Broad-Winged Hawks Overwintering in the Neotropics: Landscape Composition and Threats in Wintering Areas of a Long-Distance Migrant

Authors: Cuadros, Sandra, McCabe, Rebecca A., Goodrich, Laurie J., and Barber, David R.

Source: Journal of Raptor Research, 55(2) : 139-150

Published By: Raptor Research Foundation

URL: https://doi.org/10.3356/0892-1016-55.2.139

J. Raptor Res. 55(2):139–150

BROAD-WINGED HAWKS OVERWINTERING IN THE NEOTROPICS: LANDSCAPE COMPOSITION AND THREATS IN WINTERING AREAS OF A LONG-DISTANCE MIGRANT

SANDRA CUADROS
Acopian Center for Conservation Learning, Hawk Mountain Sanctuary, 410 Summer Valley Road, Orwigsburg, PA 17961 USA
and
Universidad Nacional Agraria La Molina, La Molina 15024, Lima, Perú

REBECCA A. MCCABE, LAURIE J. GOODRICH,[1] AND DAVID R. BARBER
Acopian Center for Conservation Learning, Hawk Mountain Sanctuary, 410 Summer Valley Road, Orwigsburg, PA 17961 USA

ABSTRACT.—The Broad-winged Hawk (*Buteo platypterus*) is an obligate long-distance migrant that breeds in deciduous and mixed forests of North America and migrates to Neotropical regions to overwinter. Despite advances in understanding the breeding ecology and migration of this species, the overwintering period and associated threats remain understudied. We used telemetry data to quantify land cover composition and threats during the overwintering period of seven females affixed with Argos solar-powered transmitters between 2014 and 2018. Broad-winged Hawks in our study nested in Pennsylvania, USA, and overwintered in Colombia, Brazil, and Peru. Overwintering areas varied in size ($\bar{x} = 243.6 \pm 101.2$ km^2) and were composed of evergreen sub-montane forests, lowland non-flooded forests, and lowland flooded evergreen forest. In general, the loss of forest cover in all areas used by Broad-winged Hawks in our study did not exceed 10% of the total overwintering area used, suggesting Broad-winged Hawks may select wintering areas with little forest disturbance. Illegal mining was a common disturbance in areas used by Broad-winged Hawks overwintering in southern Peru, and forest fires were the prevalent disturbance in the overwintering area of Mato Grosso in western Brazil. These results provide the first analysis of land cover composition and threats of Broad-winged Hawks during the overwintering period. Although more data are needed to determine specific habitat selection for this species, our study suggests large forested areas in the Neotropics are key to ensure the conservation of the Broad-winged Hawk during the overwintering period, an understudied stage of its annual cycle.

KEY WORDS: *Broad-winged Hawk*; Buteo platypterus; *Amazon forest*; *Neotropical*; *raptor*; *satellite telemetry*; *winter habitat*.

INDIVIDUOS INVERNANTES DE *BUTEO PLATYPTERUS* EN EL NEOTRÓPICO: COMPOSICIÓN DEL PAISAJE Y AMENAZAS EN ÁREAS DE INVERNADA DE UN MIGRANTE DE LARGA DISTANCIA

RESUMEN.—*Buteo platypterus* es un migrante de larga distancia obligado que cría en bosques deciduos y mixtos de Norteamérica y que migra a regiones neotropicales para invernar. A pesar de los avances para entender la ecología reproductiva y la migración de esta especie, el período de invernada y las amenazas asociadas durante este periodo no han sido suficientemente estudiadas. Entre 2014 y 2018 usamos datos de telemetría para cuantificar la composición de la cobertura del suelo y las amenazas durante el período de invernada en siete hembras de *B. platypterus* provistas con transmisores solares Argos. En nuestro estudio, *B. platypterus* anidó en Pensilvania, EEUU, e invernó en Colombia, Brasil y Perú. Las áreas de invernada variaron en tamaño ($\bar{x} = 243.6 \pm 101.2$ km^2) y estuvieron compuestas por bosques sub-montanos siempre-verdes, bosques no inundables de tierras bajas y bosques siempre-verdes inundables de tierras bajas. En general, la pérdida de cobertura boscosa en todas las áreas usadas por *B. platypterus* en nuestro estudio no excedió el 10% del área total de invernada usada, sugiriendo que *B. platypterus* puede seleccionar áreas de invernada en

[1] Email address: goodrich@hawkmountain.org

bosques poco perturbados. La minería ilegal fue un disturbio común en las áreas usadas por los individuos de *B. platypterus* invernando en el sur de Perú, y los fuegos del bosque fue el disturbio predominante en el área de invernada de Mato Grosso, en el oeste de Brasil. Estos resultados brindan el primer análisis de la composición de la cobertura del suelo y de las amenazas de *B. platypterus* durante el período de invernada. Aunque se necesitan más datos para determinar la selección específica de hábitat para esta especie, nuestro estudio sugiere que grandes áreas de bosque en el Neotrópico son clave para asegurar la conservación de *B. platypterus* durante el período de invernada, una etapa poco estudiada de su ciclo anual.

[Traducción de los autores editada]

INTRODUCTION

The complexity of migration and the variety of areas occupied during the full annual cycle of migrating birds pose a challenge in the conservation of raptor populations (Céspedes and Bayly 2018). At least 60% of all raptors undergo a biannual migration (Bildstein 2006), with 32 species of raptors migrating from North to Central and South America (e.g., Swainson's Hawks [*Buteo swainsoni*], Ospreys [*Pandion haliaetus*], Peregrine Falcons [*Falco peregrinus*], Swallow-tailed Kites [*Elanoides forticatus*], Mississippi Kites [*Ictinia mississippiensis*]; Bildstein 2006). These long-distance Neotropical migrants are exposed to many threats throughout their annual cycle such as hunting, pollution in stopover and overwintering sites, and habitat destruction and fragmentation in their breeding and overwintering areas (Newton 2004, Sanderson et al. 2006, Klaassen et al. 2014). Historically, research on migratory species focused on population dynamics of the breeding season and habitat use in temperate and boreal regions (Faaborg et al. 2010a, 2010b). Therefore, our understanding of the overwintering period, especially for long-distance migrants overwintering in the Neotropics, remains limited (Marra et al. 2015, Bayly et al. 2017, Wilson et al. 2018).

