Journal of Caribbean Ornithology

RESEARCH ARTICLE

Vol. 35:108–119. 2022

Status and distribution of the Antillean Broad-winged Hawk (*Buteo platypterus antillarum*) on the island of Grenada

Ezra Angella Campbell Jody Daniel Andrea Easter-Pilcher Nicola Koper

Photo: Ezra Angella Campbell

BirdsCaribbean

Journal of Caribbean Ornithology
Research Article Vol. 35:108–119. 2022
jco.birdscaribbean.org ISSN 1544-4953 https://doi.org/10.55431/jco.2022.35.108-119

BirdsCaribbean
birdscaribbean.org

Status and distribution of the Antillean Broad-winged Hawk (*Buteo platypterus antillarum*) on the island of Grenada

Ezra Angella Campbell[1,2,3], Jody Daniel[3,4,5], Andrea Easter-Pilcher[6], and Nicola Koper*[1,7]

Abstract Because raptors usually occur at low densities and occupy large territories, they can be particularly sensitive to habitat degradation and loss. However, the impacts of these environmental changes on Caribbean raptors are not well understood. This is a significant conservation problem, as the restricted area of islands limits the ability of raptors to find alternate habitats when forests are degraded through agriculture, tourism, forestry, or urbanization. We surveyed the status, distribution, and habitat use of one of the resident diurnal raptors, the Antillean Broad-winged Hawk (*Buteo platypterus antillarum*), on the southern Caribbean island of Grenada. We surveyed this raptor species using double-observer point count and road transect surveys in the wet season (June–December 2016) and the dry season (January–May 2017). We detected a total of 262 hawks during the surveys, 70% (n = 182) in the wet season and 30% (n = 80) in the dry season. We assessed hawk habitat use based on elevation and land cover using generalized linear models and maximum entropy models and modeled detectability using N-mixture modelling. Our surveys suggest Antillean Broad-winged Hawks are abundant and widely distributed on Grenada. Broad-winged Hawks use both anthropogenically modified and naturally occurring forest, particularly in sites at relatively low elevation, and show no seasonal changes in habitat use.

Keywords *Buteo platypterus antillarum*, detectability, diurnal raptors, Grenada, habitat loss, modelling, status

Resumen Estado y distribución de *Buteo platypterus antillarum* en la isla de Granada • Dado que las rapaces suelen aparecer en bajas densidades y ocupan grandes territorios, pueden ser especialmente sensibles a la degradación y pérdida de hábitat. Sin embargo, los impactos de estos cambios ambientales en las rapaces del Caribe no se conocen bien. Esto es un problema de conservación importante, ya que la superficie restringida de las islas limita la capacidad de las rapaces para encontrar hábitats alternativos cuando los bosques se degradan debido a la agricultura, el turismo, la silvicultura o la urbanización. Estudiamos el estado, la distribución y el uso del hábitat de una de las rapaces diurnas residentes, *Buteo platypterus antillarum*, en la isla de Granada, en el sur del Caribe. Muestreamos esta especie de rapaz utilizando puntos de conteo con doble observador y transectos en carretera en la estación húmeda (junio–diciembre de 2016) y en la estación seca (enero–mayo de 2017). Detectamos un total de 262 halcones durante los muestreos, el 70% (n = 182) en la estación húmeda y el 30% (n = 80) en la estación seca. Evaluamos el uso del hábitat de los halcones en función de la elevación y la cobertura del suelo utilizando modelos lineales generalizados y modelos de máxima entropía y modelamos la detectabilidad utilizando modelos de N-mixture. Nuestros estudios sugieren que esta especie es abundante y está ampliamente distribuida en Granada. Además utilizan tanto los bosques modificados antropogénicamente como los naturales, particularmente los sitios de relativa baja altitud, y no muestran cambios estacionales en el uso del hábitat.

Palabras clave *Buteo platypterus antillarum*, detectabilidad, estado, Granada, modelización, pérdida de hábitat, rapaces diurnas

Résumé Statut et répartition de la Petite Buse (*Buteo platypterus antillarum*) sur l'île de Grenade • Les rapaces étant généralement peu nombreux et occupant de vastes territoires, ils peuvent être particulièrement sensibles à la dégradation et à la perte d'habitats. Cependant, les conséquences de ces changements environnementaux sur les rapaces de la Caraïbe ne sont pas bien connues. Il s'agit d'un problème de conservation important, car la superficie restreinte des îles limite les possibilités des rapaces de trouver d'autres habitats lorsque les forêts sont dégradées par l'agriculture, le tourisme, la sylviculture ou l'urbanisation. Nous avons étudié le statut, la répartition et l'utilisation des habitats de la Petite Buse (*Buteo platypterus antillarum*), un des rapaces diurnes présents toute l'année sur l'île de Grenade, dans le sud de la Caraïbe. Nous avons dénombré cette espèce par des comptages ponctuels à deux observateurs et par des transects le long des routes pendant la saison humide (juin–décembre 2016) et la saison sèche (janvier–mai 2017). Nous avons détecté un total de 262 individus lors des relevés, 70 % (n = 182) au cours de la saison humide et 30 % (n = 80) au cours de la saison sèche. Nous avons évalué l'utilisation

*Corresponding author: [1]Natural Resources Institute, University of Manitoba, Winnipeg, MB R3T 2M6, Canada; [7]e-mail: nicola.koper@umanitoba.ca. Full list of author information is available at the end of the article.

des habitats par la Petite Buse en fonction de l'altitude et de la couverture terrestre à l'aide de modèles linéaires généralisés et de modèles d'entropie maximale, et nous avons modélisé la détectabilité à l'aide d'un modèle mixte. Notre étude montre que l'espèce est abondante et largement répandue sur la Grenade. Elle occupe à la fois les forêts modifiées par les activités humaines et les forêts naturelles, en particulier celles situées à une altitude relativement faible, et son utilisation des habitats ne présente aucun changement saisonnier.

Mots clés *Buteo platypterus antillarum*, détectabilité, Grenade, modélisation, perte d'habitat, rapaces diurnes, statut

Habitat loss, degradation, and fragmentation have led to massive declines in the populations of numerous species around the world (e.g., Brooks *et al.* 2006, Laurance 2010). These changes are particularly detrimental to endemic, threatened, endangered, and range-restricted taxa (Smith and Temple 1982). As such, understanding habitat requirements and the specific factors that influence species' habitat use are crucial to protection and conservation efforts. The effects of habitat loss, degradation, and fragmentation are particularly severe for tropical island species, as their populations are limited by island size and restricted ranges (Nijman *et al.* 2009). Habitat conversion for agriculture, tourism, forestry, and urbanization continues unabated in many locations, further limiting available habitat. Combined, these factors may explain why raptor populations have declined significantly in the Caribbean over the past decade (Bildstein *et al.* 1998, Gallardo and Thorstrom 2019).

Raptors usually occur at low densities and occupy large territories, and as such, they are particularly sensitive to habitat loss and degradation (Thiollay 1989). Although some raptor species can adapt to anthropogenic habitat changes (Thiollay 1985, 1989, Ferrer-Sánchez and Rodríguez-Estrella 2016), habitat loss and land use change have had adverse effects on many raptor species, particularly those dependent on specialized niches and diets, such as the Snail Kite (*Rostrhamus sociabilis*) and Grenada Hook-billed Kite (*Chondrohierax uncinatus mirus*) (Ferrer-Sánchez and Rodríguez-Estrella 2015, Navarro-López and Fargallo 2015).

One resident subspecies of diurnal raptor that, to the best of our knowledge, has not been formally surveyed is the Antillean Broad-winged Hawk (*Buteo platypterus antillarum*), which occurs in Grenada, St. Vincent and the Grenadines, Barbados, Trinidad, and Little Tobago (Clark 1905, Gallardo and Thorstrom 2019). The Broad-winged Hawk is classified as Least Concern by the IUCN Red List of Threatened Species (BirdLife International 2016), but little is known about the status, range, distribution, and habitat preference of the Antillean subspecies. As a top predator, this raptor makes important contributions to the biodiversity and ecosystem health of the islands it inhabits (Rodriguez-Estrella *et al.* 1998, Carrete *et al.* 2009), suggesting that further information about its population trends and habitat selection would be helpful in aiding its conservation. The Antillean Broad-winged Hawk is often mistaken for the Grenada Hook-billed Kite when in flight, introducing further confusion and uncertainty into the status of both species.

