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LANDFILL USE BY BALD EAGLES IN THE CHESAPEAKE BAY REGION

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ABSTRACT.—We examined patterns in the use of landfills (rubbish dumps) in the Chesapeake Bay by Bald Eagles (*Haliaeetus leucocephalus*). Sites of solid waste landfills (n = 72) were located using state databases. Satellite tracking data from 64 eagles were used to track eagle movements hourly during daylight and once at midnight to determine roosting locations (2007–2012). Landfill use varied significantly with age class, with hatch-year birds using landfills six times more often than adults and twice as often as third- and fourth-year birds. Hatch-year birds spent significantly more time at landfills than expected based on landfill area relative to the study area outside of landfills. The relationship between time of year and eagle presence at landfills was not significant, though the results suggest a peak in landfill use in the late fall. There was spatial variation in landfill use, with 10% of the landfills used by study birds receiving 75% of the total landfill use. Landfills within two km of communal roosts received significantly more eagle activity than landfills farther from communal roosting sites. If eagle presence at landfills is indicative of foraging at these sites, the results provide evidence that foraging strategies in Bald Eagles change with age. Landfills may serve as important scavenging sites for hatch-year and second-year eagles, whereas older birds may be more successful obtaining higher quality prey elsewhere.

KEY WORDS: *Bald Eagle*; Haliaeetus leucocephalus; *delayed maturation*; *Chesapeake Bay*; *foraging ecology*; *landfills*; *learning*; *satellite telemetry.*

USO DE VERTEDEROS POR PARTE DE *HALIAEETUS LEUCOCEPHALUS* EN LA REGIÓN DE LA BAHÍA CHESAPEAKE

RESUMEN.—Examinamos los patrones en el uso de vertederos (basureros) en la Bahía de Chesapeake por parte de *Haliaeetus leucocephalus*. Los sitios en los que se deposita la basura sólida (n = 72) fueron ubicados utilizando las bases de datos estatales. Se siguieron los movimientos por hora de 64 águilas utilizando telemetría vía satélite durante las horas diurnas y una vez a la medianoche para determinar las ubicaciones de los dormideros (2007–2012). El uso de los vertederos varió significativamente con la clase de edad. Las aves menores a un año utilizaron los vertederos con una frecuencia seis veces mayor que los adultos y dos veces mayor que las aves de tres y cuatro años. Las aves menores de un año permanecieron significativamente más tiempo que lo esperado en los vertederos, considerando la superficie del vertedero relativa a la superficie del área de estudio. La relación entre la época del año y la presencia de águilas en los vertederos no fue significativa, aunque los resultados sugieren un pico en el uso de los vertederos al final del otoño. El uso de los vertederos varió espacialmente, aglutinando el 10% de los vertederos utilizados por las aves de estudio el 75% del uso total de los mismos. Los vertederos ubicados a una distancia de hasta 2 km de los dormideros comunales evidenciaron una actividad significativamente mayor por parte de las águilas que los vertederos más alejados de los dormideros comunales. Si la presencia de águilas en los vertederos es indicativa de actividades de alimentación en estos sitios, los resultados proporcionan evidencia de que las estrategias de alimentación de *H. leucocephalus* cambian con la edad. Los vertederos pueden servir como sitios importantes donde las águilas de primer y segundo año buscan carroña, mientras que las águilas de mayor edad pueden tener mayor éxito al obtener presas de mayor calidad en otros lugares.

[Traducción del equipo editorial]

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The Bald Eagle (*Haliaeetus leucocephalus*) is a species showing delayed maturation, with most individuals reaching sexual maturity in the fifth calendar year (Grier et al. 1983, Buehler 2000). Over this time period, foraging behaviors change as young birds develop the skills necessary to successfully obtain prey (Stalmaster 1976, Knight and Knight 1983). Juvenile and subadult birds tend to be less successful at foraging and hunting than adults (Stalmaster and Gessaman 1984, Brown 1993, Bennetts and McClelland 1997) and may use different foraging strategies (Stalmaster 1976, Knight and Knight 1983). Immature birds learn foraging skills, including locating food sources (Stalmaster 1976, Elliott et al. 2006), and food-stealing (Jorde and Lingle 1988) by watching or following older birds and through experience. The year after hatching is a particularly difficult period for eagles, with post-fledging first-year survival rates averaging 83%, compared to 90% in subsequent years (Hodges et al. 1987, Buehler et al. 1991, Wood 1992, McClelland et al. 1996, Harmata et al. 1999, Jenkins et al. 1999).

The Chesapeake Bay and its tributaries support a large number of Bald Eagles throughout the year (Watts et al. 2007, 2008). Despite an abundance of food, potential prey items are not always readily available to foraging eagles. When ambient temperatures decrease in the winter months, fish move to more benthic zones, becoming unobtainable for many avian predators (Mersmann 1989, Cunjak 1996). Eagles respond to decreased fish availability with dietary shifts, feeding more heavily on waterfowl and mammalian carrion from November through February (Mersmann 1989). When food is scarce, Bald Eagles, particularly young birds, learn of food locations by following other eagles (Knight and Knight 1983), are attracted to foraging conspecifics (Hinde 1961), and rely more on scavenging and kleptoparasitism as foraging strategies (Jorde and Lingle 1988, Mersmann 1989). Eagles may therefore frequent communal foraging sites more often in winter months when food is less accessible.