Recent research has shown that land-use changes in tropical regions (e.g., expansion of agriculture and cattle ranching) may contribute to the global declines of Neotropical migrants (Taylor and Stutchbury 2016, Kramer et al. 2018, Wilson et al. 2018). Habitat conversion and fragmentation due to human disturbances in the overwintering habitat of Neotropical migrants can reduce overwinter survival or potentially reduce breeding success of surviving individuals (Rockwell et al. 2017). An increasing number of studies of songbirds have addressed the importance of the wintering grounds for survival of migrant bird populations. For example, Wilson et al. (2018) concluded landscape disturbances in the overwintering areas are a limiting factor contributing to population declines of the Canada Warbler (*Cardellina canadensis*). Other studies in songbirds have identified lower survival rates related to availability of quality habitat during the overwintering period (Marra and Holmes 2001, Sillett and Holmes 2002, Martin et al. 2007, Paxton et al. 2017). Studies of raptors breeding in Europe have also suggested the importance of resource availability in their overwintering areas. For example, Lesser Kestrels (*Falco naumanni*) overwintering in the Sahel region showed a strong correlation between first-year survival and rainfall in the overwintering area, due to the increase in prey availability (Mihoub et al. 2010). Other studies in grassland ecosystems show the importance of prey availability (i.e., Wuczyński 2003, Baltag et al. 2013, Limaña et al. 2015) and human disturbance (Woodbridge et al. 1995, Goldstein et al. 1997, Goldstein et al. 1999a, 1999b) in overwintering areas for survival of raptor populations. For example, Swainson's Hawks overwintering in agricultural lands in the Pampas of Argentina were incidentally poisoned with the insecticide Monocrotophos, which killed more than 6000 individuals (Woodbridge et al. 1995, Goldstein et al. 1997, Goldstein et al. 1999a, 1999b). This finding led to a successful agreement banning this insecticide in the region, resulting in reduced overwinter mortality. Unfortunately, studies of winter habitat use by Neotropical migratory raptors remain limited, especially for forest-dwelling species.

The Broad-winged Hawk (*Buteo platypterus*) is a long-distance migrant that breeds across central and eastern North America and nests in continuous mixed deciduous forests (Goodrich et al. 2014). Broad-winged Hawks migrate to the Neotropics and overwinter in Central and South America, with many individuals overwintering in the Amazon basin (Haines et al. 2003, Goodrich et al. 2014, McCabe et al. 2020). Information (e.g., survival, foraging ecology, resource selection) on the overwintering period of the Broad-winged Hawk annual cycle is limited (Thiollay 2007, Goodrich et al. 2014). Broad-winged Hawk populations have undergone declines in the northeast and mid-Atlantic United States (Farmer et al. 2008, Wilson et al. 2012); therefore, it is important to identify factors limiting populations across their geographic distribution to develop reliable range-wide conservation strategies. Some Broad-winged Hawks overwinter in forested regions of the Amazon basin, an area recognized as a global reservoir of biodiversity (Stotz et al. 1996, Steege et al. 2003). However, the Amazon basin has experienced increased anthropogenic disturbance during past decades, including conversion of primary forest to crop production and pasture, resulting in widespread loss of forest cover (Curtis et al. 2018, Carvalho et al. 2019).

In this study, our goals were to: (1) characterize land cover of overwintering areas of Broad-winged Hawks, (2) identify land cover availability and anthropogenic disturbance (i.e., deforestation, illegal mining, forest fires) within the immediate available landscape surrounding Broad-winged Hawk overwintering areas, and (3) summarize the conservation implications of our results. We predicted Broad-winged Hawks would use large, contiguous forest during the winter period, similar to what they use during the breeding season (Goodrich et al. 2014). We expected wintering areas used by Broad-winged Hawks to have low levels of anthropogenic disturbance and include areas with some level of legal protection (i.e., protected areas or indigenous territories) compared to the available landscape.

METHODS

Capture and Telemetry. Adult Broad-winged Hawks were captured and equipped with satellite transmitters during the nesting period in three forested regions of Pennsylvania, United States (40°77′N, 75°59′W; 41°14′N, 75°9′W; and 41°39′N, 79°2′W) from June to July 2014–2018. Nest sites were predominantly found in forest that comprised oaks (*Quercus rubra*, *Q. alba*, *Q. velutina*, and *Q. prinus*), red maple (*Acer rubrum*), hickories (*Carya* spp.), white pine (*Pinus strobus*), and eastern hemlock (*Tsuga canadensis*; McCabe et al. 2019). We used mist nets, and a mechanical Great Horned Owl (*Bubo virginianus*) with playback calls as a lure (Jacobs 1996, McCloskey and Dewey 1999) to trap adult females near nests at least 1–2 wk after young hatched. Sex of individuals was determined based on nesting behavior and weight (Mosher and Matray 1974). All birds received a US Geological Survey aluminum leg band and two plastic color leg bands for individual identification. We attached solar-powered Argos satellite 9.5-g platform transmitter terminals (PTTs; Microwave Telemetry, Inc., Columbia, MD, USA) using the backpack harness method (Steenhof et al. 2006) and 4–6 mm Teflon ribbon (Bally Ribbon Mills, Bally, PA, USA). We deployed satellite tags on individuals with a body weight of $\geq$380 g to ensure the combined tag and harness weight (approximately 11.5 g) did not exceed 3% of the bird's mass (Murray and Fuller 2000, Barron et al. 2010). For this study, we only included females with one complete annual cycle of data, and with known arrival and departure dates from overwintering areas, resulting in a sample size of seven females.

We defined the start and end of the overwintering period following methods in McCabe et al. (2020), with the start of the overwintering periods as the farthest southern location after which all subsequent locations were localized (nondirectional movements) and once no further migration movement occurred. We defined the end of the overwintering period, and the start of spring migration, as the last location prior to northward migration that was $<$32 km from the overwintering area. We filtered overwintering location estimates to include only the most accurate location classes of 3, 2, and 1 ($<$250 m, $<$500 m, and $<$1500 m error, respectively; ARGOS 2017).

Overwintering Areas and Land Cover Composition. We first determined the 95% occurrence distribution for each female's overwintering area using continuous-time movement models in the ctmm package (Fleming et al. 2017) in R 3.5.2 (R Core Team 2018). The occurrence distribution uses locations and the error to estimate where the animal was located over a distribution of times during the sampling period (Fleming et al. 2015, Fleming et al. 2016). This approach is sampling dependent, so it is based on where the animal was located during the study period, and does not require a minimum sample of locations, as opposed to home range estimates based on location probability (Fleming et al. 2015). This method leverages autocorrelation because it reflects where the animal was located and does not interpolate the data to estimate a range (Fleming et al. 2016) and allows for model selection prior to analysis (Fleming et al. 2017). Model selection was based on the Akaike Information Criteria (AIC; Akaike 1974) following Fleming et al. (2017). For each bird, we calculated the error model which then was fitted into the occurrence distribution. Further, we exported the occurrence distributions as shape files in ArcGIS 10.3 (Esri

Table 1. Overwintering areas (occurrence distributions) of adult female Broad-winged Hawks in South America from 2014–2018 ($n=7$). Number of locations represents the total number of locations for the entire overwintering period from October–February.

BIRD ID	YEAR	LOCATION	OVERWINTERING AREA (km^2)	NO. OF LOCATIONS
135760	2014	Mato Grosso, Brazil	10.2	17
146904	2015	Amazonas, Brazil	23.7	34
146902	2015	Boyacá, Colombia	23.7	18
146905	2015	Madre de Dios, Peru	651.8	17
	2016	Madre de Dios, Peru	348.0	13
161202	2016	Madre de Dios, Peru	303.4	16
146909	2016	Amazonas, Peru	442.9	105
	2017	Amazonas, Peru	4.1	128
	2018	Amazonas, Peru	7.2	21
146907	2016	Madre de Dios, Peru	16.3	12
	2017	Madre de Dios, Peru	6.1	21
	2018	Madre de Dios, Peru	3256.9	26

2019) and calculated total area (km^2) of the occurrence distribution for each individual using the Calculate Geometry tool.