Species distribution models (SDM) can help us understand species distribution and habitat selection while providing important baseline data on key habitat variables that can be instrumental to the conservation and management of raptors (Elith and Franklin 2013). Our objectives were to assess which habitat types are used by the Antillean Broad-winged Hawk, and to assess whether habitat use varies between dry and wet seasons, using systematic, reproducible survey techniques. We assessed the detectability of Antillean Broad-winged Hawks using *N*-mixture models to determine how the variables: observer, time of day, day of year, land cover, and elevation influenced detection probability and thus observations of this species.

Methods

Study Area

We conducted this study on the main island of Grenada (12°03'N, 61°45'W), which is at the southern end of the Eastern Caribbean (Fig. 1). The island has an area of approximately 34,400 ha and is characterized by a tropical climate with a distinct dry season (January–May) and wet season (June–December). Annual precipitation in Grenada ranges from 990–1500 mm in the coastal areas to 3750–5000 mm in the high montane areas. The mean daily temperature is ~27°C throughout the year and can drop to ~19–24°C in the high montane areas. Vegetation varies from xeric woodland forest along the low elevation and coastal areas to mixed deciduous (mostly secondary growth, following deforestation by European colonists who cleared about 75% of the island for agricultural purposes; Groome 1970) and dense but short-statured montane forest towards the higher elevation interior of the island. The highest point above sea level (asl) is 840 m, at the peak of Mt. St. Catherine (Government of Grenada 2000). Natural disasters (i.e., storms and hurricanes) have reduced the amount of natural habitat and mature trees available for raptor species (Thorstrom and McQueen 2008).

Data Collection

Survey Design.— We conducted raptor surveys from June 2016 to April 2017, sampling in both the wet season (June–December) and the dry season (January–May). We established seven survey routes ("routes") throughout the island (Fig. 1) and included both roadside transects and point counts to sample our focal species. We surveyed each route four times during the wet season and four times during the dry season. To select the survey routes, we divided the island into eight quadrats and selected random start points along primary roads. Next, we created routes such that they were: 1) 25–26 km in length; 2) ended at the randomly selected start location; and 3) included both primary and secondary roads. We had to merge two routes because they overlapped due to the road network. Because Grenada is about 30 km × 50 km in size, we were confident that our seven survey routes covered a large extent of the island. We located point-count plots that were within 500 m of a road survey route (usually on the route) and spaced at least 1.6 km

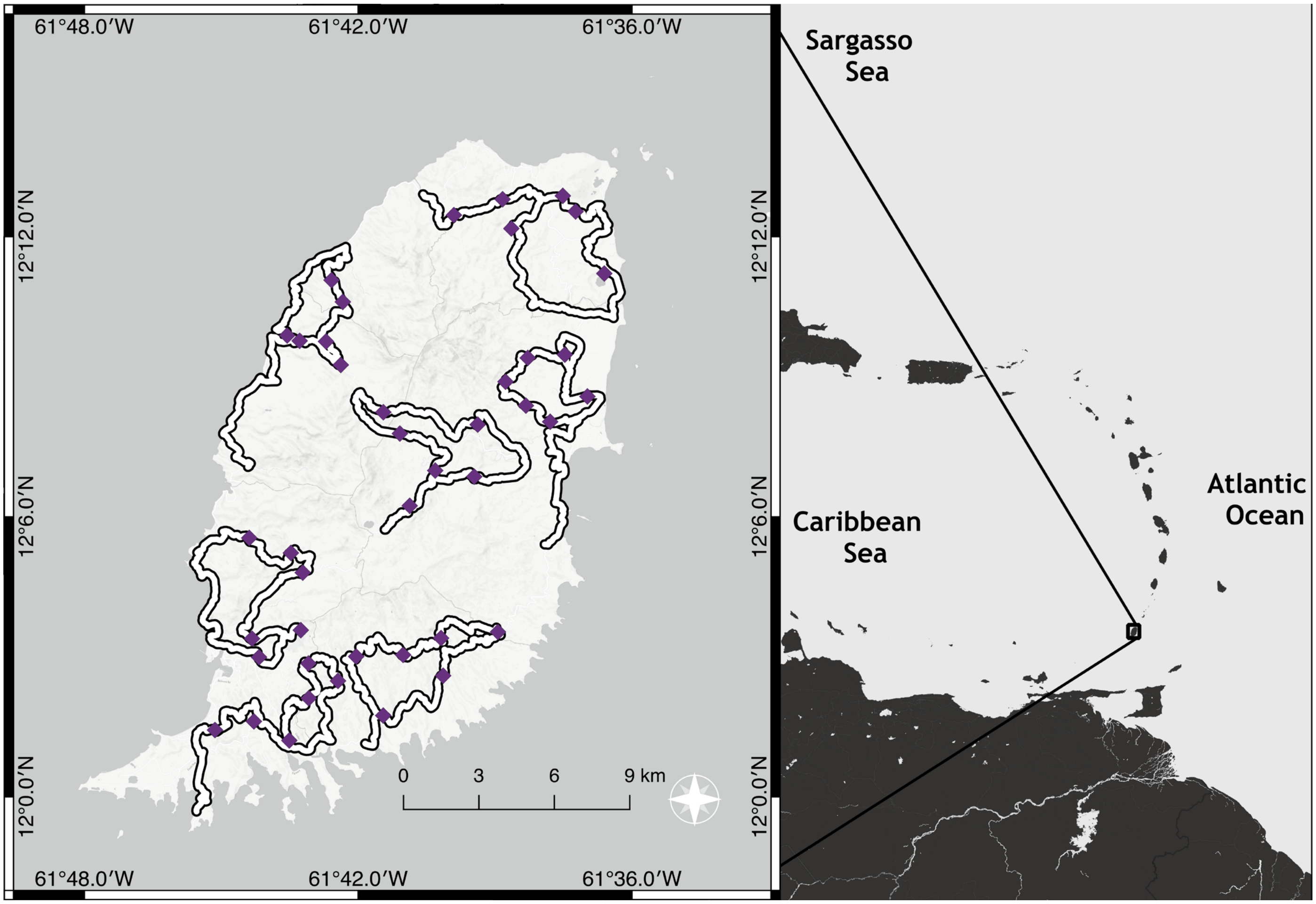

Fig. 1. Map showing the location of the seven (7) road transects and forty-two (42) point-count locations surveyed for diurnal raptors on the island of Grenada. Base maps were sourced from Mapbox.

apart. Each road transect included six point-count plots (n = 42), which we selected to ensure an unobstructed view of at least 90 degrees within a 500 m radius. We selected these survey methods as they are best suited for covering large areas while allowing for quantitative seasonal comparisons, habitat type comparisons, and detectability analyses.

Two observers surveyed each route every 4 to 5 weeks. Surveys started between 0800 and 0900, which is approximately 3 hr after local sunrise, or later if adverse early morning weather conditions reduced raptor activity. We completed each route in 2–3 hr and only surveyed one route per day. We recorded all diurnal raptors along each route, noting whether individuals were flying or perched and if they were seen or only heard. To measure the horizontal distance from the observer to each raptor encountered, we used a rangefinder when possible, or a visual estimate. To permit standardization of our encounter data, we recorded the time of each survey and the distance travelled. We avoided double counting of individuals by selecting survey routes that were at least 1 km from each other (Figs. 1 and 2; Buckland *et al.* 2001, Rosenstock *et al.* 2002). We did not conduct surveys during adverse weather conditions such as heavy rain or strong wind.

Point Counts.— As it is challenging to estimate detectability with transect data (Conn *et al.* 2004), we also conducted point count surveys to better understand habitat use and the potential impacts of time of day and date on our surveys. We conducted independent double-observer sampling where two observers surveyed for 6 min at each point location. Each survey included a 1-min scan with bare eyes followed by a 2-min scan with binoculars, and then a repeat of this sequence. We recorded all raptors seen or heard within the 500-m radius, along with the distance and direction of the raptor from the observer. We also recorded raptors observed outside 500 m to minimize double counting.