Landfills are important foraging grounds for numerous avian species (e.g., Burger and Gochfeld 1983, Belant et al. 1995, Blanco 1997). These sites provide an accessible, consistent food source and are thought to be influential in supporting large, otherwise unsustainable populations of some species (Sherrod et al. 1976, Jackson 1981, Sibly and McCleery 1983, Blanco 1997, Hancock 2003). However, landfills are associated with low-quality food (Belant et al. 1993, Smith and Carlile 1993, Annett and Pierotti 1999), increased risk of disease (Monaghan et al. 1985, Ortiz and Smith 1994, Nelson et al. 2008) and toxicity (Millsap et al. 2004), and increased threat of food piracy and injury (Knight and Knight 1986, Elliott et al. 2006). Bald Eagles are known to congregate at landfills (Elliott et al. 2006). The accessible food in landfills may be especially attractive to immature eagles, whose foraging skills are still developing. Older, more experienced eagles are expected to favor higher quality food sources and, therefore, may use landfills less frequently than younger individuals.

The objectives of our study were to assess the presence of Bald Eagles at solid waste landfills in the Chesapeake Bay. Specifically, we examined whether eagles' use of landfills varies with age class and time of year. We hypothesized that (1) immature eagles spend more time at landfills than adult eagles, as the former are less skilled at foraging and hunting live prey, and (2) eagle presence at landfills is higher in the winter months. We expect that eagles rely on landfills as foraging sites more often in the winter months, when preferred prey items are less available than in warmer seasons.

METHODS

Between August 2007 and February 2011, resident and migrant Bald Eagles were captured on Aberdeen Proving Ground and fitted with satellite transmitters (Watts and Mojica 2012). Age class (hatch year [HY], second year [SY], third year [TY], fourth year [FY], or adult [AD]) was determined at the time of banding based on plumage (McCollough 1989) for captured birds and was recorded as HY for birds banded in the nest. Transmitters reported GPS locations (± 18 m) every hour during daylight and once at midnight (0000 H).

The study area (Fig. 1) was selected based on the area of highest density of satellite tracking locations from study birds, as high densities signified areas of heavy use. Municipal solid waste (MSW) landfills within the study area were located using information provided by official state and county websites for New Jersey, Pennsylvania, Delaware, Maryland, and Virginia, as well as company websites for privately-owned MSW landfills. Landfill sites (n = 72) were plotted using Google Earth software. Eagles using landfills as foraging sites spend the majority of their time resting (Elliott et al. 2006) and frequently move between perches in the surrounding area outside of the landfill and the landfill itself (e.g., Elliott et al. 2006). Thus, a 2-km buffer zone was drawn around the