For all seven individuals, we used the first year of data to calculate average occurrence distribution ($\pm$ SE) for the overwintering areas using InfoStat 5.13 (Di Rienzo et al. 2001). We estimated the correlation between the number of locations used and the area of the occurrence distribution modeled using the Spearman's rank correlation index between size of the occurrence distribution and the number of locations.

To calculate land cover composition of overwintering areas, we intersected each individual's occurrence distribution polygons with major vegetation types from the Terrestrial Ecoregions (1:7,500,000) shape file product by The Nature Conservancy (TNC; Olson and Dinerstein 2002) in ArcGIS. The TNC layer was used because it standardized ecoregions for all of South America, allowing for comparison among different countries. We grouped land cover types into categories using information on their physiography, phenology, and flood regime (see Supplemental Materials Table S1). The resulting categories included: (1) Yungas montane evergreen rainforest, (2) Sub-montane evergreen rainforest, (3) Lowland non-flooded evergreen rainforest, (4) Lowland flooded evergreen rainforest, (5) Dry Andean scrub and shrub, (6) Other natural vegetation, and (7) Human-altered landscape. Percent cover was calculated for each category listed above, within individual occurrence distributions (hereafter, overwintering area).

Landscape Composition and Threats. To estimate land cover and anthropogenic disturbance surrounding Broad-winged Hawk overwintering areas we calculated the centroid of each bird's occurrence distribution using the Spatial Statistics tool (Esri 2019) in ArcGIS. We then created a 32-km radius buffer (area = 3217 km^2) around each centroid, a measure based on the radius obtained from the largest overwintering area used by a Broad-winged Hawk in our study (area = 3256.9 km^2, radius = 32 km). Due to the small number of location fixes for some individuals (Table 1), we decided to use the 32-km radius buffer to estimate percent of protected areas and anthropogenic disturbances surrounding (i.e., available landscape) Broad-winged Hawk overwintering areas as opposed to using the overwintering areas themselves. Given the significant correlation between the number of locations per bird and the size of overwintering areas (Spearman 0.6, $P = 0.04$), using the overwintering areas might have underestimated the percent of protected area and anthropogenic disturbances for individuals with a small number of locations. Hence, using the 32-km radius provides a more comprehensive and standard approach to assess the disturbances in the landscape. Because we aimed to assess the land cover as a percentage in the overwintering areas, this correlation does not interfere with our results.

We used the 32-km radius buffer to calculate the percentage of areas with: (a) some degree of protection (i.e., legally designated areas by governments and indigenous reserves [United Nations Environment Programme–World Conservation Monitoring Centre 2020]), (b) areas impacted by

Table 2. Major land cover types and the percent used by Broad-winged Hawks ($n = 7$) in their overwintering areas in South America from 2014–2018.

Bird ID	Year	Yungas Montane Evergreen Rainforest	Sub-montane Evergreen Rainforest	Lowland Non-flooded Evergreen Rainforest	Lowland Flooded Evergreen Rainforest	Dry Andean Scrub and Shrub	Other Natural Vegetation	Human-altered Landscapes
135760	2014	-	76.7	-	-	-	23.3	-
146904	2015	-	100	-	-	-	-	-
146902	2015	56.4	36.2	-	-	-	-	7.43
146905	2015	-	-	66.6	25.2	-	-	8.2
	2016	-	-	89.2	4.2	-	-	6.6
161202	2016	-	-	82.3	-	-	-	17.7
146909	2016	29.4	-	-	48.1	12.5	10	-
	2017	29.9	-	-	-	-	-	70.1
	2018	51.4	-	-	-	-	3.6	45
146907	2016	-	68.7	-	29.3	-	-	2
	2017	-	61.8	28	9.6	-	-	0.6
	2018	-	72.9	0.9	6.6	-	-	19.6

illegal mining (Red Amazónica de Información Socioambiental Georreferenciada [RAISG] 2019), (c) forest fires (RAISG 2019), and (d) loss of forest cover greater than 30% during 2014–2018 per Forest Global Watch (Hansen et al. 2013). We were not able to assess illegal mining and fire impact assessment for Colombia as this information was only available for the Amazon basin. Finally, we compared land cover composition in the surrounding available landscape (i.e., at 32-km radius) to land cover composition within overwintering areas as derived from telemetry data (using a Pearson's chi-square test in R 3.5.2 (Patefield 1981).

Results

Overwintering Areas and Land Cover Composition. Overwintering areas of Broad-winged Hawks ranged from 10.2 km^2 to 651.8 km^2 ($\bar{x} = 243.6 \pm 101.2$ km^2; $n = 7$ birds [first year of data]; Table 1). All birds overwintered in areas dominated by forests ($\bar{x} = 88.5 \pm 3.6\%$), including sub-montane evergreen rainforests ($\bar{x} = 40.2 \pm 15.9\%$) and lowland non-flooded evergreen rainforests ($\bar{x} = 21.3 \pm 13.8\%$), followed by lowland flooded evergreen rainforest ($\bar{x} = 14.6 \pm 7.4\%$) and Yungas montane evergreen forests ($\bar{x} = 12.3 \pm 8.4\%$). Human-altered landscapes made up only 5% of the land cover ($\bar{x} = 5.0 \pm 2.5\%$), and other natural vegetation contributed to the remaining 6.5% (Table 2, Fig. 1).

Landscape Composition and Threats. The most common available land cover type surrounding overwintering areas was sub-montane evergreen rainforest ($\bar{x} = 38.7 \pm 14.1\%$), followed by human-altered landscapes ($\bar{x} = 18.6 \pm 7.9\%$) and lowland non-flooded evergreen rainforest ($\bar{x} = 17.4 \pm 8.4\%$). Other land cover in the area included lowland flooded evergreen rainforest (10%), Yungas montane evergreen forest (7.1%), and dry Andean scrub and shrub, and other natural vegetation accounted for <4%. Total forest available composed 74.8% of the surrounding landscape. We found no difference between available forest in the surrounding landscape and forest within Broad-winged Hawk overwintering areas (74.8% available vs. 89.7% overwintering areas, chi-square, $P = 0.14$).

Protected areas. The amount of protected areas in the available landscape surrounding overwintering areas of Broad-winged Hawks varied from 0% to 100% ($\bar{x} = 35.8 \pm 13.4\%$). Two of the seven females had wintering ranges outside of protected areas or indigenous territories. Four females wintered in areas containing more than 20% protected areas, and one female stayed almost exclusively (92–100%) in a protected area (Tambopata National Reserve, Peru; Table 3).

