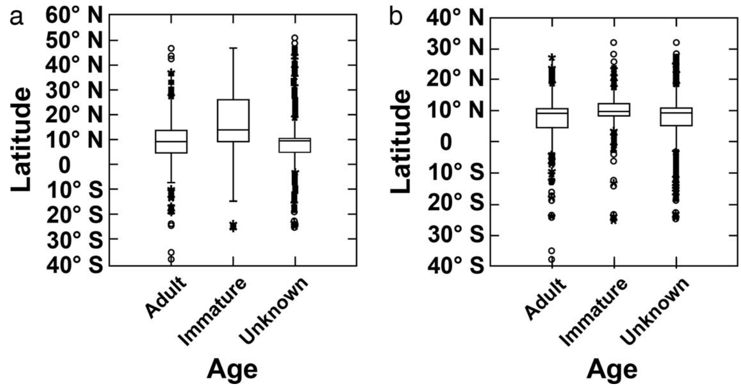

Figure 2. (a) Box plot showing range-wide latitude distribution of adult, immature and unknown age Broad-winged Hawk winter sightings as reported in eBird, 2002–2020, $n = 27{,}961$; (b) Box plot showing restricted (does not include the United States and Canada) latitude distribution of adult, immature and unknown age Broad-winged Hawk sightings in winter, 2002–2020, $n = 25{,}287$. (Each box includes 50% of values with 25% of values above and below the line in the box representing the median latitude. Whiskers (i.e., lines above and below the box) show the range of observed values within 1.5 times the interquartile range. Asterisks are values beyond 1.5 times the interquartile range.) Note: Y-axis scale differs from one graph to the other.

degrees N (Costa Rica) and one north of 25 degrees N largely representing 143 eBird sightings of immatures in Florida (59.1% of the aged birds in Florida; Fig. 1).

Distribution South of the United States. To examine the patterns in the southern part of the Broad-winged Hawk winter distribution only, we re-analyzed winter latitude by age class for eBird sightings excluding those in the United States and Canada (n = 1740). South of United States, winter sightings included more adults (n = 1082, 62.2%) than immatures (n = 658, 37.8%). The mean wintering latitude of adults south of the United States and Canada was significantly farther south than immatures ($F = 1400.12$, df = 2, $P < 0.001$; Fig. 2b, Table S1).

DISCUSSION

Despite a broad overlap in winter distribution by age, immature Broad-winged Hawks showed a more northern winter distribution than adults even when we excluded birds overwintering in the United States and Canada. Immatures dominate winter sightings in the United States and Canada, whereas adults represent a greater proportion of winter sightings in the southern part of the winter range in South America. The clustered distribution of immatures in the United States and Canada may be shaped by the geography of the United States, particularly in the Florida peninsula. Broad-winged Hawks in Florida may represent birds wind-drifted to the east during migration that remained on the peninsula due to their aversion to cross water (Bildstein 2006, Goodrich et al. 2020). Because immature raptors are more susceptible to wind drift and less experienced in migration (Bildstein 2006, Newton 2008), more young birds may end up in Florida.

Migratory short-stopping behavior by immature, inexperienced Broad-winged Hawks that have depleted migration fuel reserves also may play a factor in the age distribution. Juvenile raptors tend to have lower fat reserves than adults (Yosef et al. 2002), so they may be more prone to stop short of adult wintering latitudes as has been documented in a small sample of satellite-tagged birds (McCabe et al. 2020).

Wind drift by immatures on migration also could result in immatures having different migration routes compared to adults (Bildstein 2006, Newton 2008). Capitolo et al. (2020) tracked five juveniles trapped in California into the Baja region of western Mexico and suggested these birds may have wintered on the Baja peninsula. Although we do not know if many adults migrate to the Baja peninsula, this region is north of the primary wintering latitude for Broad-winged Hawks (McCabe et al. 2020, Goodrich et al. 2020). And, like birds wintering in Florida, western Broad-winged Hawks migrating to the Baja peninsula may remain for the winter rather than moving north to leave the peninsula. With lower fat reserves, wind-drifted immatures could be less likely to retrace their path north to continue to main wintering areas as is suggested to occur in Florida. Further data on numbers and age-ratios of Baja-wintering Broad-winged Hawks is needed to examine if age and number of birds wintering on the Baja peninsula is dominated by the immature age class.

