Homeward bound: annual breeding home range size and overlap in Broad-winged Hawks (Buteo platypterus) and the effects of sex, productivity, and ecoregion

Rumbo a casa: tamaño anual y superposición del ámbito hogareño reproductivo de Buteo platypterus y los efectos del sexo, la productividad y la ecorregión

Diego Gallego, Rebecca McCabe, and Laurie Goodrich

ABSTRACT. Documenting home range size, and identifying the variables influencing it, is key to understanding raptor population ecology and to addressing conservation issues. The Broad-winged Hawk (Buteo platypterus, hereafter broadwing) is a small forest buteo that travels over 8,000 km between its breeding range in North America and wintering range in Central and South America. Although conspicuous during migration, its secretive behavior while nesting hinders data collection on behavior and movements during the breeding season. We calculated breeding home ranges of 14 telemetry-tracked broadwings in northeastern USA and analyzed the effects of intrinsic (sex and nest productivity) and extrinsic (ecoregion) variables, using autocorrelated kernel density estimations. Breeding home ranges were 20 times larger in males than in females, in line with the strong division of labor between sexes observed in raptors. We found annual breeding home ranges overlapped (>0.85 in all cases) and inter-annual nest distances were less than 200 m on average, indicating a strong fidelity to the breeding home range and to the nest site area. To our knowledge, this is the first study using telemetry data to calculate breeding home ranges of this secretive forest raptor. Our findings indicate that breeding broadwing home ranges and nesting locations may remain stable over several years. Understanding and protecting the habitats used by nesting broadwings throughout their breeding range could be important to their long-term conservation.

INTRODUCTION

Space-use movements and patterns are key aspects of the ecology, distribution, and population dynamics of many species (Nathan et al. 2008, Morales et al. 2010, Powell and Mitchell 2012). In fact, understanding animal movements can inform a wide array of topics, including animal physiology, the spread of diseases, and gene flow, and it can help us better address management and conservation issues (Nathan et al. 2008). Among the many...
Migration, broadwings are showing declines at 15% of 2020, McCabe et al. 2020). Despite its abundance during Central and South America (Haines et al. 2003, Goodrich et al. 2020) and migrates each winter to broadwing) is a small buteo that breeds in deciduous or mixed- Buteo platypterus. The Broad-winged Hawk (hereafter BHRs) of the broadwing and to examine its fidelity to the range and nest area across different years using telemetry data. We aim to analyze the effects of intrinsic (sex and nest productivity) and extrinsic (ecoregion) parameters on the size of BHRs. We hypothesize that: (1) the BHRs of breeding females will be smaller than those of males due to the sex role specialization (Mirski et al. 2021), (2) the BHRs of successful and more productive seasons will be smaller than those of unsuccessful and less productive seasons (Pfeiffer and Meyburg 2015, Moser and Garton 2019), and (3) individuals breeding in more diverse forest types (which have more wetlands and a greater proportion of evergreen forest and conifer species; Bailey et al. 1994, Perry 1994, Herlihy et al. 2008) will have smaller BHRs as prey density and diversity is expected to be higher (Perry 1994).

METHODS

Study Area

Research was conducted in four ecoregions in Pennsylvania, Connecticut, and New Hampshire, USA (U.S. Forest Service; Bailey et al. 1994, Fig. 1). The Central Appalachian Broadleaf Forest (hereafter CABF) is dominated by mixed deciduous forests with interspersed small stands of eastern hemlock (Tsuga canadensis) or white pine (Pinus strobus). The Laurentian Mixed Forest (hereafter LMF) is a transitional forest between deciduous hardwoods and needleleaf spruce and pines, with a greater evergreen component when compared with the CABF. The Eastern Broadleaf Forest (EBF) is characterized by diverse deciduous forest with mixed oak species and widespread dominants including American beech (Fagus grandifolia) and yellow poplar (Liriodendron tulipifera) with occasional pockets of eastern hemlock (Tsuga canadensis) (Bailey et al. 1994). Lastly, the Adirondack–New England Mixed Forest (hereafter ANEMF), is more similar to boreal forests than the other ecoregions, being heavily dominated by evergreen trees, including species of spruce, pine, and hemlock with mixed stands of hardwoods. Both LMF and ANEMF are characterized by higher abundance of forested wetlands than CABF, with the EBF ecoregion—particularly the glaciated sections in the north—also showing more wetlands compared with the CABF (Tiner 1990, Bailey et al. 1994, Herlihy et al. 2008).