Anthropogenic disturbances. Of the six overwintering areas analyzed for illegal mining, four had available landscapes that overlapped with illegal mining areas, two of which had illegal mining disturbances in <20% of the available landscape (Fig. 1). Broad-winged Hawks wintering in Peru ($n = 4$) showed the greatest percentage of overwintering areas impacted by illegal mining ($\bar{x} = 12.3 \pm 7.1\%$), especially within

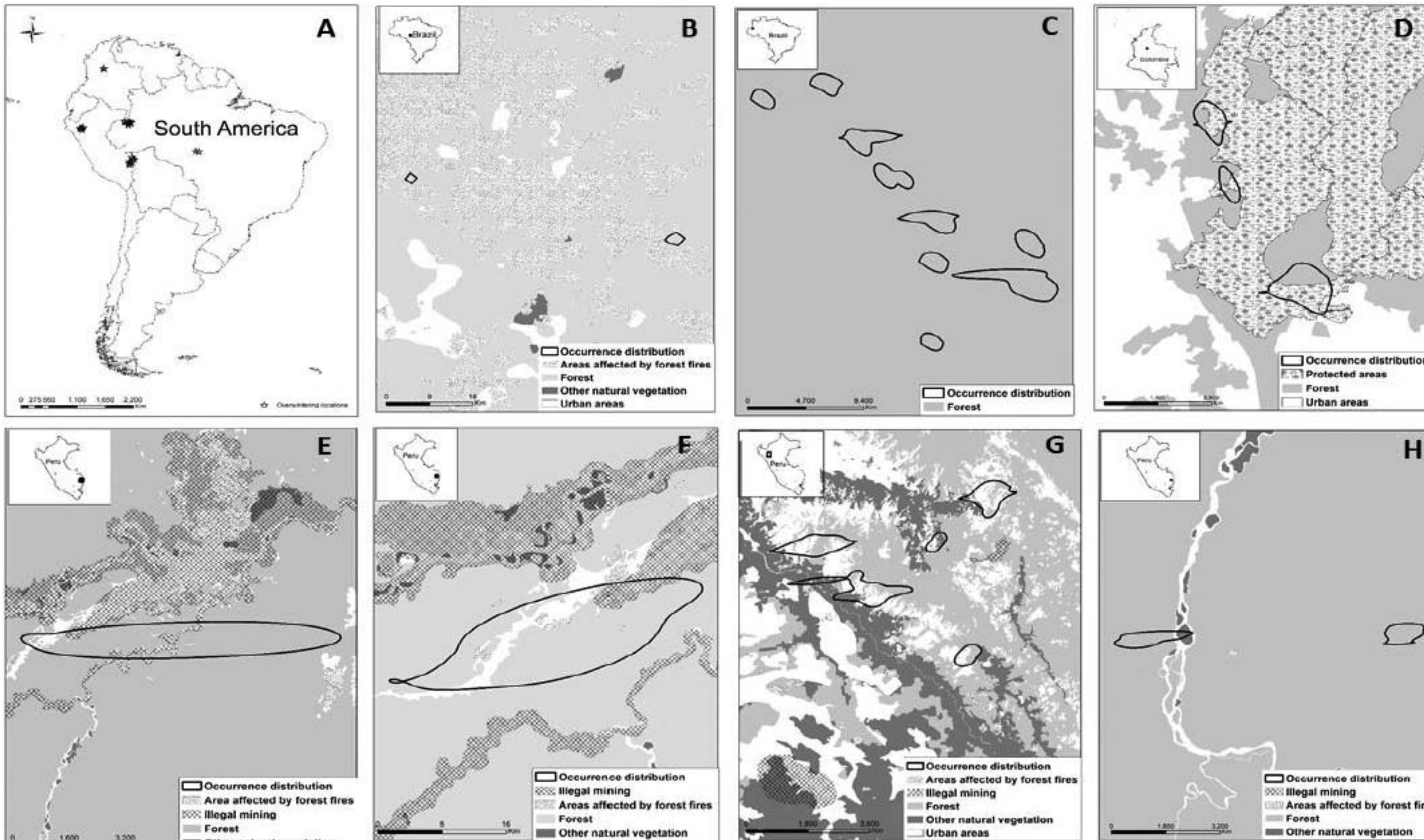

Figure 1. (A) Overwintering areas of Broad-winged Hawks tracked from Pennsylvania, USA, to Brazil, Peru, and Colombia, South America in 2014–2018. (B) Bird 135760, (C) Bird 146904, (D) Bird 146902, (E) Bird 146905, (F) Bird 161202, (G) Bird 146909, and (H) Bird 146907. Overwintering occurrence distributions (black outlined polygons) for the seven adult female Broad-winged Hawks, with land-cover types, anthropogenic disturbances (including illegal mining and areas affected by forest fires 2000–2018), and protected areas.

Table 3. Percent of protected areas and habitat disturbance within Broad-winged Hawk ($n = 7$) overwintering areas and the surrounding available landscape (32-km radius buffer) in South America from 2014–2018.

Bird ID	Year	Protected Areas and Indigenous Territories	Areas Affected by Illegal Mining	Areas Affected by Forest Fires	Tree Cover Loss (>30%)
135760	2014	0.0	0.0	38.2	7.0
146904	2015	45.1	0.0	0.0	0.0
146902	2015	22.0	-	-	1.9
146905	2015	58.0	27.4	2.2	3.0
	2016	6.5	6.9	2.4	3.2
161202	2016	25.2	21.6	1.0	4.5
146909	2016	0.0	0.4	1.0	0.9
	2017	0.0	0.0	1.3	0.8
	2018	0.0	0.1	1.2	0.8
146907	2016	100.0	0.0	0.0	0.3
	2017	92.1	2.4	0.0	0.4
	2018	100.0	0.0	0.0	0.3

the southern region of Madre de Dios. Broad-winged Hawks overwintering in Brazil ($n = 2$) did not appear to use areas affected by illegal mining. Available landscape affected by forest fires represented <5% for five females, while one individual (Bird ID #135760) in 2014 overwintered in an area progressively impacted by forest fire (38% of the area affected from 2000 to 2017; Table 3). Deforestation occurred in all Broad-winged Hawk overwintering areas in our study ($\bar{x} = 2.5 \pm 0.9\%$), with the greatest forest cover loss occurring in Mato Grosso, Brazil (Bird ID #135760; Table 3). Conversely, the other bird overwintering in Brazil (Bird ID # 146904) had the lowest value of tree cover loss (0.01%).