Roadside Surveys.— We conducted a preliminary survey in June 2016 to ground-truth the roadside survey routes and to ensure that the point-count sites were accessible and provided appropriate vantage points. Once we finalized these survey methods, two observers drove together and collaboratively conducted surveys along each transect. The vehicle was driven at a speed of 20–40 km/hr while the observers scanned the area for perched and soaring raptors (Steenhof and Kochert 1982). Every time a raptor was seen or heard within a 500-m buffer on either side of the road, the car was stopped and the observer(s) recorded the species, distance, direction, time of observation, and the individual's behavior (i.e., perched, flying, etc.). The observers recorded raptors > 500 m away as incidentals. For raptors that could not be identified, we observed them for as long as possible, occasionally following individuals until their identification

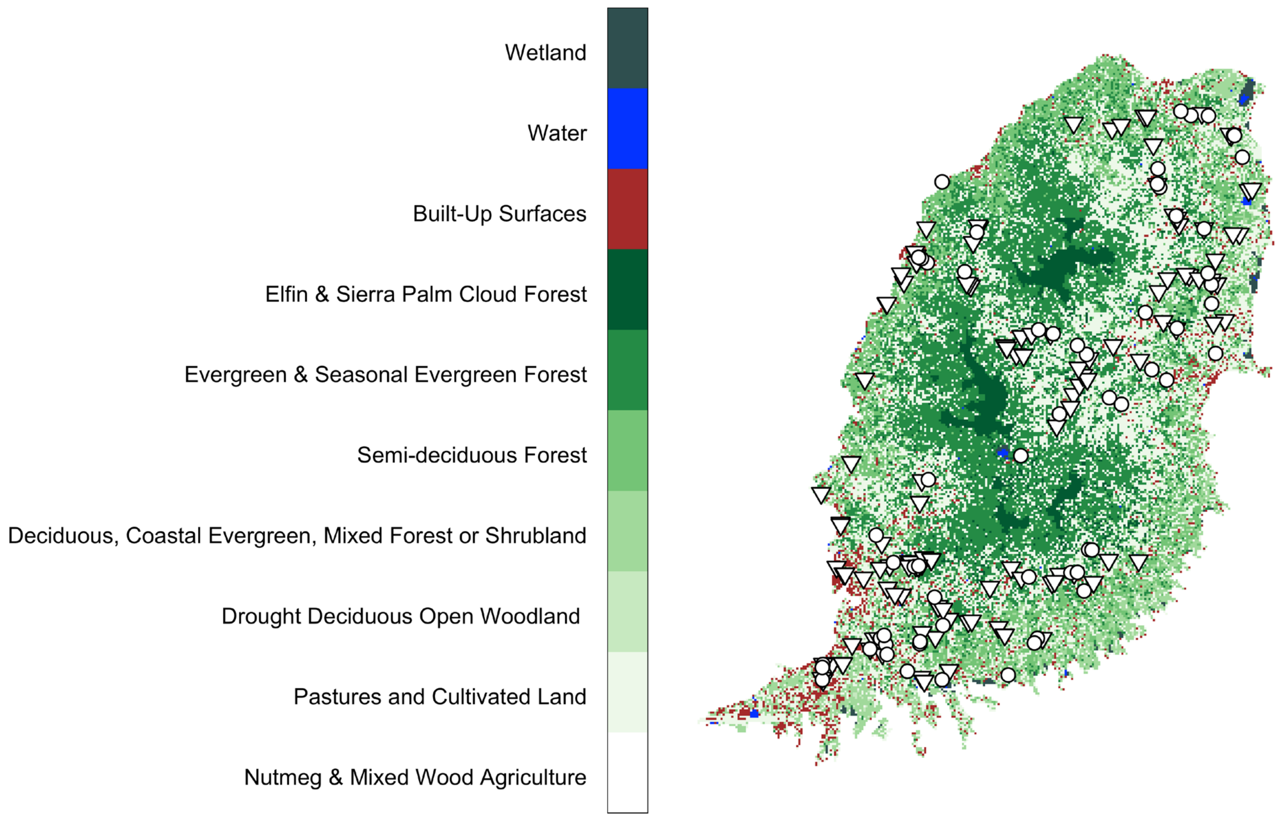

Fig. 2. Map of the sites where we observed Antillean Broad-winged Hawks during the study (2016–2017) from road transect surveys; triangles indicate where Antillean Broad-winged Hawks were seen in the dry season, and circles indicate where they were seen in the wet season. The key describes the land cover categories per Helmer *et al.* (2008).

could be attempted at a closer distance. When possible, we noted specific behavior or other features, such as feather wear or absence, to help prevent double counting.

Spatial Data.— We obtained land cover and elevation data from the Caribbean Risk Information Program, as these factors are known to influence raptor occurrences (e.g., Thiollay 1996, Bustamante 1997, Dykstra *et al.* 2001). The Caribbean Risk Information Program delineated 12 land cover categories for Grenada, including: Nutmeg and Mixed Wood Agriculture; Pastures and Cultivated Land; Drought Deciduous Open Woodland; Deciduous, Coastal Evergreen, Mixed Forest or Shrubland; Semi-deciduous Forest, Evergreen and Seasonal Evergreen Forest; Elfin and Sierra Palm Cloud Forest; Buildings; Roads and other Built-up Surfaces; Bare Ground; Golf Course, Water, and Wetland (Helmer *et al.* 2008). We reclassified all urban land covers to a single variable named "built-up", which included Buildings, Roads and other Built-up Surfaces, Golf Course, and Bare Ground, since the literature suggests similar raptor occurrences in urban areas (e.g., Stout *et al.* 2009, McCabe *et al.* 2018). The land cover data was produced by the British Geological Survey (BGS), which used a combination of Earth Observation satellite data for 2014, existing data, and ground-truthing exercises to create the land cover raster file (CHARIM 2016a). Land cover classes delineated by the BGS in the land cover map were based on the International Institute of Tropical Forestry forest classification system (for more information on the forest-based classes, see Helmer *et al.* 2008). The elevation data was derived from LiDAR by the International Institute for Geo-Information Science and Earth Observation. The resolution of the elevation data was 5 m, and the sinks in the digital elevation model were filled using data from the NASA Shuttle Radar Topography Mission (CHARIM 2016b).

Data Analysis

Detectability.— Using the point-count data, we developed *N*-mixture models to estimate the effects of time, date, land cover, and elevation on detectability of Antillean Broad-winged Hawks. We used the "gcount" function in the *unmarked* package in R to model detection probabilities (Fiske and Chandler 2011, R Core Team 2017). We allowed the function to set *K*, the upper index of integration for *N*-mixture, at the maximum number of birds detected (5) + 100. In *N*-mixture models, covariates are specified that are likely to influence detection (i.e., variables that influence the probability of detecting a bird if it is present) versus those that are likely to influence availability (i.e., whether a bird that is present is visible or vocalizing) and abundance (i.e., variables that affect the number of birds that can use an area). In some cases, we concluded that a variable (such as land cover) might influence both abundance and detectability, so we compared the fit of models that allowed either definition. Therefore, we compared the fit of a null model with models that allowed detectability to vary by time, date, or land cover; models that allowed availability to vary by elevation and land cover; models that allowed abundance to vary with elevation and land cover;

and combinations of these parameter specifications (n = 14 models; Appendix 1).

Species Distribution Model.— Using the road transect data, we developed models of the Antillean Broad-winged Hawk distribution. We compared results derived from two different modeling approaches, generalized linear models (GLM) and maximum entropy models (MaxEnt), to evaluate whether our conclusions were robust to the analysis method. All models were implemented in R (R Core Team 2017).

We created GLMs using a presence-available approach. To quantify habitat availability, we randomly selected pseudo-absence (or "background") locations (Elith *et al.* 2011). To ensure we had equal sample sizes of absence and presence locations, we selected 19 random points per land cover class for the observations in the wet season (n = 290) and 10 for the observations in the dry season (n = 180). We used the "Stratified" function in the *dismo* package (Hijmans *et al.* 2017) to locate the pseudo-absences, and the same package to extract land cover class and elevation from pseudo-absence and observation locations.