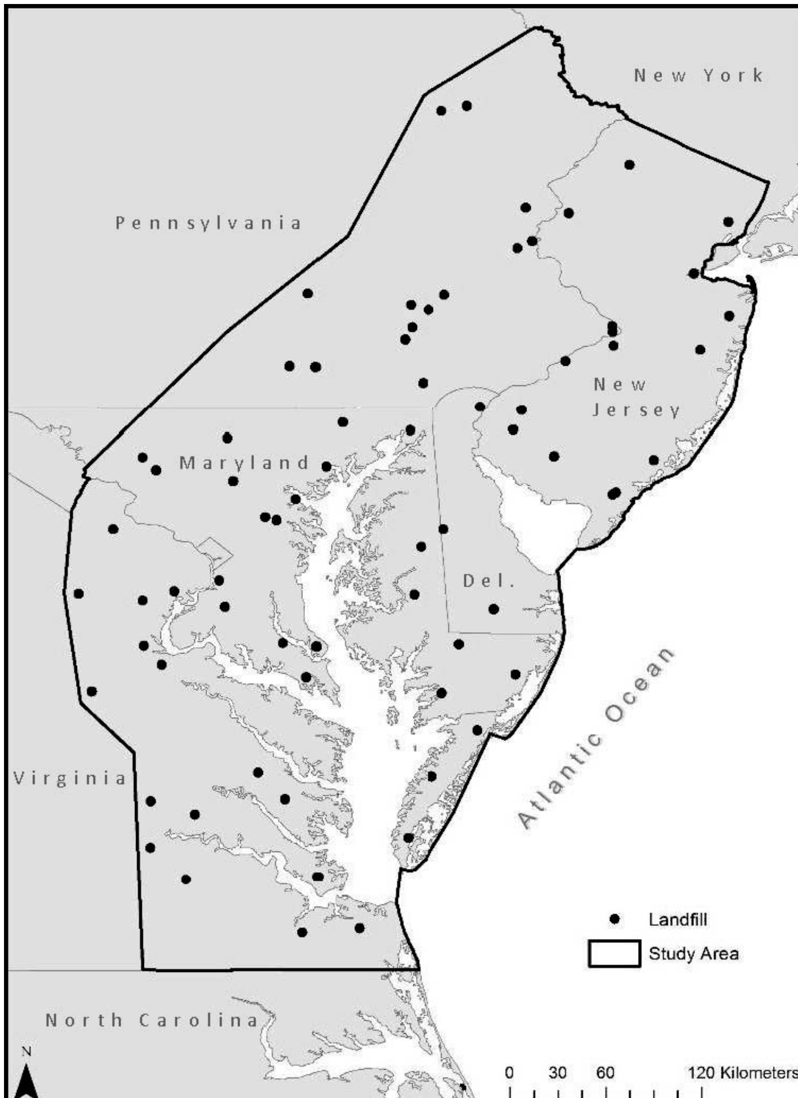

Figure 1. Map of the study area in the Chesapeake Bay where movements of Bald Eagles were tracked to assess landfill use. Points denote landfill locations.

border of each landfill, and eagles within this buffer were considered to be present at the landfill. Because eagles feeding at landfills are thought to use nearby major roosts (Elliott et al. 2006), we expected that there might be a relationship between eagle presence at a given landfill and the presence of a communal roosting site within close proximity to the landfill. We plotted the locations of communal roosts delineated by Watts and Mojica (2012) to identify landfills that overlapped with a communal roost, within either the landfill or the 2-km buffer.

We used ArcMap (9.3) to determine the area within and outside of landfill buffer zones. We then determined the number of daytime GPS locations from study birds falling within and outside of landfill buffer zones from August 2007 through June 2012. These methods were repeated using midnight GPS fixes to determine roosting locations.

Each GPS location was attributable to an individual of known age. To avoid pseudoreplication in cases in which an individual was tracked over multiple years of adulthood, the average number of locations per month during that individual's adult years was calculated for each month (January–December). A correction factor was calculated for each individual in each month of the study by dividing the number of expected total locations in that month (one per hour of daylight plus one at midnight every day) by the number of observed locations. The numbers of observed locations within and outside of buffer zones were then multiplied by the correction factor. If an individual was present within the study area for fewer than one-third of the expected times in a given month, data for that month were excluded from the analysis due to low confidence. Because breeding adults are tied to nesting territories (Stalmaster and Kaiser 1997) and their use of landfills, particularly during the breeding season, may be affected (Blanco 1997, Ciach and Kruszyk 2010), only nonbreeding eagles were included in the study sample (n = 64). Data from study birds known to have become active breeders during the study period were excluded from the analysis during the years in which breeding occurred.

We assessed the effect of time of year on landfill use on both a monthly and a seasonal basis. For the seasonal analysis, months were grouped with October through March constituting the winter season, when we expected eagles to be most food-stressed, and April through September as the spring/summer season, when food was likely more accessible and abundant. Primary food sources also shift from winter to spring and summer (Mersmann 1989, Elliott et al. 2011). As fish move to greater depths in response to temperature changes (Cunjak 1996, Mersmann 1989), fall migration brings an influx of waterfowl into the bay, and the start of deer hunting season contributes to more available carrion in the area (Mersmann 1989). Eagles shift from a diet consisting primarily of fish to one dominated by waterfowl and carrion (Mersmann 1989). During this dietary shift, we expected that some eagles may use landfills as an alternate food source. To assess whether landfill use varied across months of the year, we determined the average number of locations within and outside of the landfill buffers in each month (January–December) during the study period for each tracked eagle. We then averaged the number of locations per month from April–September within and outside of landfill buffers to determine landfill use by each study bird during the spring/summer season. Finally, we averaged the number of locations per month from October–March within and outside of landfill buffers to determine landfill use by study birds during the winter season.

Statistical calculations were computed using R (R Core Team 2013). Pearson's chi-square test for independence was used to determine whether observed monthly landfill use differed from expected use based on the relative study area within and outside of buffer zones. One-way analyses of variance (ANOVA) tests were used to examine effects of age class, month, and season on landfill use. Where the ANOVA test was significant, *post hoc* comparisons using Tukey's honestly significant difference (HSD) test were performed. Two-way ANOVA tests were run with age and month, and with age and season as factors to assess potential interaction effects. Due to small expected cell counts, two-tailed Fisher's exact tests were used to assess the relationship between eagle presence at a landfill and the presence of one or more communal roosting sites within the landfill or within its 2-km buffer.

According to U.S. Geological Survey Bird Banding Lab convention, January 1 is the date upon which birds advance from one age class to another. Because the nesting period in the Chesapeake Bay does not coincide with the calendar year, each age class covers parts of two chronological years. Birds typically fledge between May and July and are considered HY birds until December 31 of that year, after which they are classified as SY birds despite not yet being one year old. Thus, from January through March, SY birds are actually in the second half of their first winter. To determine whether first winter (i.e., January–March) use of landfills by SY birds disproportionately increases the annual SY bird presence at landfills, we investigated monthly patterns of landfill use by SY birds. We examined two samples of SY birds, one group consisting of only those birds that were tracked throughout their entire second year, and a second group with incomplete coverage during their SY period because of transmitter failure during the second year, or because they were first captured and received a transmitter midway through their second year. All reported values are means ± SD, unless otherwise stated.