DISCUSSION

Broad-winged Hawks remained in discrete areas throughout the overwintering period and as predicted, wintered predominantly in large continuous evergreen forests in the Amazon basin. Overwintering areas were dominated by two forest types, submontane and lowland non-flooded rainforests. These land cover types are widely found throughout the Amazon rainforest and are a component of the habitat of many other congeneric year-round resident raptors (e.g., Short-tailed Hawk [*Buteo brachyurus*], Roadside Hawk [*Rupornis magnirostris*], Gray-lined Hawk [*B. nitidus*], and White-throated Hawk [*B. albigula*]; Schulenberg et al. 2010). Meller and Bencke (2012) recorded Broad-winged Hawks in Brazil using *terra firme* forests (e.g., lowland non-flooded evergreen rainforests). Interestingly, these types of forest were the second most common forest type in our study. Other authors have reported the species in similar montane humid well-preserved forests of Argentina (Roesler and Mazar Barnett 2004, Klavins et al. 2012). In addition, Kilpp et al. (2018) reported records of Broad-winged Hawks in Andean forests based on eBird records and other unpublished data. EBird data may not be representative of the entire winter range due to the site bias inherent in birdwatching proximity to roads and edges. Vilella and Hengstenberg (2006) found similar vegetation types used by radio-tagged Broad-winged Hawks of the nonmigratory subspecies in Puerto Rico (*B. platypterus brunnescens*), although their study concluded adult Broad-winged Hawks mostly used closed sub-montane evergreen forests, while inexperienced juveniles preferred areas with easily accessible prey (e.g., open areas, roads).

In this study, we only report on landscape composition of overwintering areas for adult females wintering in South America; landscape use could vary by age, sex, and region. For example, Meller and Bencke (2012) recorded two immature Broad-winged Hawks in southern Brazil, which represented the southernmost published records of the wintering areas known for the species. As discussed by Farmer et al. (2008), there is a tendency in some raptors for juveniles to overwinter farther south than adults. However, this hypothesis remains to be tested as recent documented records in eBird (2020) show adults in locations farther south than the ones reported by Meller and Bencke (2012). Whether these records correspond to overwintering areas regularly used by the species, as suggested by Kilpp et al. (2018), or to cases of vagrancy will require further research.

Furthermore, observations made by Thiollay (2007) in the French Guianas indicate Broad-winged Hawks rarely use interior primary forests and are more common in coastal areas and forest edges. Although the results from our study do not exclude the use of secondary forests and human-disturbed areas, the most common land cover types observed in this study are less-disturbed interior forests. This finding was consistent with the records compiled by other authors (e.g., Roesler and Mazar Barnett 2004, Meller and Bencke 2012), who conclude that the species is primarily associated with dense primary forests. Our findings suggest Broad-winged Hawks avoid urban and open areas during the winter period, consistent with behavior during the breeding period (Goodrich et al. 2014, McCabe 2016).

Many studies analyzing overwintering areas in raptors use the home range approach (e.g., Higuchi et al. 2006, Washburn et al. 2014, Domenech et al. 2015, Hadjikyriakou et al. 2020). However, we were unable to use home range analyses given the limited number of location fixes per bird. Our inability to obtain daily fixes was likely due to feathers covering the solar panels on the transmitters, or the lack of sunlight reaching the solar panels due to dense forest canopy and the below-canopy foraging behavior of Broad-winged Hawks (Titus and Mosher 1987, Thiollay 2007, Goodrich et al. 2014). Thus, we were unable to compare the size of Broad-winged Hawk overwintering areas to home ranges of other raptors wintering in the tropics. The low detectability of Broad-winged Hawks within more contiguous forest areas could diminish our ability to use anecdotal or observation-only data sources; thus, further research using satellite telemetry may be needed. Alternatives including road surveys, ground surveys in already known overwintering areas (derived from telemetry data), the use of camera traps, drones or other autonomous recording units may be useful to provide reliable information on overwintering behavior in remote areas.

Overwintering areas of Broad-winged Hawks overlapped to some degree with protected lands. Unfortunately, protected areas may not alleviate the degree of threats experienced because lack of law enforcement may fail to provide sufficient protection. For example, one individual (Bird ID #135760) was potentially displaced by wide-scale forest fires and logging in the Brazilian Amazon during the winter of 2014–2015 (Hansen et al. 2013, NASA Earth Observations 2014), and displayed a more erratic pattern of winter movements compared to the other six birds. However, the lack of multiple years of data limits the analysis of long-term consequences of these disturbances. Given the vast diversity of raptors in the Neotropics, displaced individuals could be moving to potentially occupied territories and thus forced into lower quality habitats, or forced to move continually, possibly affecting their survival (Rockwell et al. 2017).

Most Broad-winged Hawks in our study (86%) overwintered in areas affected by forest fires and deforestation. Deforestation is a key threat to wildlife in all countries within the Amazon basin (Laurance et al. 2002). In particular, illegal logging occurs within indigenous territories mainly due to the lack of law enforcement and the difficulty in accessing these areas (Finer et al. 2015a). Legal expansion of agriculture (e.g., commodity-driven plantations of soy and corn in Brazil and Bolivia, slash-and-burn agriculture in Peru and Colombia) also remains a threat in the region (Curtis et al. 2018). Recent political decisions in the Amazon regions are promoting continued deforestation through the conversion of forest to agriculture and cattle ranching (Carvalho et al. 2019). These policies are especially worrisome in light of the recent forest fires that ravaged the Amazon in 2019, with drastic effects on the landscape further reducing tree cover (Finer and Mamani 2019, Lovejoy and Nobre 2019).

Additionally, in the southern Peruvian Amazon, illegal gold mining may pose a threat to overwintering areas used by Broad-winged Hawks. This activity has been occurring inside the Tambopata National Reserve (Asner and Tupayachi 2017), a key protected area of Peru that was used by three of the seven birds in our study. Unfortunately, poor law enforcement and lack of sufficient resources has allowed the expansion of illegal mining in the area, and is beginning to affect core areas of the reserve (Finer et al. 2015b, 2016). This is an important, yet understudied, threat as top predators are especially vulnerable to biomagnification of non-biodegradable substances (Eisler 1987, Barnes et al. 2019). Shrum (2009) assessed the concentration of mercury in various resident and overwintering raptors in the Tambopata National Reserve and found that some individuals of Roadside Hawks (*Rupornis magnirostris*), Barred Forest Falcons (*Micrastur ruficollis*), and Broad-winged Hawks had values of mercury (i.e., $\geq$9 mg/kg) in their feathers that suggested chronic exposure. Exposure to mercury can result in decreased reproductive success, abnormal behavior, reduced survival, and other neurological functions in birds (Whitney and Cristol 2017). Furthermore, mercury may affect migration, although this remains under studied (Seewagen 2010).

The role of disturbance in the overwintering range as a population limiting factor for the Broad-winged Hawk and other migrant raptors is of paramount importance for long-term conservation, especially given the winter site fidelity of many raptors (Plumpton and Andersen 1997, Shiu et al. 2006, McKinley and Mattox 2010, Rozhon 2018). At least three Broad-winged Hawks in our study overwintered in the same general area in subsequent years (within 16–80 km). Although some studies have reported plasticity in habitat use by raptors during the overwintering period (Plumpton and Andersen 1997), in this study all birds showed affinity to largely intact, less-disturbed forest. The recent declines in many Neotropical migratory species have led to increased efforts to improve conservation strategies across the species' range (Mehlman et al. 2005, North American Bird Conservation Initiative Canada 2016); however, the reliance of Broad-winged Hawks on large areas of forest and the continued threats to these habitats within the Amazon basin suggest further conservation attention is needed.