We used a hierarchical modeling approach to evaluate the effects of season, land cover, and elevation on the probability of Antillean Broad-winged Hawk occurrence (i.e., the chance that the species is present) using the "glm" function in the *stats* package (R Core Team 2017). We first assessed whether the probability of occurrence was random (null model), and then evaluated whether there was a difference in occurrence between seasons (wet and dry). We then assessed whether elevation and land cover affected the probability of occurrence by comparing the fit of the above models with models including a linear combination of land cover and elevation and an additional model that also included interaction terms between land cover and elevation. We concluded that the model with the highest Akaike Information Criterion (AIC) weight and lowest AIC value had the best fit to our data and used this to model hawk distributions. We interpreted our results such that predictors with 95% confidence intervals that did not overlap with zero had a significant influence on the probability of occurrence. To ensure that our models were not confounded by a correlation between predictors, we tested for correlation between elevation and land cover using a generalized variance inflation (Fox and Monette 1992, Alessandro 2020) and determined that our predictors were not correlated (Land Cover: GDIF = 1.017, df = 9; Elevation: GDIF = 1.172, df = 1).

Although we found some variation in detectability among habitat types, we chose not to include detectability offsets within the SDM analyses because the challenges associated with estimating detectability under real-world conditions, namely that statistically modeling detectability can increase rather than decrease bias (e.g., Efford and Dawson 2009). As a result, we believe that it is better to assess detectability and apparent habitat use separately. Nonetheless, we consider it important to recognize the potential impacts of detectability on habitat suitability models. As such, below, we explicitly consider our detectability results when interpreting apparent variation in abundance among habitats.

We used k-fold cross validation to validate the best-fitting GLMs using the "evaluate" function in the *dismo* package (Hijmans *et al.* 2017). A 3-fold validation was used because this scale captured all land cover classes in the training set. The mean Area Under the Curve (AUC) value was used to determine the performance of models.

We used maximum entropy (MaxEnt) to model species distributions, which also compares the locations of detected individuals with background points (Elith *et al.* 2011). While MaxEnt is widely used to predict species distribution with presence-only data, there are some constraints, and caution should be taken when interpreting the results. Because MaxEnt models assume that species are sampled randomly, and also that there is no bias in sampling (Merow *et al.* 2013), it can produce unreliable estimates of occurrences when sites are revisited, which must be considered when interpreting the results. Typically, MaxEnt uses a cross-validation bootstrapping approach with replacement. This means that the function selects a portion of the data to build the model and the rest to test the model; this process is then repeated many times using the entire dataset with replacement. We used the *dismo* package to implement MaxEnt (Hijmans *et al.* 2017). Using land cover and elevation as predictors, we implemented the "MaxEnt" function, specifying the number of background points as 10,000.

We also used k-fold cross validation to validate the MaxEnt model. We ran a 10-fold cross validation as opposed to 3-fold as with the GLM because the inclusion of more background points in MaxEnt meant that all land cover classes were captured in the training set. After running the cross validation ten times, we used the mean AUC value to determine the performance of models.

Results

We conducted 56 roadside surveys along seven road transects and 336 point-count surveys in the wet season of 2016 (July–December) and dry season of 2017 (January–May). We recorded a total of 262 sightings of the Antillean Broad-winged Hawk along the road transect surveys. Although sampling effort was equal between seasons, we recorded 70% (n = 182) in the wet season and 30% (n = 80) in the dry season (Fig. 2). During the study, we observed Antillean Broad-winged Hawks feeding on a variety of food types, mostly reptiles, such as tree and ground lizards, and occasionally small rodents and birds. We also observed evidence of breeding (i.e., courtship display and copulation) during the dry season, between January and March.

Detection Probabilities

There were five competitive models (ΔAIC within 2 AIC units of the best model). Of these five competitive models, all suggested that the detectability of Antillean Broad-winged Hawks was influenced by land cover, time of day, and day of year, though only three included availability (influenced by elevation or land cover), and one included abundance (influenced by land cover) (Appendix 1). Adding covariates other than land cover, time of day, and day of year improved model fit by less than 2 AIC units, suggesting that other covariates were not informative (Arnold 2010). All the top-ranked models indicated that detection probabilities were higher earlier in the day and earlier in the year and were lower in Evergreen Forests than other habitat types (Fig. 3). Detectability was high (> 0.8) throughout the daily period during which we conducted surveys, throughout most of the year (until the end of October), and in all habitats except Evergreen Forests (Fig. 3).

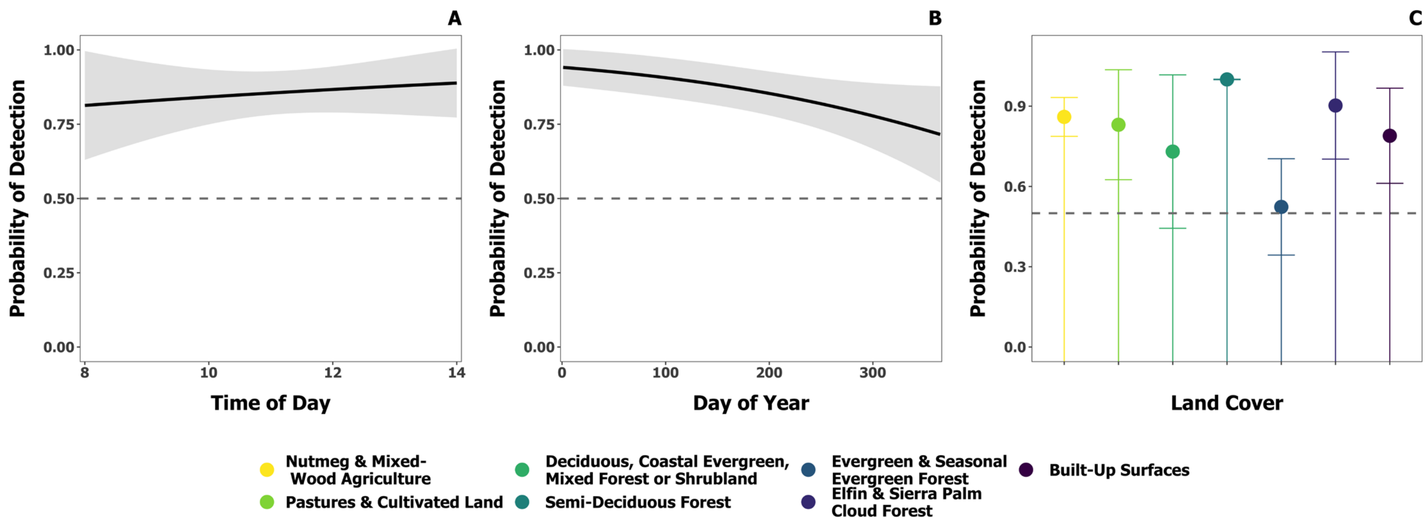

Fig. 3. Plot of the probability of detection for Antillean Broad-winged Hawks by time of day (A), day of year the survey was conducted (B) and land cover class (C). For the time-of-day model (A), we used the mean number of days across surveys (290) to predict the probability of occurrence. For the day of year model (B), we used the average start time of the surveys (1140) to predict the probability of detection. Ribbons on the plot show 95% confidence intervals in A and B. For the land cover model (C), we used the land cover class to predict the probability of occurrence and represent 95% confidence intervals as error bars. These models do not show abundance or availability covariates.

Distribution Models

Based on the AUC results, GLM-based species distribution models had cross-validated accuracy rated as fair to good (both seasons: 81.1%; dry season: 81.0%; wet season: 79.6%; Safari *et al.* 2016), while MaxEnt-based species distribution models were slightly less accurate (both seasons: 71.7%; dry season: 69.5%; wet season: 75.2%).