Capture and Telemetry

Adult broadwings were captured and equipped with satellite and GPS-GSM transmitters during the nesting phase of the nest cycle from mid-June to mid-July 2015–2021. 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 adults near the nest when nestlings were at least 1–2 wks old.
During the breeding season, we visited nests twice a week to check if young fledged at four nests. Of the 16 successful nests, 16 were successful, two failed, and we were unable to confirm if young fledged at four nests. Of the 22 nests monitored, 16 were successful, two failed, and we were unable to confirm if young fledged at four nests. Of the 22 nests monitored, 16 were successful, two failed, and we were unable to confirm if young fledged at four nests. Of the 16 successful nests, nine nests fledged two young each, five nests fledged one young each, and two nests fledged three young each (Table 2).

**Fig. 1.** Map of the study area showing the four ecoregions in northeastern USA where the Broad-winged Hawks (*Buteo platypterus*) were monitored during the breeding season from 2015–2021. CABF = Central Appalachian Broadleaf Forest; LMF = Laurentian Mixed Forest; EBF = Eastern Broadleaf Forest; ANEMF = Adirondack-New England Mixed Forest.

**Table 1.** Results from the Tukey’s Honest Significant Differences (HSD) test to test the post hoc differences in breeding home ranges (BHRs) of Broad-winged Hawks (*Buteo platypterus*) between ecoregions (Central Appalachian Broadleaf Forest [CABF]; n = 4); Laurentian Mixed Forest [LMF]; n = 7); Eastern Broadleaf Forest [EBF]; n = 4); Adirondack - New England Mixed Forest [ANEMF]; n = 3) in northeastern USA in 2015–2022.

<table>
<thead>
<tr>
<th>Ecoregions</th>
<th>Estimate</th>
<th>SE</th>
<th>df</th>
<th>t.ratio</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABF - EBF</td>
<td>4.7297</td>
<td>1.24</td>
<td>5.15</td>
<td>3.824</td>
<td>0.0401*</td>
</tr>
<tr>
<td>CABF - LMF</td>
<td>1.3591</td>
<td>1.18</td>
<td>3.44</td>
<td>3.305</td>
<td>0.06118</td>
</tr>
<tr>
<td>CABF - ANEMF</td>
<td>4.7488</td>
<td>1.33</td>
<td>7.37</td>
<td>3.569</td>
<td>0.0335*</td>
</tr>
<tr>
<td>EBF - LMF</td>
<td>-3.1906</td>
<td>1.12</td>
<td>5.57</td>
<td>-2.860</td>
<td>0.1081</td>
</tr>
<tr>
<td>EBF - ANEMF</td>
<td>0.0191</td>
<td>1.27</td>
<td>10.79</td>
<td>0.015</td>
<td>1.0000</td>
</tr>
<tr>
<td>LMF - ANEMF</td>
<td>3.6097</td>
<td>1.19</td>
<td>13.62</td>
<td>2.699</td>
<td>0.0538</td>
</tr>
</tbody>
</table>

**RESULTS**

We tracked 11 adult females and three adult males across a total of 22 reproductive seasons, within four ecoregions in northeastern USA (Table 2). None of the tagged males and females were paired with another tagged bird during our study. Of the 22 nests monitored, 16 were successful, two failed, and we were unable to confirm if young fledged at four nests. Of the 16 successful nests, nine nests fledged two young each, five nests fledged one young each, and two nests fledged three young each (Table 2).
Breeding home ranges (95% estimator) were more than 20 times larger ($\chi^2 = 15.39; P < 0.001$) in males (60.19 ± 21.61 km²; $n = 4$) than in females (2.77 ± 2.45 km²; $n = 18$). A similar difference was found with core range sizes (50% estimator), which averaged 0.43 ± 0.36 km² in females and 7.32 ± 2.81 km² in males. We found no relationship between BHR and nest productivity ($\chi^2 = 0.28; P = 0.60, n = 18$) (Table 1).