RESULTS

The collective daylight and nighttime time budgets indicated that study birds spent an average of 4.0 ± 17.5 hr/mo and 0.3 ± 2.1 nights/mo within landfills, respectively. Of the total GPS locations within landfills and buffer zones, 850 (14%) were within the landfill borders, 2813 (46%) were within

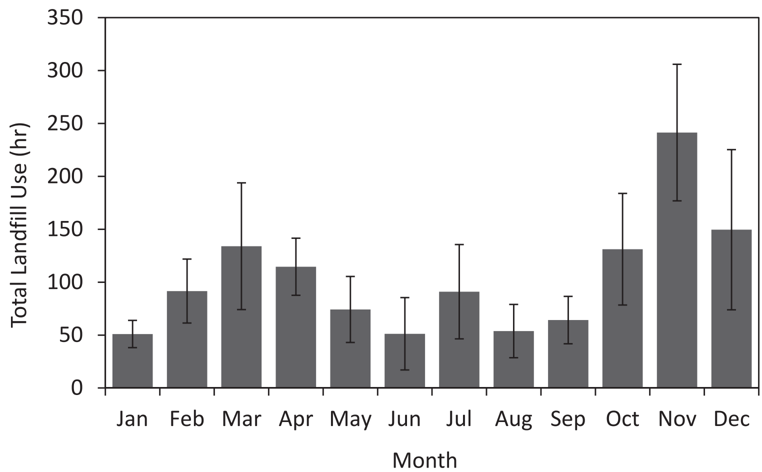

Figure 2. Interannual average (±SE) presence (hr/mo) of Bald Eagles at landfills in the Chesapeake Bay, including daytime and nighttime use (2007–2012). There was no significant seasonal or monthly pattern to eagle presence at landfills.

a 1-km buffer of the landfill border, and 2394 (40%) were within a buffer zone between 1 km and 2 km from the landfill border. The total area within the landfill borders was 65.9 km^2 (4% of the total area that was considered landfills, which included the buffers), the area within the 1-km buffers was 507.6 km^2 (34%), and the area of the 1-2-km buffers was 938.4 km^2 (62%).

Overall, the study birds spent significantly less time within the landfill buffer zones during daylight than expected ($\chi^2 = 329.617$, df = 1, $P < 0.0001$). When age classes were assessed separately, the results were consistent for nonbreeding AD ($\chi^2 = 1055.369$, df = 1, $P < 0.0001$), FY ($\chi^2 = 55.609$, df = 1, $P < 0.0001$), and TY ($\chi^2 = 48.201$, df = 1, $P < 0.0001$) eagles. Conversely, HY birds spent significantly more time at landfills than expected ($\chi^2 = 132.514$, df = 1, $P < 0.0001$). Landfill use by SY eagles was not significantly different from expected use ($\chi^2 = 0.517$, df = 1, $P = 0.472$).

Patterns in the use of landfills as roosting sites were similar to daytime patterns. Landfills were used as roost locations significantly less often than expected by nonbreeding AD ($\chi^2 = 76.143$, df = 1, $P < 0.0001$), FY ($\chi^2 = 6.939$, df = 1, $P < 0.01$), and TY ($\chi^2 = 9.447$, df = 1, $P < 0.01$) eagles. HY birds roosted in landfills significantly more often than expected ($\chi^2 = 14.465$, df = 1 $P < 0.001$). There was no difference in SY birds' observed and expected landfill use ($\chi^2 = 0.002$, df = 1, $P = 0.97$).

Daytime landfill use by Bald Eagles varied significantly with age class ($F_{4,1513} = 5.827$, $P < 0.001$) but not with time of year when assessed on a monthly (one-way ANOVA, $F_{11,1513} = 1.658$, $P = 0.077$) or seasonal ($F_{1,351} = 1.72$, $P = 0.191$) basis. There was no interactive effect of age and month (two-way ANOVA, $F_{38,1513} = 0.722$, $P = 0.896$), nor of age and season ($F_{4,351} = 0.955$, $P = 0.433$) on daytime landfill use. Roosting landfill use showed similar patterns, with an effect of age class (one way: $F_{4,1506} = 3.457$, $P < 0.01$), no effect of month (one way: $F_{11,1506} = 1.029$, $P = 0.418$), and no effect of season (one way: $F_{1,366} = 0.208$, $P = 0.649$). Again, there was no interactive effect of age and month (two-way ANOVA, $F_{39,1506} = 0.710$, $P = 0.910$) nor of age and season ($F_{4,366} = 0.426$, $P = 0.790$) on the use of landfills as roost sites. Despite the lack of a significant relationship between daytime and roosting landfill use and time of year, the data suggest a trend toward higher eagle presence at landfills during the late fall (Fig. 2).