Our conclusions were similar regardless of which model we derived them from, suggesting that our results were robust to analytical method. The probability of Antillean Broad-winged Hawk occurrence was best explained by elevation (Fig. 4) and land cover (Fig. 5) and not by season (AIC weightland+elevation > 0.836), suggesting similar habitat use in the dry and wet seasons. For comparative purposes, we separately modeled the probability of occurrence in the dry season and in the wet season, as well as both seasons combined, for subsequent analyses.

The probability of Antillean Broad-winged Hawk occurrence was highest in mid- to low-elevation coastal areas (Fig. 4), regardless of season, and this result was consistent between both models. The MaxEnt output suggests that occurrences were highest between 8–280 m asl, peaking at 50 m (Fig. 4). However, our results suggest that land cover had a larger influence on the probability of occurrence than elevation. Based on the permutation of importance, which is an estimate of how influential an environmental variable is on the probability of occurrence based on permutations of the data in MaxEnt, land cover had the largest influence on hawk occurrence (both seasons, land cover: 61.5%, elevation: 38.5%; wet season, land cover: 78.6%, elevation: 21.4%; dry season, land cover: 70.6%, elevation: 29.4%). Both models suggested that Nutmeg and Mixed-Wood Agricultural habitat was used at a higher rate than its availability on the landscape, while results from the GLM suggested that Pastures and Cropland, Wetlands, and Xeric Deciduous Open Woodland were avoided (Fig. 5). Deciduous and Coastal Evergreen, Semi-Deciduous, and Evergreen Forests were apparently used in approximate ratio with their availability; however, as detectability of hawks was lower in Evergreen Forests, hawk abundance might be higher there than our surveys suggest. Interestingly, results from both models suggest that Elfin and Sierra Palm Cloud Forest was avoided only during the wet season (Fig. 5E–F).

Antillean Broad-winged Hawks were widely distributed across the island (Fig. 6). However, they occurred at slightly higher abundances in the northeast and southwest of the island, which are also relatively more populated by humans, and were less likely to be found in the island's interior (Fig. 6).

Discussion

Our results suggest that Antillean Broad-winged Hawks are widely distributed across the island of Grenada and have adapted successfully to anthropogenically modified habitats, such as coniferous plantations (i.e., nutmeg and mixed wood plantations) and agroforests (Government of Grenada 1996), while they avoid relatively planar or open habitats, such as wetlands, pastures, and cropland. Antillean Broad-winged Hawks frequently use nutmeg and mixed wood agriculture habitats, suggesting that some anthropic land uses may be consistent with the habitat needs of wildlife. We caution, however, that our limited ability to detect Antillean Broad-winged Hawks in evergreen forests may underestimate the importance of this habitat for foraging and nesting.

The abundance and broad distribution of Antillean Broad-winged Hawks across Grenada suggests that this subspecies is thriving and has adapted successfully to using anthropogenically modified, tree-dominated habitats on this island. Many populations of this species adapt well to anthropogenically modified landscapes (Thiollay 1985, Pérez-García *et al.* 2014);

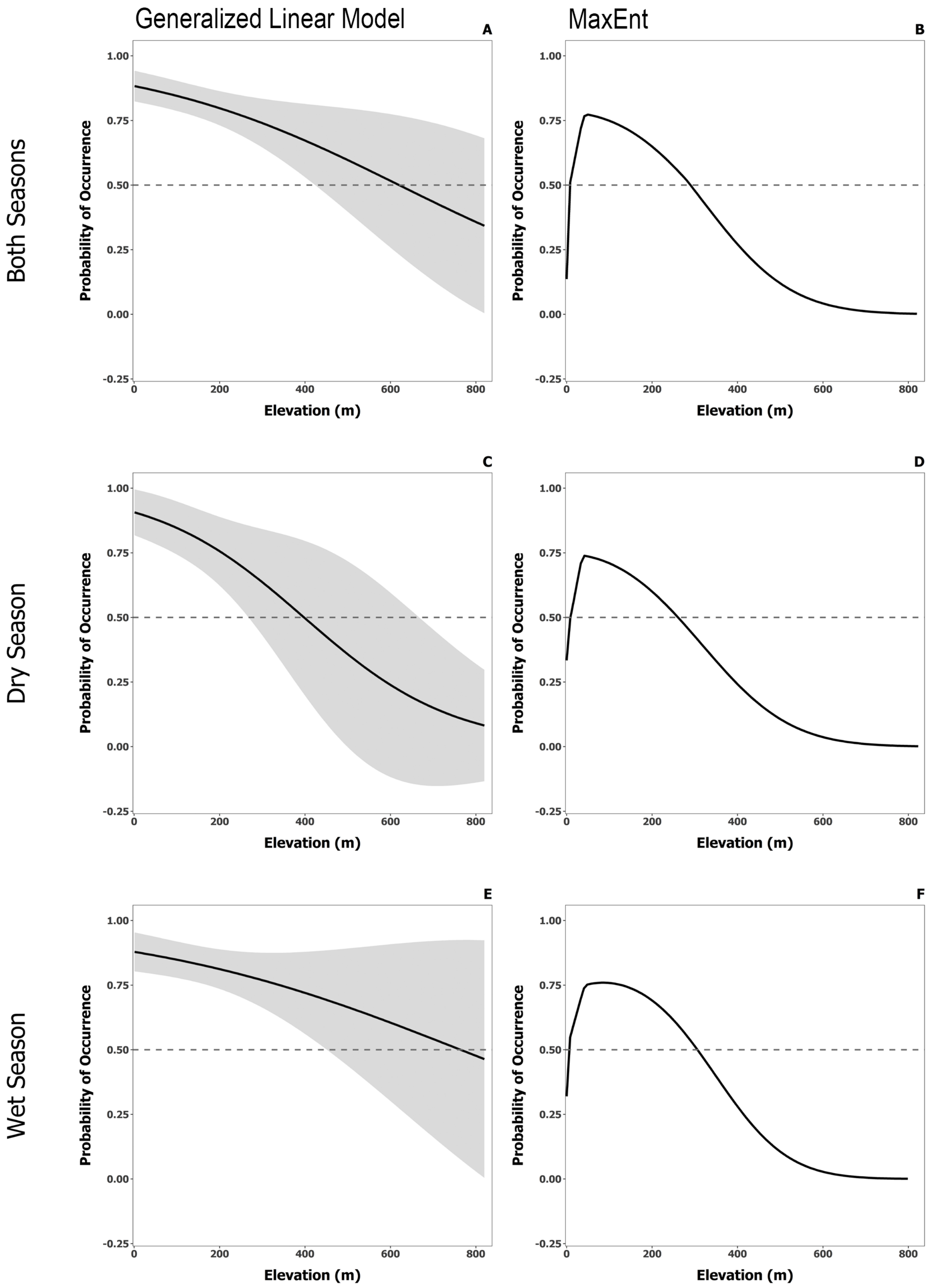

Fig. 4. Probability of Antillean Broad-winged Hawk occurrence varies with elevation and land cover type across both seasons (A–B), in the dry season (C–D), and in the wet season (E–F), as modeled using generalized linear models (A, C, E) and maximum entropy (MaxEnt) models (B, D, F). For the elevation plots, we used the most commonly observed land cover type (Nutmeg & Mixed Wood Agriculture) when predicting the probability of occurrence. Because it is not possible to estimate error for MaxEnt outputs for response curves, only the generalized linear model plots show the 95% confidence intervals.