SUPPLEMENTAL MATERIAL (available online). Figure S1: Major land cover types and specific land cover/ vegetation types from the Terrestrial Ecoregions layer by The Nature Conservancy (Olson and Dinerstein 2002) used for the overwintering areas of Broad-winged Hawks.

ACKNOWLEDGMENTS

We thank the landowners who granted access to nest sites for trapping, including the Pennsylvania Department of Conservation and Natural Resources (PA DCNR) and Pennsylvania Game Commission, and the field assistants, particularly Z. Bordner. S. Cuadros was a conservation science trainee at Hawk Mountain Sanctuary Association in spring 2019 when the analyses were initiated. Trapping, handling, and processing of birds were under permits from the Pennsylvania Game Commission (Permit #32125, L. Goodrich) and the US Geological Survey Bird Banding Laboratory (Permit #22749, L. Goodrich). Funding was provided by State Wildlife Grants Pennsylvania Game Commission, The Kittatinny Coalition, the Wild Resource Conservation Fund of PA DCNR, East Stroudsburg University, ATAS Inc., D. & D. Allison, D. & P. McNicholas, Hawk Mountain members and other private donors. This is Hawk Mountain Conservation Science Contribution number 332.

LITERATURE CITED

Akaike, H. (1974). A new look at the statistical model identification. IEEE Transactions on Automatic Control AC-19:716–723.

ARGOS (2017). Argos User's Manual. CLS, Toulouse, France. https://www.argos-system.org/manual/.

Asner, G. P., and R. Tupayachi (2017). Accelerated losses of protected forests from gold mining in the Peruvian Amazon. Environmental Research Letters 12:094004. https://iopscience.iop.org/article/10.1088/1748-9326/aa7dab.

Baltag, E. S., V. Pocora, L. Sfica, and L. E. Bolboaca (2013). Common Buzzard (*Buteo buteo*) population during winter season in north-eastern Romania: The influences of density, habitat selection, and weather. Ornis Fennica 90:186–192.

Barnes, J. G., G. E. Doney, M. A. Yates, W. S. Seegar, and S. L. Gerstenberger (2019). A broad scale assessment of mercury contamination in Peregrine Falcons across the northern latitudes of North America. Journal of Raptor Research 53:1–13.

Barron, D. G., J. D. Brawn, and P. J. Weatherhead (2010). Meta-analysis of transmitter effects on avian behavior and ecology. Methods in Ecology and Evolution 1:180–187.

Bayly, N. J., K. V. Rosenberg, W. E. Easton, C. Gómez, J. Carlisle, D. N. Ewert, A. Drake, and L. J. Goodrich (2017). Major stopover regions and migratory bottlenecks for Nearctic-Neotropical land birds within the Neotropics: A review. Bird Conservation International 8:1–26.

Bildstein, K. L. (2006). Migrating Raptors of the World: Their Ecology and Conservation. Cornell University Press, Ithaca, NY, USA.

Carvalho, W. D., K. Mustin, R. R. Hilário, I. M. Vasconcelos, V. Eilers, and P. M. Fearnsideg (2019). Deforestation control in the Brazilian Amazon: A conservation struggle being lost as agreements and regulations are subverted and bypassed. Perspectives in Ecology and Conservation 17:122–130.

Céspedes, L. N., and N. J. Bayly (2018). Over-winter ecology and relative density of Canada Warbler *Cardellina canadensis* in Colombia: The basis for defining conservation priorities for a sharply declining long-distance migrant. Bird Conservation International 29:232–248. doi:10.1017/S0959270918000229.

Curtis, P. G., C. M. Slay, N. L. Harris, A. Tyukavina, and M. C. Hansen (2018). Classifying drivers of global forest loss. Science 361:1108–1111.

Di Rienzo, J. A., M. Balzarini, F. Casanoves, L. A. Gonzalez, M. Tablada, and C. W. Robledo (2001). InfoStat: Software estadístico. Universidad Nacional de Córdoba, Córdoba, Argentina.

Domenech, R., B. E. Bedrosian, R. H. Crandall, and S. A. Vincent (2015). Space use and habitat selection by adult migrant Golden Eagles wintering in the western United States. Journal of Raptor Research 49:429–440.

eBird (2020). An online database of bird distribution and abundance. eBird, Ithaca, NY, USA. http://www.ebird.org.

Eisler, R. (1987). Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85 (1.10). USDA Fish and Wildlife Service, Laurel, MD, USA.

Esri (2019). ArcGIS desktop: Release 10. Environmental Systems Research Institute, Redlands, CA, USA.

Faaborg, J., R. T. Holmes, A. D. Anders, K. L. Bildstein, K. M. Dugger, S. A. Gauthreaux, P. Heglund, K. A. Hobson, A. E. Jahn, D. H. Johnson, S. C. Latta, et al. (2010a). Conserving migratory land birds in the New World: Do we know enough? Ecological Applications 20:398–418.

Faaborg, J., R. T. Holmes, A. D. Anders, K. L. Bildstein, K. M. Dugger, S. A. Gauthreaux, P. Heglund, K. A. Hobson, A. E. Jahn, D. H. Johnson, S. C. Latta, et al. (2010b). Recent advances in understanding migration systems of New World land birds. Ecological Monographs 80:3–48.

Farmer, C. J., R. J. Bell, B. Drolet, L. J. Goodrich, E. Greenstone, D. Grove, D. J. T. Hussel, D. Mizrahi, F. J. Nicoletti, and J. Sodergren (2008). Trends in autumn counts of migratory raptors in northeastern North America, 1974–2004. In State of North America's Birds of Prey (K. L. Bildstein, J. P. Smith, E. Ruelas Inzunza, and R. R. Veit, Editors). Series in Ornithology No. 3. Nuttall Ornithological Club, Cambridge, MA, USA, and The American Ornithologists' Union, Washington, DC, USA. pp. 179–215.

Finer, M., C. N. Jenkins, M. A. Blue Sky, and J. Pine (2015a). Logging concessions enable illegal logging crisis in the Peruvian Amazon. Scientific Reports 4:4719.

Finer, M., and N. Mamani (2019). Fires and Deforestation in the Brazilian Amazon. Monitoring of the Andean Amazon Project: 109. Washington, DC, USA.

Finer, M., S. Novoa, and T. Olexy (2016). Illegal Gold Mining Penetrates Deeper into Tambopata National Reserve. Monitoring of the Andean Amazon Project: 24. Washington, DC, USA.

Finer, M., S. Novoa, C. Snelgrove, and N. Peña (2015b). Confirming an Illegal Gold Mining Invasion of the Tambopata National Reserve (Madre de Dios, Peru) [High-Resolution View]. Monitoring of the Andean Amazon Project: 21. Washington, DC, USA.

Fleming, C. H., W. F. Fagan, T. Mueller, K. A. Olson, P. Leimgruber, and M. Calabrese (2015). Rigorous home range estimation with movement data: A new auto correlated kernel density estimator. Ecology 96:1182–1188.