Presence at landfills was greatest for HY birds and declined across age classes during both daytime and roosting, with adults visiting landfills least frequently. *Post hoc* analyses of daytime landfill use indicated that on average HY eagles used landfills six times more frequently than nonbreeding adults (Tukey's HSD, $P < 0.001$) and twice as often as FY (Tukey's HSD, $P = 0.044$) and TY birds (Tukey's HSD, $P = 0.049$; Fig. 3). In addition, SY birds used landfills four times more often than nonbreeding adults during daylight hours (Tukey's HSD, $P = 0.013$; Fig. 3). Hatch-year (mean ± SE = 0.8 ± 0.3 nights/mo) eagles also roosted at landfills significantly more often than nonbreeding AD birds (mean ± SE =

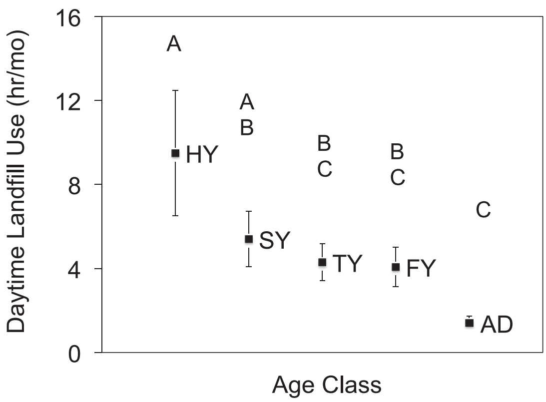

Figure 3. Daytime landfill use (mean ± SE) by hatch year (HY), second year (SY), third year (TY), fourth year (FY), and nonbreeding adult (AD) Bald Eagles in the Chesapeake Bay (2007–2012). The letters ''A,'' ''B,'' and ''C'' indicate significance of Tukey's HSD tests comparing daytime landfill use among eagles of different ages; age classes labelled with the same letter did not differ in time spent at landfills. There was an inverse relationship between time present at landfills and age class, with HY birds using landfills six times more often than AD eagles.

0.10 ± 0.03 nights/mo; $P = 0.014$). The difference between SY (mean ± SE = 0.5 ± 0.2 nights/mo) and AD roosting frequency at landfills approached statistical significance ($P = 0.052$).

Although SY birds in January–March were only in their first winter, and scarcely older than HY birds in December, monthly patterns in SY landfill use were consistent with study-wide trends. When we included all SY birds, locations in January–March made up 7% of total SY landfill presence, while locations in October–December accounted for 65%. When we included only the birds tracked throughout their complete second year, monthly trends showed a similar pattern, with January–March and October–December comprising 5% and 66% of total landfill use, respectively.

Variance in landfill use was high overall (var = 306.4 daylight hr/mo and 4.4 nights/mo). Variation in daytime landfill use among HY birds was higher than within other age classes; the coefficient of variation (CV) of HY presence was 0.31, whereas SY, TY, FY, and AD CVs were relatively close in value at 0.24, 0.21, 0.23, and 0.24, respectively. Landfill use also varied spatially. Some landfills were the sites of hundreds or in one case >1000 GPS locations during the study period, whereas 18% of landfills were the sites of one GPS location during the study.