We found a significant difference in BHRs and the ecoregions where the broadwings nested in ($\chi^2 = 25.52; P < 0.001$, $n = 18$ reproductive seasons; Table 1, Fig. 2). Female broadwings nesting in the CABF ecoregion had the largest BHRs (5.25 ± 0.88 km²), being significantly larger than those nesting in EBF (0.35 ± 0.46 km²; $P = 0.04$) and in ANEMF (0.35 ± 0.46 km²; $n = 3$ reproductive seasons; $P = 0.03$). Female broadwings nesting in the LMF ecoregion (3.67 ± 2.28 km², $n = 7$), however, had larger BHRs than those nesting in the ANEMF ecoregion, although the difference was marginally significant (Table 1).

Breeding home ranges (95% estimator) of individuals nesting in the same territory in consecutive years overlapped by 0.92 ± 0.04; ($n = 5$ individuals, Fig. 3). Also, on average, interannual nest distances were = 194.7 ± 326.1 m ($n = 5$), including a female that re-nested in the same tree in two consecutive years.

**DISCUSSION**

Our findings demonstrate that the size of breeding home ranges in broadwings is influenced by both intrinsic and extrinsic factors, as found in some other raptors (Mirsiki et al. 2021, Spatz et al. 2022). In addition, BHRs of broadwings nesting in northeastern USA were larger than the ranges found for the Puerto Rican Broadwing (*Buteo platypterus brunnescens*; Delannoy and Tossas 2000, Vilella and Hengstenberg 2006). Smaller home ranges of the island subspecies may be attributed to the habitat type (i.e., tropical forest) and higher densities of suitable prey on the island (Miller et al. 2017). In northern latitudes, compared with tropical latitudes, forests can be less diverse in both tree species and vertebrates, requiring raptors to expand their range to meet the energetic requirements necessary for survival and breeding (Titus and Mosher 1981, Peery 2000, Miller et al. 2017).

Table 2. Home range size, nest success, and productivity for 22 Broad-winged Hawk (*Buteo platypterus*) breeding seasons in eastern North America. Ecoregions: CABF = Central Appalachian Broadleaf Forest; LMF = Laurentian Mixed Forest; EBF = Eastern Broadleaf Forest; ANEMF = Adirondack New England Mixed Forest. Home ranges: BHR (95%) = breeding home range size (km²); Core (50%) = core home range (km²). Missing values are indicated by NA.

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>ID</th>
<th>Year</th>
<th>Sex</th>
<th>Tagged days</th>
<th>BHR (95%)</th>
<th>Core (50%)</th>
<th>Success</th>
<th>Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABFC</td>
<td>146902</td>
<td>2015</td>
<td>Female</td>
<td>54</td>
<td>4.950</td>
<td>0.869</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CABFC</td>
<td>146907</td>
<td>2016</td>
<td>Female</td>
<td>37</td>
<td>4.180</td>
<td>0.726</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>CABFC</td>
<td>146907</td>
<td>2017</td>
<td>Female</td>
<td>98</td>
<td>6.210</td>
<td>1.030</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>CABFC</td>
<td>146907</td>
<td>2018</td>
<td>Female</td>
<td>121</td>
<td>5.640</td>
<td>0.704</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CABFC</td>
<td>179255</td>
<td>2019</td>
<td>Male</td>
<td>62</td>
<td>46.090</td>
<td>7.630</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>LMF</td>
<td>146905</td>
<td>2015</td>
<td>Female</td>
<td>31</td>
<td>4.570</td>
<td>0.793</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>LMF</td>
<td>146905</td>
<td>2016</td>
<td>Female</td>
<td>89</td>
<td>7.310</td>
<td>0.966</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LMF</td>
<td>146905</td>
<td>2017</td>
<td>Female</td>
<td>58</td>
<td>1.990</td>
<td>0.386</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>LMF</td>
<td>146909A</td>
<td>2016</td>
<td>Female</td>
<td>69</td>
<td>5.730</td>
<td>0.742</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LMF</td>
<td>146909A</td>
<td>2016</td>
<td>Female</td>
<td>39</td>
<td>1.680</td>
<td>0.286</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LMF</td>
<td>146909B</td>
<td>2018</td>
<td>Female</td>
<td>119</td>
<td>3.130</td>
<td>0.464</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>EBF</td>
<td>146904</td>
<td>2015</td>
<td>Female</td>
<td>32</td>
<td>0.640</td>
<td>0.130</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>EBF</td>
<td>146904</td>
<td>2016</td>
<td>Female</td>
<td>96</td>
<td>0.624</td>
<td>0.116</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>EBF</td>
<td>146904</td>
<td>2016</td>
<td>Female</td>
<td>38</td>
<td>0.690</td>
<td>0.120</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>EBF</td>
<td>17423</td>
<td>2022</td>
<td>Female</td>
<td>77</td>
<td>0.078</td>
<td>0.015</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>EBF</td>
<td>16949</td>
<td>2021</td>
<td>Male</td>
<td>35</td>
<td>77.180</td>
<td>10.760</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>ANEMF</td>
<td>146909B</td>
<td>2021</td>
<td>Female</td>
<td>47</td>
<td>0.878</td>
<td>0.144</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>ANEMF</td>
<td>17373</td>
<td>2022</td>
<td>Female</td>
<td>33</td>
<td>0.076</td>
<td>0.016</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ANEMF</td>
<td>14513</td>
<td>2022</td>
<td>Female</td>
<td>38</td>
<td>0.103</td>
<td>0.015</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ANEMF</td>
<td>175124</td>
<td>2021</td>
<td>Male</td>
<td>81</td>
<td>37.420</td>
<td>3.920</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ANEMF</td>
<td>175124</td>
<td>2022</td>
<td>Male</td>
<td>112</td>
<td>30.800</td>
<td>6.960</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Fig. 2. Breeding home ranges of 11 female Broad-winged Hawks ($n = 18$ reproductive attempts) nesting in four ecoregions (Central Appalachian Broadleaf Forest [CABF]; $n = 4$; Laurentian Mixed Forest [LMF]; $n = 7$; Eastern Broadleaf Forest [EBF]; $n = 4$; Adirondack - New England Mixed Forest [ANEMF]; $n = 3$) of northeastern USA in 2015–2022.
Fig. 3. Annual breeding home ranges and nest sites of three telemetry-tracked adult females (A, B, and C) and one adult male (D) Broad-winged Hawk (*Buteo platypterus*) nesting in northeastern USA between 2015–2022.