Fleming, C. H., W. F. Fagan, T. Mueller, K. A. Olson, P. Leimgruber, and M. Calabrese (2016). Estimating where and how animals travel: An optimal framework for path reconstruction from auto correlated tracking data. Ecology 97:576–582.

Fleming, C. H., D. Sheldon, E. Gurarie, W. F. Fagan, S. LaPoint, and J. M. Calabrese (2017). Kálmán filters for continuous-time movement models. Ecological Informatics 40:8–21.

Goldstein, M. I., T. E. Lacher, B. Woodbridge, M. J. Bechard, S. B. Canavelli, M. E. Zaccagnini, G. P. Cobb, E. J. Scollon, R. Tribolet, and M. J. Hooper (1999b). Monocrotophos-induced mass mortality of Swainson's Hawks in Argentina, 1995–96. Ecotoxicology 8:201–214.

Goldstein, M. I., T. E. Lacher, M. E. Zaccagnini, M. L. Parker, and M. J. Hooper (1999a). Monitoring and assessment of Swainson's Hawks in Argentina following restrictions on monocrotophos use, 1996–97. Ecotoxicology 8:215–224.

Goldstein, M. I., B. Woodbridge, M. E. Zaccagnini, and S. B. Canavelli (1997). An assessment of mortality of Swainson's Hawks on wintering grounds in Argentina. Journal of Raptor Research 30:106–107.

Goodrich, L. J., S. T. Crocoll, and S. E. Senner (2014). Broad-winged Hawk (*Buteo platypterus*). In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.brwhaw.01.

Hadjikyriakou, T. G., C. Kassara, L. R. de Roland, S. Giokas, N. Tsiopelas, A. Evangelidis, R. Thorstrom, and A. N. G. Kirschel (2020). Phenology, variation in habitat use, and daily activity patterns of Eleonora's Falcon overwintering in Madagascar. Landscape Ecology 5:159–172.

Haines, A. M., M. J. McGrady, M. S. Martell, J. Dayton, M. Blake Henke, and W. S. Seegar (2003). Migration routes and wintering locations of Broad-winged Hawks tracked by satellite telemetry. Wilson Bulletin 115:166–169.

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, et al. (2013). High-resolution global maps of 21st-century forest cover change. Science 342:850–53. earthenginepartners.appspot.com/science-2013-global-forest.

Higuchi, H., H. Shiu, H. Nakamura, A. Uematsu, K. Kuno, M. Saeki, M. Hotta, K. Tokita, E. Moriya, E. Morishita, and M. Tamura (2006). Migration of Honey-buzzards *Pernis apivorus* based on satellite tracking. Ornithological Science 4:109–115.

Jacobs, E. A. (1996). A mechanical owl as a trapping lure for raptors. Journal of Raptor Research 30:31–32.

Kilpp, J. C., P. Cruz, M. E. Iezzi, D. Varela, and U. Balza (2018). Determining the wintering range of Broad-winged Hawk (*Buteo platypterus*) in South America using citizen-science database. Ornitología Neotropical 29:337–342.

Klaassen, R. H., M. Hake, R. Strandberg, B. J. Koks, C. Trierweiler, K. M. Exo, F. Bairlein, and T. Alerstam (2014). When and where does mortality occur in migratory birds? Direct evidence from long-term satellite tracking of raptors. Journal of Animal Ecology 83:176–84.

Klavins, J., M. Huck, M. Rotundo, and E. Fernández-Duque (2012). Trampa-cámara descubre el primer aguilucho alas anchas *Buteo platypterus* en el chaco argentino. Cotinga 34:57–59.

Kramer, G. R., D. E Andersen, D. A. Buehler, P. B. Wood, S. M. Peterson, J. A. Lehman, K. R. Aldinger, L. P. Bulluck, S. Harding, J. A. Jones, J. P. Loegering, et al. (2018). Population trends in Vermivora warblers are linked to strong migratory connectivity. Proceeding of the National Academy of Sciences 115(14):192–200.

Laurance, W. F., T. E. Lovejoy, H. L. Vasconcelos, E. M. Bruna, R. K. Didham, P. C. Stouffer, C. Gascon, R. O. Bierregaard, S. G. Laurance, and E. Sampaio (2002). Ecosystem decay of Amazonian forest fragments: A 22-year investigation. Conservation Biology 13:605–618.

Limaña, R., B. Arroyo, J. Terraube, M. McGrady, and F. Mougeot (2015). Using satellite telemetry and environmental niche modelling to inform conservation targets for a long-distance migratory raptor in its wintering grounds. Oryx 49:329–337.

Lovejoy, T. E., and C. Nobre (2019). Winds of will: Tipping change in the Amazon. Science Advances 5:eaba2949. DOI:10.1126/sciadv.aba2949.

Marra, P. P., E. B. Cohen, S. R. Loss, J. E. Rutter, and C. M. Tonra (2015). A call for full annual cycle research in animal ecology. Biology Letters 11:20150552. https://doi.org/10.1098/rsbl.2015.0552.

Marra, P. P., and R. T. Holmes (2001). Consequences of dominance mediated habitat segregation in American Redstarts during the nonbreeding season. The Auk 118:92–104.

Martin, T. G., I. Chadès, P. Arcese, P. P. Marra, H. P. Possingham, and D. R. Norris (2007). Optimal conservation of migratory species. PLoS One 2(8):e751. https://doi.org/10.1371/journal.pone.0000751.

McCabe, R. A. (2016). Nesting ecology of Broad-winged Hawks in eastern Pennsylvania. M.S. thesis. East Stroudsburg University, East Stroudsburg, PA, USA.

McCabe, R. A., L. J. Goodrich, D. R. Barber, T. L. Master, J. L. Watson, E. M. Bayne, A. L. Harrison, P. P. Marra, and K. L. Bildstein (2020). Satellite tracking reveals age and origin-differences in migration ecology of two populations of Broad-winged Hawks (*Buteo platypterus*). Wilson Journal of Ornithology 132(2):1–14.

McCabe, R. A., L. J. Goodrich, T. L. Master, and Z. Bordner (2019). Broad-winged Hawk nesting behavior in forested landscapes of Pennsylvania. Journal of Raptor Research 53:293–308.

McCloskey, J. T., and S. R. Dewey (1999). Improving the success of a mounted Great Horned Owl lure for trapping Northern Goshawks. Journal of Raptor Research 33:168–169.

McKinley, J. O., and B. Mattox (2010). Winter site fidelity of migratory raptors in southwestern Idaho. Journal of Raptor Research 44:240–243.

Mehlman, D. W., S. E. Mabey, D. N. Ewert, C. Duncan, B. Abel, D. Cimprich, R. D. Sutter, and M. Woodrey (2005). Conserving stopover sites for forest-dwelling migratory land birds. The Auk 122:1281–1290.

Meller, D. A., and G. A. Bencke (2012). First record of the Broad-winged Hawk *Buteo platypterus* in southern Brazil, with a compilation of published records for the country. Revista Brasileira de Ornitologia 20:75–80.