Bildstein (2006) suggested that immature raptors may be more inclined to modify migration behavior if there is an increase in prey availability along their migration route or a favorable change in environmental conditions. In

McCabe et al. (2020), several adult birds showed high fidelity to the same winter area for up to three winters of monitoring, suggesting they may not deviate from known wintering areas once they are established. Immatures with no set destination could be more likely to stop where prey are abundant, which could explain the clusters of sightings in the United States and Canada.

Migration ecology and wintering behavior of Neotropical migrant raptors such as the Broad-winged Hawk has not been well studied. Differences in migration connectivity among populations could influence the winter distribution pattern shown in this study. For example, adults nesting in Alberta had a more easterly winter range than adults nesting in Pennsylvania (McCabe et al. 2020). If adults and immatures from the same population winter at distinctly different latitudes, yet different nesting populations move different distances, this could result in the broad overlap of age classes observed in this study.

The Broad-winged Hawk age class distribution in winter contrasts with that reported in many other raptors. For several raptors, immatures winter farther south compared to adults possibly due to social dominance of the adults and the need for adults to stay closer to breeding areas so they can return sooner in the spring, in order to secure their breeding territories (Kerlinger 1989, Newton 2008). This wintering pattern was observed for Ospreys (*Pandion haliaetus*; Kjellén 1994), Swainson's Hawks (*Buteo swainsoni*; Jaramillo 1993), Sharp-shinned Hawks (Goodrich et al. 2012), Red-tailed Hawks (*Buteo jamaicensis*; Morrison and Baird 2016), and Snowy Owls (*Bubo scandiacus*; Kerlinger and Lein 1985), although adult and immature Swedish Ospreys and Eurasian Buzzards (*Buteo buteo*) wintered at similar latitudes (Kjellén et. al. 2001, Hake et al. 2003).

If migratory short-stopping increases in a changing climate, as has been shown for the Red-tailed Hawk (Paprocki et al. 2017), increasing numbers of Broad-winged Hawks could be recorded wintering in the United States, with immatures likely responding more readily. We did not document any increase in the proportion of immatures in United States in more recent years. However, diligent reporting (in eBird) of age class of birds sighted in winter may assist in tracking this response.

The wintering latitude patterns by age observed in this study should be verified with studies using marked or tagged birds. Migration distance and winter latitude, as well as overwinter behavior and survival, should be examined for both age classes to fully understand implications of different wintering areas. Such data are important for fine-tuning conservation priorities for this species. For example, adults may be more susceptible than immatures to threats to South American tropical forests (Cuadros et al. 2021). Research on individually marked birds from different nesting regions also could further illuminate our understanding of migration connectivity and age class differences.

The eBird database (eBird 2021) provided an extensive data source on Broad-winged Hawk winter distribution that is not available from banding records or other surveys. Current eBird data could be improved further with greater attention by birders to recording descriptors including age and habitat in their checklists (Sullivan et al. 2017). We recognize that the eBird reports can be less numerous in some countries, and this may have affected our results although in part of the winter range (Central America south through Colombia) we found abundant records. Although data quality and usage concerns exist, the extensive data available to researchers in the eBird database provides a rich resource for understanding bird distributions. We encourage greater exploration of this citizen science dataset for evaluation of differential wintering or migration behavior in other raptors.

SUPPLEMENTAL MATERIAL (available online). Table S1: Mean and median latitude of Broad-winged Hawk winter sightings reported in eBird by age and region, 2002–2020.

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