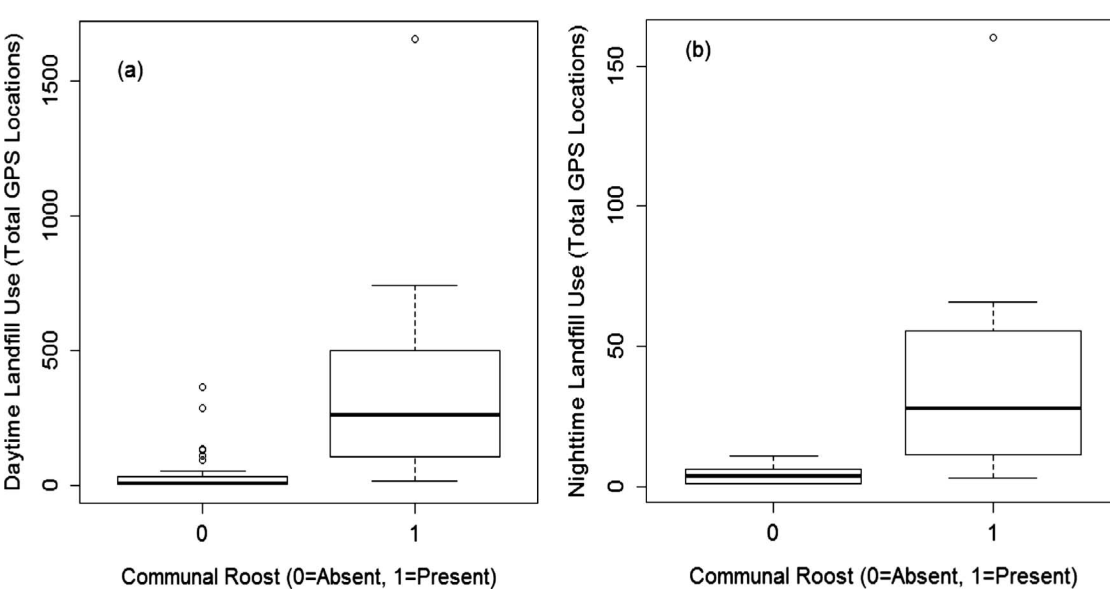

Figure 4. Bald Eagle presence at landfills with and without communal roosts within the landfill sites or within 2 km of the landfill borders. All municipal solid waste landfills within the study area in the Chesapeake Bay were included in the analysis. Both daytime (a) and nighttime (b) landfill attendance by eagles were significantly higher at landfills near communal roosts.

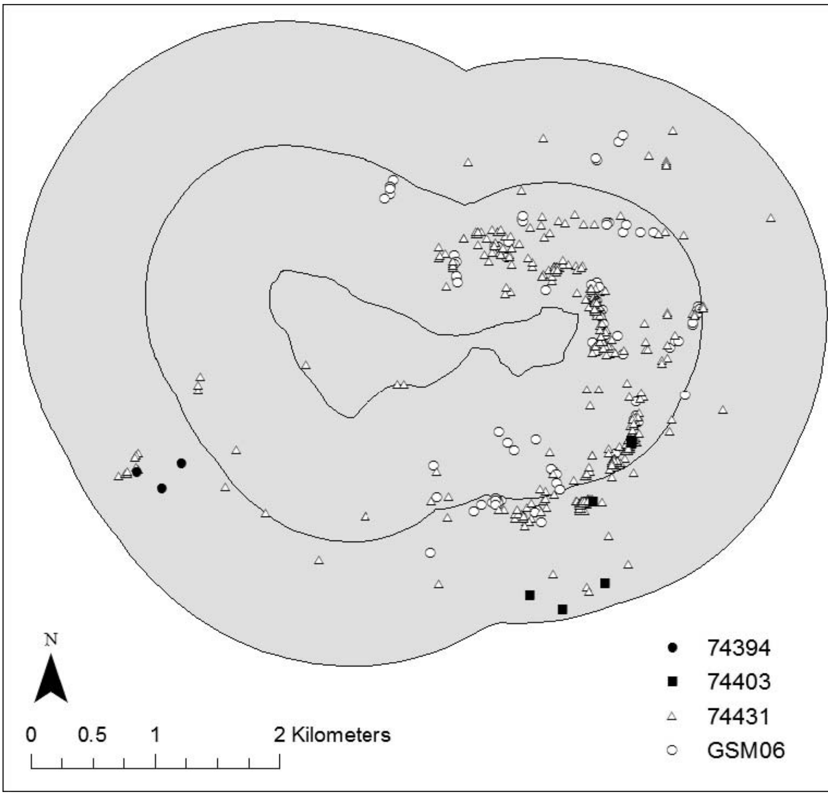

Figure 5. All locations of two subadult Bald Eagles, 74431 and GSM06, and two adult eagles, 74403 and 74394, at the most heavily used landfill (Eastern Landfill, MD) within the study area (2007–2012). GPS locations outside of the landfill are not shown. Bird 74431 was a ''refuse specialist,'' using the landfill over a 2-yr period (March 2009–August 2010) as a second- and third-year subadult. Bird GSM06 used the landfill only in April 2011 as a second-year bird. Bird 74394 visited the landfill only in October 2011, and 74403 visited during January and February 2012, both as adults. The interior border denotes the border of the landfill itself, while the two outer borders indicate 1-km and 2-km buffers.

All landfills were visited at least once during the study period. Ten percent of landfills received 75% of the study birds' total landfill use. As expected, there was a significant relationship between the frequency of eagle presence at a given landfill during both daytime and nighttime and the presence of one or more communal roosts within 2 km of the landfill (Fisher's exact test, $P = 0.013$ and 0.023, respectively; Fig. 4).

Some of the variation in eagle presence among landfills can be attributed to certain individuals utilizing particular landfills much more frequently than others (e.g., Fig. 5), and our study design was such that each bird contributed many locations to the data set (9748 $\pm$ 6810 locations/bird). Two eagles accounted for 48% of the daytime use at the most heavily used landfill in the study. At the second-most heavily used landfill, one individual accounted for 83% of the total use. Excluding landfills that were visited by a bird just once, which may result from passing over the site at the time of GPS signal transmission, 43 of the 64 study birds (67%) used two or more different landfills. Furthermore, 17 birds (27%) used two or more landfills 10 or more times each, and 13 birds (20%) used two or more landfills 20 or more times each.