Mihoub, J., O. Gimenez, P. Pilard, and F. Sarrazin. (2010). Challenging conservation of migratory species: Sahelian rainfalls drive first-year survival of the vulnerable Lesser Kestrel *Falco naumanni*. Biological Conservation 143:839–847.

Mosher, J. A., and P. F. Matray (1974). Size dimorphism: A factor in energy savings for Broad-winged Hawks. The Auk 91:325–341.

Murray, D. L., and M. R. Fuller (2000). A critical review of the effects of marking on the biology of vertebrates. In Research Techniques in Animal Ecology: Controversies and Consequences (L. Boitani and T. K. Fuller, Editors). Columbia University Press, New York, NY, USA. pp. 15–64.

NASA Earth Observations (2014). Active Fires. https://neo.sci.gsfc.nasa.gov/view.php?datasetId=MOD14A1_M_FIRE.

Newton, I. (2004). Population limitation in migrants. Ibis 146:197–226.

North American Bird Conservation Initiative Canada (2016). The State of North America's Birds. Environment and Climate Change Canada, Ottawa, ON, Canada.

Olson, D. M., and E. Dinerstein (2002). The Global 200: Priority ecoregions for global conservation. Annals of the Missouri Botanical Garden 89:125–126. http://maps.tnc.org/gis_data.html.

Patefield, W. M. (1981). Algorithm AS159. An efficient method of generating random r x c tables with given row and column totals. Applied Statistics 30:91–97.

Paxton, E. H., S. L. Durst, M. K. Sogge, T. J. Koronkiewicz, and K. L. Paxton (2017). Survivorship across the annual cycle of a migratory passerine, the Willow Flycatcher. Journal of Avian Biology 48:1126–1131.

Plumpton, D. L., and D. E. Andersen (1997). Habitat use and time budgeting by wintering Ferruginous Hawks. The Condor 99:888–893.

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Red Amazónica de Información Socioambiental Georreferenciada (RAISG) (2019). https://www.amazoniasocioambiental.org/es/mapas/.

Rockwell, S. M., J. M. Wunderle, Jr., T. S. Sillett, C. I. Bocetti, D. N. Ewert, D. Currie, J. D. White, and P. P. Marra (2017). Seasonal survival estimation for a long-distance migratory bird and the influence of winter precipitation. Oecologia 183:715–726.

Roesler, I., and J. Mazar Barnett (2004). Nuevos registros del aguilucho de alas anchas (*Buteo platypterus*) en Argentina. Hornero 19:37–40.

Rozhon, G. C. (2018). Sex-specific habitat selection of Rough-legged Hawks (*Buteo lagopus*) wintering in western North America. M.S. thesis. Humboldt State University, Arcata, CA, USA.

Sanderson, F. J., P. F. Donald, D. J. Pain, I.J. Burfield, and F. P. J. VanBommel (2006). Long-term population declines in Afro-Palearctic migrant birds. Biological Conservation 131:93–105.

Schulenberg, T. S., D. F. Stotz, D. F. Lane, J. P. O'Neill, T. A. Parker, III, and A. B. Egg (2010). Birds of Peru: Revised and Updated Edition. Princeton University Press, Princeton, NJ, USA.

Seewagen, C. L. (2010). Threats of environmental mercury to birds: Knowledge gaps and priorities for future research. Bird Conservation International 20:112–123.

Shiu, H., K. Tokita, E. Morishita, E. Hiraoka, Y. Wu, H. Nakamura, and H. Higuchi (2006). Route and site fidelity of two migratory raptors: Grey-faced Buzzards *Butastur indicus* and Honey Buzzards *Pernis apivorus*. Ornithological Science 5:151–156.

Shrum, P. (2009). Analysis of mercury and lead in birds of prey from gold-mining areas of the Peruvian Amazon. M.S. thesis, Clemson University, Clemson, SC, USA.

Sillett, T. S., and R. T. Holmes (2002). Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71:296–308.

Steege, H. T., N. Pitman, D. Sabatier, H. Castellanos, P. Van Der Hout, D. C. Daly, M. Silveira, O. Phillips, R. Vasquez, T. Van Andel, J. Duivenvoorden, et al. (2003). A spatial model of tree α-diversity and β-density for the Amazon Region. Biodiversity and Conservation 12:2255–2276.

Steenhof, K., K. K. Bates, M. R. Fuller, M. N. Kochert, J. O. McKinley, and P. M. Lukacs (2006). Effects of radio marking on Prairie Falcons: Attachment failures provide insights about survival. Wildlife Society Bulletin 34:116–126.

Stotz, D. F., J. W. Fitzpatrick, T. E. Parker, III, and D. K. Moskowitz (1996). Neotropical Birds, Ecology and Conservation. University of Chicago Press, Chicago, IL, USA.

Taylor, C. M., and B. J. M. Stutchbury (2016). Effect of breeding vs. winter habitat loss and fragmentation on the population dynamics of a migratory songbird. Ecological Applications 26:424–437.

Thiollay, J. M. (2007). Raptor communities in French Guiana: Distribution, habitat selection, and conservation. Journal of Raptor Research 41:90–105.

Titus, K., and J. A. Mosher (1987). Selection of nest tree species by Red-shouldered and Broad-winged Hawks in two temperate forest regions. Journal of Field Ornithology 58:274–283.

United Nations Environment Programme – World Conservation Monitoring Centre (2020). Protected Area Profile for Latin America and Caribbean from the World Database of Protected Areas, March 2020. www.protectedplanet.net.

Vilella, F. J., and D. W. Hengstenberg (2006). Broad-winged Hawk (*Buteo platypterus brunnescens*) movements and habitat use in a moist limestone forest of Puerto Rico. Ornitología Neotropical 17:563–579.

Washburn, B. E., M. S. Martell, R. O. Bierregaard, Jr., C. J. Henny, B. S. Dorr, and T. J. Olexa (2014). Wintering ecology of adult North American Ospreys. Journal of Raptor Research 48:325–333.

Whitney, M. C., and D. A. Cristol (2017). Impacts of sublethal mercury exposure on birds: A detailed review. Reviews of Environmental Contamination and Toxicology 244:113–163.

Wilson, A. M., D. W. Brauning, and R. S. Mulvihill (2012). The Second Atlas of Breeding Birds in Pennsylvania. The Pennsylvania State University Press, University Park, PA, USA.

Wilson, S., J. F. Saracco, R. Krikun, D. T. Tyler Flockhart, C. M. Godwin, and K. R. Foster (2018). Drivers of demographic decline across the annual cycle of a threatened migratory bird. Scientific Reports 8:7316. https://doi.org/10.1038/s41598-018-25633-z.

Woodbridge, B., K. K. Finley, and T. S. Seager (1995). An investigation of the Swainson's Hawk in Argentina. Journal of Raptor Research 29:202–204.

Wuczyński, A. (2003). Abundance of Common Buzzard (*Buteo buteo*) in the central European wintering ground in relation to the weather conditions and food supply. Buteo 13:11–20.

Received 20 April 2020; accepted 14 July 2020
Associate Editor: Christopher J. W. McClure