The Effect of the Intrinsic and Extrinsic Variables on the Breeding Home Ranges

Our findings support our prediction that BHRs of males are bigger than those of females, which is in accordance with other raptor studies (Vilella and Hengstenberg 2006, Moss et al. 2014, Pfeiffer and Meyburg 2015, Hernández-Pliego et al. 2017, Moser and Garton 2019, Mirski et al. 2021). This difference is likely due to the strong division of roles between sexes that is shown by broadwings (Matray 1974, Lyons and Mosher 1987; Hawk Mountain Sanctuary, unpublished data). Our results thus indicate that space use is a sex-related behavior (Mirski et al. 2021). Female raptors often show small home ranges (Cardador et al. 2009, Arroyo et al. 2014), especially during breeding season, when they are attached to the nest, whereas males often range farther and explore higher risk habitats and open spaces (Preston 1990). Although breeding success can be correlated with the range size in birds (especially for the male parent; Pfeiffer and Meyburg 2015), broadwing productivity was not related to female range size in this study. As we did not have many males for our analyses, we cannot examine this hypothesis.

Breeding home ranges of broadwings in CABF ecoregion were larger than BHRs in EBF and ANEMF ecoregions, and BHRs in LMF were intermediate in size when compared with CABF and the other three ecoregions. The greater diversity of forest trees, particularly evergreen species, and abundance of wetlands found in EBF, LMF, and NEMF, may be one of the possible reasons why we observed smaller home ranges for broadwings nesting in these three ecoregions. As a generalist predator, broadwings feed mainly on small mammals but also on birds, reptiles, and amphibians, which can be associated with wetlands (McCabe et al. 2019, Goodrich et al. 2020). By contrast, the forest in CABF is mostly dry, mixed deciduous and may have lower prey abundance than the other forest types, thus broadwings could have to move farther to find adequate prey to feed their nestlings. This is in line with the hypothesis that raptors increase their foraging range when preferred habitats or prey are scarce or deficient (Kenward 1982, Santangeli et al. 2012, Miller et al. 2017, Tucker et al. 2019, Mirski et al. 2021). As the LMF is a transitional ecoregion between CABF and the other two ecoregions (EBF and ANEMF), it seems logical that it shares some characteristics of both forest types (i.e., intermediate diversity and abundance of species) and, thus, BHRs of LMF fall in between the sizes of BHRs from birds nesting in CABF and the other two ecoregions. Prey availability surveys within the BHRs fall in between the sizes of BHRs from birds nesting in CABF and the other two ecoregions. Prey availability surveys within the BHRs would aid in confirming the link between habitat type and prey abundance and diversity. Finally, more northern forest types (i.e., EBF, LMF, NEMF) may also have higher densities of broadwings, leading to greater competition, which also can reduce range size (Peery 2000).