Discussion

Our results supported the hypothesis that immature Bald Eagles attended landfills more frequently than nonbreeding adult eagles, but did not support our hypothesis that eagles used landfills more often in the winter months. Overall eagle presence at landfills was low, but high variance indicates that these sites are more important for some individuals than others. Particularly within the HY age class, variation in use was high. This suggests that some individuals forage more efficiently outside of landfill sites, while others may be ''refuse specialists'' that rely on the potentially lower quality but easily accessible food in landfills for most or all of their energy needs (Elliott et al. 2006). Further evidence of refuse specialists was the movement among different landfills exhibited by some study birds, which indicates that these birds spent time and possibly foraged at multiple sites. The decline in variability in landfill usage after the hatch year may indicate that landfill use declines overall with age. Alternatively, individuals that use landfills more often may be at increased risk of early death due to negative factors associated with landfills, including low-quality food (Belant et al. 1993, Smith and Carlile 1993, Annett and Pierotti 1999), disease (Monaghan et al. 1985, Ortiz and Smith 1994, Nelson et al. 2008), toxicity (Millsap et al. 2004), and injury resulting from agonistic encounters (Knight and Knight 1986, Elliott et al. 2006).

In addition to individual variation in landfill use among the study birds, there was significant spatial variation in the use of landfills, with a fraction of the total landfills supporting the majority of eagle presence. Spatial variation may be driven by site characteristics, including proximity of the landfill to water, size of the site, location relative to flyways, volume of waste processed, and wildlife management actions, such as avian harassment and other methods intended to deter birds. We also found a significant relationship between presence of a communal roost within the landfills or buffer zones and the frequency of eagle attendance at the sites. This may indicate that availability of roosting substrate influences degree of landfill use, or alternatively, that presence of an attractive landfill contributes to roost formation. We expect that density of birds, both eagles and other species, at the site may also influence use. Elliott et al. (2006) found that the proportion of eagles foraging at a landfill site declined with increasing eagle presence. However, if some eagles target landfills primarily to prey upon other species using these sites, we would expect eagle presence to increase with increasing density of prey species.

The results indicate that young eagles were not randomly distributed over the landscape, but rather that activity focused around landfill sites. Past studies have shown that eagles using landfills spend the majority of their time resting. Rather than remain within the landfill, where they are exposed to loud machinery (e.g., Coulson et al. 1987) and likely subject to harassment by other birds and agonistic encounters over food (e.g., Sibly and McCleery 1983, Elliott et al. 2006), eagles frequently move between foraging sites within the landfill itself and perches in the surrounding area (e.g., Elliott et al. 2006). Foraging activity of eagles (Sherrod et al. 1976) and gulls (Sibly and McCleery 1983, Coulson et al. 1987) is also influenced by the human activity at the landfill; birds forage for food waste after deposition but prior to compaction and covering by earth (Sibly and McCleery 1983). Though eagles may habituate to the loud machinery used at landfills (Elliott et al. 2006), machine activity may deter some birds from foraging during the time of operation (e.g., Coulson et al. 1987). Thus, we expect that eagles spend much of their time within the buffer zone resting between foraging events at the landfill, and we considered eagle presence within the buffer to be indicative of landfill use. However, some birds within this buffer may not have been using the landfill, and in this case our methods will have overestimated eagle presence at landfills. The majority of eagle presence (60%) occurred within 1 km of landfills, including the landfill sites themselves, a zone that comprised 38% of the total landfill area according to our study definition. There was relatively less use (40%) within the largest buffer zone (1–2 km outside of the landfill border), which made up 62% of the total landfill area. The results suggest that eagles generally remain within 1 km of landfill sites during periods of landfill use. Further study is necessary to determine whether eagles present within the buffers, particularly the outer buffer zone, are associated with the respective landfill.

The presence of eagles at the landfills likely indicates that some birds are foraging at these sites, whether on refuse or on other species that forage at landfills. Elliott et al. (2006) found that eagles at a landfill in Vancouver, British Columbia, fed primarily on red meat waste (30.7%) and bones (22.4%), with unknown food items constituting 32.3% of observed feedings, and that some eagles were ''refuse specialists'' (Elliott et al. 2006). Though our data did not allow for an analysis of diet composition for eagles foraging at landfills, it is likely that they feed on food of anthropogenic origin (e.g., Elliott et al. 2006). They may also prey upon smaller avian species, particularly *Larus* spp. (e.g., Murie 1940, Todd et al. 1982, Buchanan and Watson 2010, Hayward et al. 2010) that frequent these sites (Burger and Gochfeld 1983, Belant et al. 1995, Caron-Beaudoin et al. 2013).

If eagles are using landfills as foraging sites, the influence of age class on frequency of landfill use may offer evidence of age-related differences in foraging strategy. During the day, hatch-year eagles visited landfills twice as often as TY and FY birds and six times more frequently than nonbreeding AD birds, and SY eagles visited landfills four times more often than nonbreeding adults. In other locations, juveniles and subadults are more likely to feed in areas of high eagle concentrations (Stalmaster 1976, Elliott et al. 2006). Young Bald Eagles may scavenge preferentially at these sites because they rely on other birds to learn of food locations (Stalmaster 1976, Knight and Knight 1983) and because they are less successful at hunting than adults (Stalmaster and Gessaman 1984, Brown 1993, Bennetts and McClelland 1997).