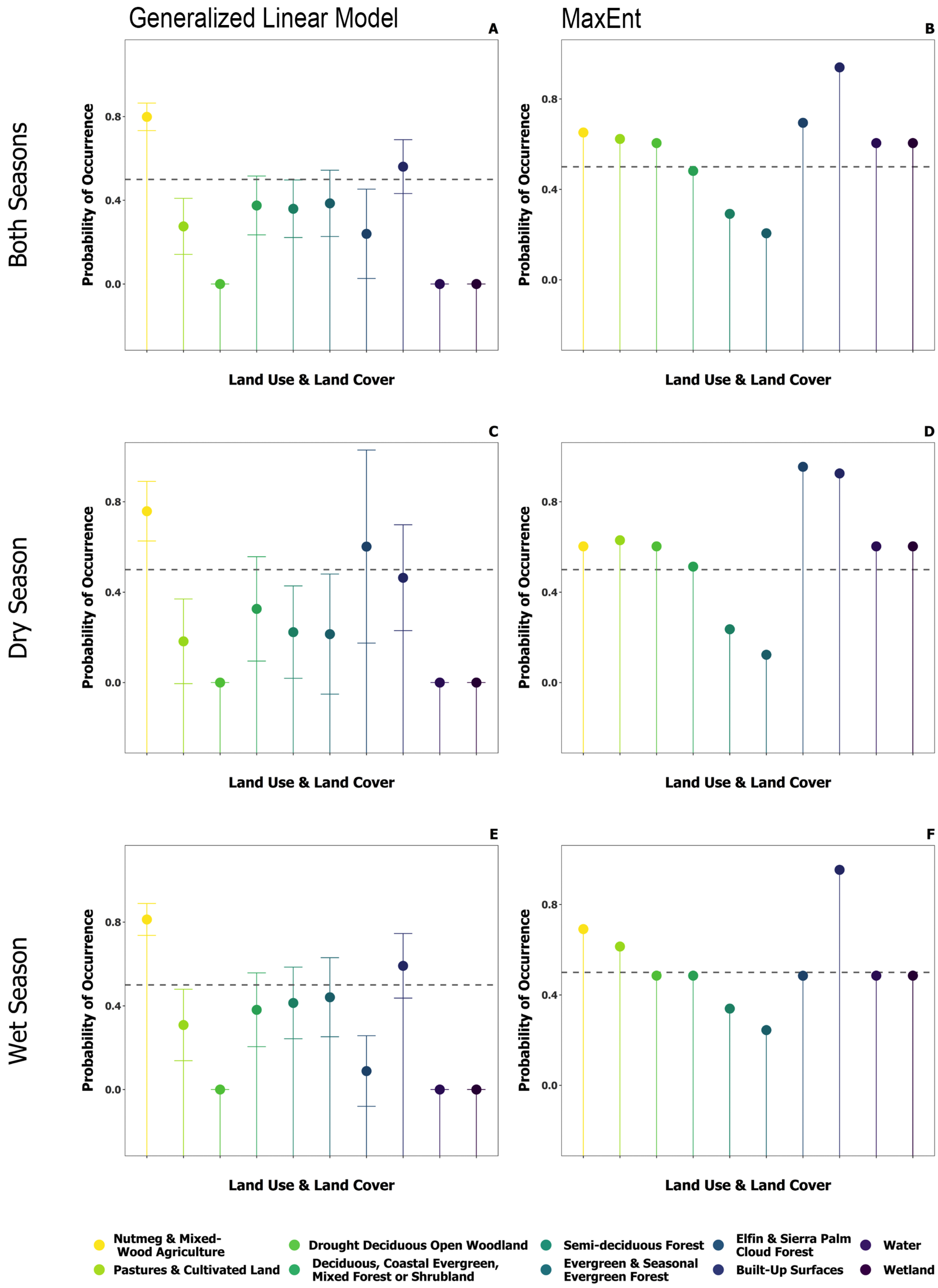

Fig. 5. Probability of Antillean Broad-winged Hawk occurrence varies with land cover type across both seasons (A–B), in the dry season (C–D), and in the wet season (E–F), as modeled using generalized linear models (A, C, E) and maximum entropy (MaxEnt) models (B, D, F). For the land cover plots, we used the mean elevation across the background points (198.55 m asl) when predicting the probability of occurrence. Because it is not possible to estimate error for MaxEnt output for response curves, only the generalized linear model plots show the 95% confidence intervals.

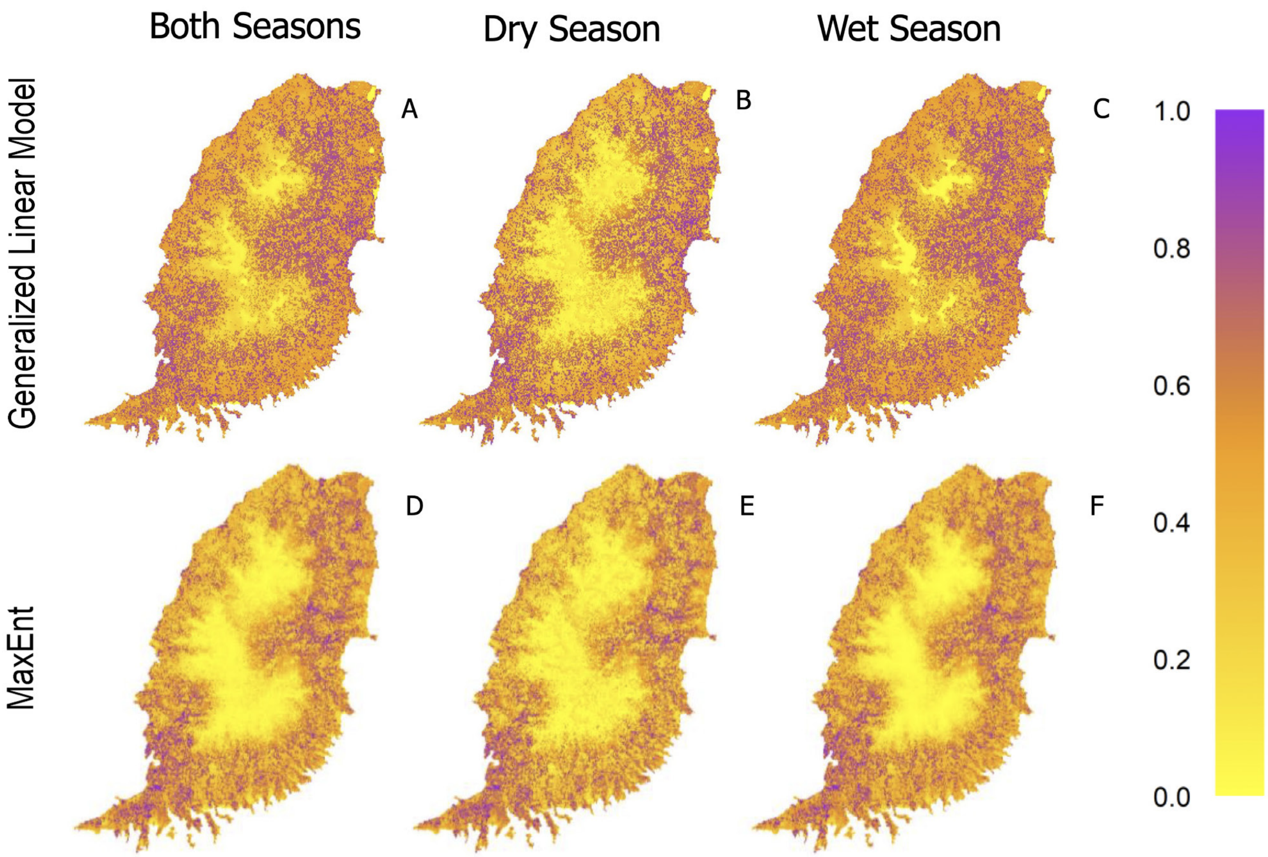

Fig. 6. Probability of occurrence maps produced by a generalized linear model and maximum entropy (MaxEnt) model for Antillean Broad-winged Hawks observed across all surveys (A and D), in the wet season (B and E), and in the dry season (C and F). A probability of one indicates a high likelihood of finding the species within the raster square and zero indicates a low likelihood.

however, Broad-winged Hawks avoid human developments in some parts of their range (Bloom *et al.* 1993). The endemic and endangered subspecies of Broad-winged Hawk in Puerto Rico (*Buteo platypterus brunnescens*) is limited to mature mountain forest (Vilella and Hengstenberg 2006), in contrast to the Antillean Broad-winged Hawks in Grenada, which avoid montane cloud forest. These distinct ranges highlight the ecological significance of differences among subspecies, which contribute to population and within-species biodiversity. Antillean Broad-winged Hawks on Grenada are thought to be non-migratory (Zalles and Bildstein 2006), consistent with the fact that we observed them in both wet and dry seasons, although they were observed less frequently in the dry season. They appeared to use similar habitat types in both seasons, though they occurred more frequently in the cloud forest in the dry than in the wet season. We speculate that prey availability in the xeric coastal forests is higher in the wet than in the dry season, which may attract hawks to lower elevations (Jedlicka *et al.* 2006), but further research is required to test this hypothesis.