Overlap of Breeding Home Ranges and Nest-site Fidelity

Our study confirms that broadwings show strong interannual breeding range overlap and nest area fidelity. The high overlapping values for the five adults that bred during consecutive years, and the relatively short distances between nests of
consecutive years, suggest that broadwings often reuse the same breeding area for several years in northeastern forests. A breeding pair in the Adirondack Mountains (New York, USA) nested approximately 400 m away from its previous year’s nest (Matray 1974), and two additional banded birds were re-trapped on the same breeding area during two consecutive years (Matray 1976). In Puerto Rico, re-occupancy (the use of traditional territories or nests by different pairs; Delannoy and Tossas 2000) was documented for the subspecies B. p. brunniceps, indicating that areas of extremely high quality of resources remain valued even after individual turnover occurs.

High nesting range and site fidelity coupled with high re-occupancy could make broadwing populations highly vulnerable to habitat alteration and destruction (Titus and Mosher 1981, Goodrich et al. 2020). Forest fragmentation is rapidly altering previously forested landscapes across many regions of the eastern USA (Hall et al. 2002, Wickham et al. 2007, Drummond and Loveland 2010). These changes can have negative effects on the abundance and diversity of some of the preferred prey of broadwings, such as the eastern chipmunk (Tamias striatus; Nupp and Swihart 1998), or bird and amphibian species (Robinson et al. 1995, Cushman 2006), and may increase interactions with possible nest predators (e.g., Great Horned Owl, Bubo virginianus, Red-tailed Hawk, Buteo jamaicensis, and raccoon, Procyon lotor), both factors potentially affecting their long-term conservation. Thus, identifying size and attributes of the broadwing breeding range, and the factors affecting it, is critical to conserving their populations for the long term.

CONCLUSION
In this study, we showed that both intrinsic and extrinsic drivers shaped space use in the broadwing during the reproductive season, providing vital knowledge on the movement ecology and space use of this elusive raptor. The study of other variables (not covered by this study) affecting BHRs, such as body mass (Ottaviani et al. 2006), the degree of anthropic disturbance (Tapia and Zuberogoitia 2018, Mirski et al. 2021), or the presence of competitors including other broadwing pairs (Ottaviani et al. 2006) may aid in clarifying the links between landscape quality, biodiversity, and viability of populations (Börger et al. 2008, Powell and Mitchell 2012, Van Moorter et al. 2016, Tapia and Zuberogoitia 2018). Also, our findings indicate that broadwing BHRs may remain stable over several years. The knowledge and protection of nesting areas may be key for broadwing long-term conservation (Goldsmith 2012, McCabe et al. 2019).

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. We thank P. Brown and Harris Center for Conservation Education volunteers for locating nests in New Hampshire and L. Fischer for locating nests in Connecticut. D. Gallego was a conservation science trainee at Hawk Mountain Sanctuary Association in spring 2022 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 U.S. 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, Harris Center for Conservation Education, East Stroudsburg University, Northeast Hawkwatch, D. and D. Allison, D. and P. McNicholas, Hawk Mountain members and other private donors. This is a Hawk Mountain conservation science contribution #387.

Data Availability:
The data on the home ranges and the different variables used will be available from the authors, as well as the code used for the analysis. 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).

LITERATURE CITED


Schmutz, J. K., M. A. Gérard, G. S. Court, and R. W. Nelson, 2014. Parental care by lone male ferruginous hawks (Buteo regalis), rough-legged hawks (Buteo lagopus), and great horned owls (Bubo virginianus) was limited to providing food. Canadian Field-Naturalist 128(2):145-150. https://doi.org/10.22621/cfn.v128i2.1578


Steenhof, K., K. K. Bates, M. R. Fuller, M. N. Kochert, J. O. McKinley, and P. M. Lukacs. 2006. Effects of radiomarking on...