Older birds visited landfills less frequently, with nonbreeding adults exhibiting the lowest attendance rates. Earlier studies point to differences in hunting skill and, subsequently, foraging strategy as a possible explanation (Stalmaster and Gessaman 1984, Brown 1993, Bennetts and McClelland 1997). Elliott et al. (2006) found that foraging efficiency and the percent of eagles foraging decreased with increasing numbers of eagles at a landfill site, suggesting that individuals increase foraging success by avoiding the large communal foraging groups and pirating that occur at landfills. Although adults are more successful at pirating than subadults and juveniles, kleptoparasitism is thought to be a suboptimal strategy in circumstances in which food is abundant and accessible because of the energy investment and risk of injury associated with conspecific contests over food (Stalmaster and Gessaman 1984). Though data from active breeders were excluded from the analysis, breeding adult attendance at landfills is also likely to be low during the nesting season (e.g., Blanco 1997), as individuals are spending much of their time within nesting territories (Stalmaster and Kaiser 1997).

Mersmann (1989) documented seasonal shifts in prey abundance and foraging habits within the population. Fish are a primary food source for Bald Eagles both within the Chesapeake Bay (Cline and Clark 1981, Mersmann 1989) and in many other populations (e.g., Watson et al. 1991, Brown 1993). Fish availability within the Chesapeake Bay declines from October through March, with one study documenting a decrease in gillnet sampling catch rates at 0.6-m depth from a monthly average of 3–7 fish/hr from April through September to 0–1 fish/hr from January through March (Mersmann 1989). Concurrent with the seasonal decline in fish availability is an increase in waterfowl abundance and an evident shift in eagle diets. Mallard (*Anas platyrhynchos*) and Canada Geese (*Branta canadensis*), as well as white-tailed deer (*Odocoileus virginianus*) and other mammals, become primary food sources for eagles from November through February (Mersmann 1989). These prey items are thought to be taken mostly as carrion or through pirating from other eagles (Cline and Clark 1981, Mersmann 1989), suggesting that scavenging and kleptoparasitism are important foraging strategies in periods of food scarcity. Elliott et al. (2006) found that Bald Eagle use of an urban landfill and nearby roosts in Vancouver peaked in late winter, reflecting the time period when fish abundance is expected to be at its lowest. It was also demonstrated that the peak in landfill use coincided with a period when eagles switched from fish to avian prey, providing additional evidence that this was a time of food shortage (Elliott et al. 2011).

Unlike the studies in British Columbia (Elliott et al. 2006, 2011), we found no statistically significant seasonal shifts in landfill use by eagles. However, our data suggested a trend in daytime landfill presence ($P = 0.077$), with an apparent peak in eagle attendance during the fall and a possible second, smaller peak in the early spring. The apparent peak in landfill attendance in the late fall may be influenced by prey shifts, as this coincides with the period when the primary food source for eagles in the bay changes from fish to waterfowl and carrion (Mersmann 1989). The gap between the time when fish become less available to eagles and when migrating waterfowl arrive may contribute to this apparent peak in landfill use if these sites are used as an alternate food source. In addition, the timing of hunting seasons in the states within the study area may affect these patterns, as gut piles and carcasses draw scavenging eagles during winter months (Mersmann 1989).

It has been suggested that for some avian species, the additional food provided by landfills may contribute to population growth by supporting an artificially inflated population size (Patton 1988). The resident Bald Eagle population in the Chesapeake Bay has been growing at an exponential rate since the early 1980s, and estimates indicate that it is approaching saturation (Watts et al. 2006, 2007, 2008). As one of the most productive aquatic systems in the world, the Chesapeake Bay provides little evidence that prey abundance will be a limiting factor for Bald Eagles in this region as it is in other populations (Sherrod et al. 1976, Swenson et al. 1986). The abundance of food may explain the lack of a seasonal pattern in landfill use, indicating that individuals who rely on landfills as food resources do not do so as a result of limited food availability. Rather, solid waste landfills may play a role in supporting population growth by fulfilling the energy demands of young birds that are more food-stressed than adults as a result of underdeveloped hunting and foraging skills (Stalmaster and Gessaman 1984, Brown 1993, Bennetts and McClelland 1997). These young birds may be more likely to exploit the readily accessible and easily located food at landfills (Stalmaster and Gessaman 1984, Elliott et al. 2006). Alternatively, eagle foraging sites may follow an ideal despotic distribution (Fretwell 1972), with young birds driven to lower quality food sources like landfills as a result of agonistic or territorial behavior at higher quality food sources.

Our results suggest that young eagles, particularly HY birds, are drawn to landfills, but further research is needed to examine how they are using these sites within the Chesapeake Bay. Behavioral observations would offer insight into the degree to which eagles at landfills feed on food of anthropogenic origin and prey species at these sites, intraspecific and interspecific interactions at landfills, time budgets, and the activities of eagles when they are within the buffer zones but not in the landfills themselves. Observations would also provide information that would contribute to our understanding of the factors driving variation in landfill use among individuals and among different landfill sites.

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