We also speculate that the successful adaptation of Antillean Broad-winged Hawks to the modern anthropogenically modified landscape may have come at a cost to co-existing species. The much rarer and rapidly declining Grenada Hook-billed Kite also occurs on Grenada (Bond 1979, Smith and Temple 1982, Blockstein 1988, Thorstrom and McQueen 2008), and our observations suggest that the Antillean Broad-winged Hawk may be out-competing the kites. During and outside of the survey periods, we observed Antillean Broad-winged Hawks nesting in trees that previously held kite nests, and we have observed hawks displaying aggressive behavior towards kites. Notably, despite a lack of large trees favored by kites for nesting (Campbell *et al.* 2013), kites often occur in Xeric Open Woodland, the only tree-dominated habitat avoided by the hawks. Whether they select this habitat or are displaced into sub-optimal habitat by the hawks is unknown. We recommend further research to better understand the interactions between these two raptor species.

Given the ecological and taxonomic uniqueness of the Antillean Broad-winged Hawk, we argue that their populations should be considered within conservation and management actions on Grenada. Protected areas can be an effective means of raptor conservation (Thiollay 2006), and Mount Hartman National Park, a 62-hectare forest parcel in the south of Grenada (Rusk 2010), could play an important role in the conservation of the Antillean Broad-winged Hawk and other raptors, such as the Grenada Hook-billed Kite, if this park remains protected from the effects of nearby development. Elsewhere on the island, individual trees that have high potential for nest sites, such as the silk cotton (*Ceiba pentandra*), could also be protected. However, protected areas alone are rarely sufficient to conserve a species. McClure *et al.* (2018) argue that identification and designation of protected areas will only conserve raptor populations if accompanied by appropriate monitoring, management, and protective enforcement actions. Private "working landscapes" are also essential to the conservation of Grenada's raptors because most of Grenada's lands are not owned by the government. For best results, key stakeholders should be involved and consulted in the development of conservation and management plans, suggesting that government, forestry, tourism, and agricultural organizations must all be engaged in the conservation process. Further, more visual surveys should be conducted in areas with poor detectability (e.g., evergreen forests), and nesting surveys should be conducted to determine if habitats with higher occurrence also have higher nesting success (e.g., Daniel and Koper 2019).

Acknowledgments

We thank Mr. Anthony Jeremiah, Forestry Department, Grenada for his support and guidance with carrying out our field research. We also thank Dr. Jack Kirkley, University of Montana Western for his support and guidance throughout this study. Finally, we thank Shanell Cyrus (Field Assistant, SGU) for her time and hard work with gathering field data. This research was supported by the Natural Sciences and Engineering Research Council of Canada, the University of Manitoba Research Grants Program as well as the Department of Biology, Ecology and Conservation, St. George's University, Grenada. Author contributions: EC and JD contributed to study design, data collection and analysis, and drafted the manuscript. NK contributed to study design, supervised analyses, edited the manuscript, and supervised participants. AEP contributed to study design, editing, and supervising participants.

Cover Page Illustration

Antillean Broad-winged Hawk (*Buteo platypterus antillarum*) perched on a telephone wire on one of our survey routes in the south of the Grenada. Photograph by Ezra Angella Campbell in 2017.

Author Information

[1]Natural Resources Institute, University of Manitoba, Winnipeg, MB R3T 2M6, Canada; [2]e-mail: ezra.a.campbell@gmail.com; [3]Gaea Conservation Network, Grand Anse, St. George, Grenada, West Indies; [4]e-mail: jodyndaniel@gmail.com; [5]B2-251, Department of Biology, University of Waterloo, Waterloo, ON N2L 3G1, Canada; [6]College of Science, Weber State University, Ogden, UT 84408, USA; e-mail: aeasterpilcher@weber.edu; [7]email: nicola.koper@umanitoba.ca.

Literature Cited

Alessandro, S.R. 2020. Pedometrics: Miscellaneous Pedometric Tools. CRAN.

Arnold, T.W. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. Journal of Wildlife Management 74:1175–1178.

Bildstein, K.L., W.M. Schelsky, J. Zalles, and S. Ellis. 1998. Conservation status of tropical raptors. Journal of Raptor Research 32:3–18.

BirdLife International. 2016. *Buteo platypterus*. The IUCN Red List of Threatened Species 2016.

Blockstein, D.E. 1988. Two endangered birds of Grenada, West Indies: Grenada Dove and Grenada Hook-billed Kite. Caribbean Journal of Science 24:127–136.

Bloom, P.H., M.D. McCrary, and M.J. Gibson. 1993. Red-shouldered hawk home-range and habitat use in southern California. Journal of Wildlife Management 57:258–265.

Bond, J. 1979. Derivations of Lesser Antillean birds. Proceedings of the Academy of Natural Sciences of Philadelphia 131:89–103.

Brooks, T.M., R.A. Mittermeier, G.A.B. Da Fonseca, J. Gerlach, M. Hoffmann, J.F. Lamoreux, C.G. Mittermeier, J.D. Pilgrim, and A.S.L. Rodrigues. 2006. Global biodiversity conservation priorities. Science 313:58–61.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, New York.

Bustamante, J. 1997. Predictive models for lesser kestrel *Falco naumanni* distribution, abundance and extinction in southern Spain. Biological Conservation 80:153–160.

Campbell, E., J. Daniel, A. Joseph-Witzig, R. Graham, W. Smart, T. Walcott, L. Romain, K. MacDonald, S. Eleazer, D. Guy, and A. Easter-Pilcher. 2013. Nest tree site selection by the Grenada Hook-billed Kite. Society for the Conservation and Study of Caribbean Birds (now BirdsCaribbean). 19th Regional Meeting. 27–31 July 2013. Grenada, West Indies.

Carrete, M., J.L. Tella, G. Blanco, and M. Bertellotti. 2009. Effects of habitat degradation on the abundance, richness and diversity of raptors across Neotropical biomes. Biological Conservation 142:2002–2011.

CHARIM. 2016a. Land cover maps. Page [Online] Data Management Book. ITC of the University of Twente, Enschede, Netherlands.

CHARIM. 2016b. Digital Elevation Models. Page [Online] Data Management Book. ITC of the University of Twente, Enschede, Netherlands.

Clark, A.H. 1905. Preliminary descriptions of three new birds from St. Vincent, West Indies. Pages 61–63 *in* Proceedings of the Biological Society of Washington. Biological Society of Washington, Washington, DC.

Conn, P.B., L.L. Bailey, and J.R. Sauer. 2004. Indexes as surrogates to abundance for low-abundance species. Pages 59–74 *in* Sampling Rare and Elusive Species: Concepts, Designs, and Techniques for Estimating Population Parameters (W.L. Thompson, ed.). Island Press, Washington, DC.

Daniel, J., and N. Koper. 2019. Cumulative impacts of roads and energy infrastructure on grassland songbirds. Condor 121:1–21.

Dykstra, C.R., F.B. Daniel, J.L. Hays, and M. M. Simon. 2001. Correlation of Red-shouldered Hawk abundance and macrohabitat characteristics in southern Ohio. Condor 103:652–656.

Efford, M.G., and D.K. Dawson. 2009. Effect of distance-related heterogeneity on population size estimates from point counts. Auk 126:100–111.

Elith, J., and J. Franklin. 2013. Species Distribution Modeling.

Pages 692–705 *in* Encyclopedia of Biodiversity, Second Edition (S.A. Levin, ed.). Academic Press, London, UK.

Elith, J., S.J. Phillips, T. Hastie, M. Dudík, Y.E. Chee, and C.J. Yates. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17:43–57.

Ferrer-Sánchez, Y., and R. Rodríguez-Estrella. 2015. Man-made environments relationships with island raptors: endemics do not cope with habitat changes, the case of the island of Cuba. Biodiversity and Conservation 24:407–425.

Ferrer-Sánchez, Y., and R. Rodríguez-Estrella. 2016. How rare species conservation management can be strengthened with the use of ecological niche modelling: the case for endangered endemic Gundlach's Hawk and Cuban Black-Hawk. Global Ecology and Conservation 5:88–99.

Fiske, I., and R. Chandler. 2011. unmarked: an R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43:1–23.

Fox, J., and G. Monette. 1992. Generalized collinearity diagnostics. Journal of the American Statistical Association 87:178–183.

Gallardo J.C., and R. Thorstrom. 2019. Status and conservation of the raptors in the West Indies: a review. Caribbean Naturalist 2:90–134.

Government of Grenada. 1996. Grenada: country report to the FAO International Technical conference on plant genetic resources. St. George's, Grenada.

Government of Grenada. 2000. Biodiversity strategy and action plan. St. George's, Grenada.

Groome, J.R. 1970. A Natural History of the Island of Grenada, W.I. Caribbean Printers Ltd., Trinidad.

Helmer, E.H., T.A. Kennaway, D.H. Pedreros, M.L. Clark, H. Marcano-Vega, L.L. Tieszen, S.R. Schill, and C.M.S. Carrington. 2008. Land cover and forest formation distributions for St. Kitts, Nevis, St. Eustatius, Grenada and Barbados from decision tree classification of cloud-cleared satellite imagery. Caribbean Journal of Science 44:175–198.

Hijmans, R.J., S. Phillips, J.R. Leathwick, and J. Elith. 2017. Package 'dismo'. Dismo: Species Distribution Modeling. R package version 1.1–4.

Jedlicka, J.A., R. Greenberg, I. Perfecto, S.M. Philpott, and T.V. Dietsch. 2006. Seasonal shift in the foraging niche of a tropical avian resident: resource competition at work? Journal of Tropical Ecology 22:385–395.

Laurance, W.F. 2010. Habitat destruction: death by a thousand cuts. Pages 73–87 *in* Conservation Biology for All. Oxford University Press, Oxford.

McCabe, J.D., H. Yin, J. Cruz, V. Radeloff, A. Pidgeon, D.N. Bonter, and B. Zuckerberg. 2018. Prey abundance and urbanization influence the establishment of avian predators in a metropolitan landscape. Proceedings of the Royal Society B: Biological Sciences 285:20182120.

McClure, C.J.W., J.R.S. Westrip, J.A. Johnson, S.E. Schulwitz, M.Z. Virani, R. Davies, A. Symes, H. Wheatley, R. Thorstrom, A. Amar, R. Buij, V.R. Jones, N.P. Williams, E.R. Buechley, and S.H.M. Butchart. 2018. State of the world's raptors: distributions, threats, and conservation recommendations. Biological Conservation 227:390–402.

Merow, C., M.J. Smith, and J.A. Silander. 2013. A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. Ecography 36:1058–1069.

Navarro-López, J., and J.A. Fargallo. 2015. Trophic niche in a raptor species: the relationship between diet diversity, habitat diversity and territory quality. PLoS One 10:e0128855.

Nijman, V., J. Booij, M. Flikweert, M. Aliabadian, J.A. de Freitas, R. Vonk, and T.G. Prins. 2009. Habitat use of raptors in response to anthropogenic land use on Bonaire and Curaçao, Netherlands Antilles. Caribbean Journal of Science 45:25–29.

Pérez-García, J.M., E. Sebastián-González, K.L. Alexander, J.A. Sánchez-Zapata, and F. Botella. 2014. Effect of landscape configuration and habitat quality on the community structure of waterbirds using a man-made habitat. European Journal of Wildlife Research 60:875–883.

R Core Team. 2017. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rodriguez-Estrella, R., J.A. Donazar, and F. Hiraldo. 1998. Raptors as indicators of environmental change in the scrub habitat of Baja California Sur, Mexico. Conservation Biology 12:921–925.

Rosenstock, S.S., D.R. Anderson, K.M. Giesen, T. Leukering, and M.F. Carter. 2002. Landbird counting techniques: current practices and an alternative. Auk 119:46–53.

Rusk, B.L. 2010. Mt. Hartman development and the Grenada Dove: finding a win-win solution. The Nature Conservancy, St. George's, Grenada.

Safari, S., A. Baratloo, M. Elfil, and A. Negida. 2016. Evidence Based Emergency Medicine; Part 5: Receiver Operating Curve and Area under the Curve. Emergency (Tehran, Iran) 4:111–113.

Smith, T.B., and S.A. Temple. 1982. Grenada Hook-billed Kites: recent status and life history notes. Condor 84:131.

Steenhof, K., and M.N. Kochert. 1982. An evaluation of methods used to estimate raptor nesting success. Journal of Wildlife Management 46:885–893.

Stout, W.E., S.A. Temple, and J.R. Cary. 2009. Landscape features of Red-tailed Hawk nesting habitat in an urban/suburban environment. Journal of Raptor Research 40:181–192.

Thiollay, J.M. 1985. The tropical rainforest raptors: state of knowledge, world situation and conservation strategy. ICBP Technical Publication 5:223–225.

Thiollay, J.M. 1989. Censusing of diurnal raptors in a primary rain forest: comparative methods and species detectability. Journal of Raptor Research 23:72–84.

Thiollay, J.M. 1996. Distributional patterns of raptors along altitudinal gradients in the northern Andes and effects of forest fragmentation. Journal of Tropical Ecology 12:535–560.

Thiollay, J.M. 2006. The decline of raptors in West Africa: long-term assessment and the role of protected areas. Ibis 148: 240–254.

Thorstrom, R., and D. McQueen. 2008. Breeding and status of the Grenada Hook-billed Kite (C*hondrohierax uncinatus mirus*). Ornitologia Neotropical 19:221–228.

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. Ornitologia Neotropical 17:563–579.

Zalles, J., and K.L. Bildstein. 2006. Old World vs. New World long-distance migration in Accipiters, Buteos and Falcons. Pages 158–167 *in* Birds of Two Worlds: the Ecology and Evolution of Migration (R. Greenberg and P.P. Marra, eds.). Smithsonian Institution, Washington, DC.

Appendix 1. AIC, ΔAIC, and AIC weight for the 14 models predicting detection probabilities and abundance. The five models marked with an asterisk (*) were within 2 ΔAIC units of the best model and thus considered equivalent.

Model	Abundance	Availability	Detection	AIC	ΔAIC	AIC Weight
1	Null	Null	Null	838.33	9.635	0.002
2	Null	Null	Time + Julian	836.42	7.721	0.005
3	Null	Null	Time + Julian + Land Cover*	829.99	1.296	0.119
4	Null	Elevation + Land Cover	Time + Julian + Land Cover	830.92	2.222	0.075
5	Null	Land Cover	Time + Julian + Land Cover*	828.94	0.241	0.202
6	Null	Elevation	Time + Julian + Land Cover*	830.67	1.976	0.085
7	Null	Elevation + Land Cover	Time + Julian + Land Cover	837.45	8.756	0.003
8	Elevation	Elevation + Land Cover	Time + Julian + Land Cover	832.82	4.121	0.029
9	Elevation + Land Cover	Elevation + Land Cover	Time + Julian + Land Cover	839.62	10.923	0.001
10	Land Cover	Null	Time + Julian + Land Cover*	828.70	0.000	0.228
11	Elevation + Land Cover	Null	Time + Julian + Land Cover	830.92	2.222	0.075
12	Elevation + Land Cover	Null	Time + Julian + Land Cover	830.70	2.003	0.084
13	Land Cover	Land Cover	Time + Julian + Land Cover	835.46	6.759	0.008
14	Land Cover	Elevation	Time + Julian + Land Cover*	830.68	1.984	0.085

Cite this article as:

Campbell, E.A, J. Daniel, A. Easter-Pilcher, and N. Koper. 2022. Status and distribution of the Antillean Broad-winged Hawk (*Buteo platypterus antillarum*) on the island of Grenada. Journal of Caribbean Ornithology 35:108–119. https://doi.org/10.55431/jco.2022.35.108-119