OCCUPANCY AND CO-OCCURRENCE OF CARNIVORES IN THE ECUADORIAN ANDES

A Thesis

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Master of Science

by

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ABSTRACT

The Chocó-Andean region of Ecuador is at the junction of two of the world's biodiversity hotspots, yet this biodiversity is at risk due to the alarming pace at which habitat is being converted for human land uses including agriculture, cattle grazing, and mining. Our study was conducted in conjunction with ongoing research to design a socio-ecological corridor between two ecological reserves in Northern Ecuador. The focal species of this corridor design is the Andean bear (*Tremarctos ornatus*), which is considered an umbrella species in the region. However, little research has been done concerning the spatial ecology of Andean bears and other carnivores that share habitat in this area. We conducted a large-scale camera trapping survey and used single and multi-species occupancy modeling to examine 1) the habitat associations of tayras (*Eira barbara*), a relatively unstudied species throughout Central and South America and 2) co-occurrence of Andean bears with humans and domestic dogs (*Canis familiaris*). Tayra occupancy was influenced positively by native forest, the dominant habitat type in the area, and pasture (land deforested for cattle grazing) was not a strong predictor on occupancy. Andean bear occupancy was independent of human and dog presence on the landscape, and instead driven by land use/cover types. Our results indicate that tayras and Andean bears may be acclimated to certain human impacts on the landscape. We recommend that further research explore the spatial ecology of these species across multiple survey seasons and at a finer scale to monitor changes over time and investigate the specific mechanisms that may allow these species to coexist with humans on the landscape.

BIOGRAPHICAL SKETCH

Vanessa Springer was raised in the San Francisco Bay Area of California, where she had many opportunities to explore the outdoors and develop her passion for animals and the environment. Her experiences volunteering at the Marin Humane Society, Marine Mammal Center, and Richardson Bay Audubon Sanctuary motivated her to pursue her passions as a career and she moved to Tucson to study at the University of Arizona. During her undergraduate years she studied for a semester in Chile to earn a Certificate in International Sustainable Resources Development and spent summers assisting on field research projects in California, Arizona, New Mexico, and Peru. She completed the Doris Duke Conservation Scholars Program (DDCSP) and earned her B.S. in Natural Resources in 2016. She then moved to Ithaca, NY to pursue her M.S. in Natural Resources and continue as a DDCSP graduate mentor. Vanessa is passionate about wildlife conservation, diversity and inclusion in the environmental field, and animal rescue. She now resides in New Mexico with her crazy pit bull Stella.

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CHAPTER 1

TAYRA OCCUPANCY INFLUENCED BY HABITAT TYPES RATHER THAN HUMAN LAND USE IN THE ECUADORIAN ANDES

Abstract

Despite being one of the most common carnivores in Central and South America, tayras (*Eira barbara*) are relatively unstudied compared to other neotropical mammal species and little is known regarding their associations with different habitat types. Tayras are generalists that are well adapted to many different habitat types and human pressures, but local populations may be impacted by accelerating conversion of habitat for human uses. In particular, deforestation for cattle grazing, agriculture and mining is a major threat to biodiversity in the Ecuadorian Andes. We conducted a camera trap study in northern Ecuador and used single-season occupancy models to examine the association of tayras with different land use and cover types in this region. Tayra occupancy was positively associated with native forest, which likely hosts a variety of food sources. Pasture was not a strong predictor of tayra occupancy, suggesting that the disturbance by deforested pasture lands and the associated presence of humans and cattle does not drive tayra occupancy. Lands used for cattle grazing can be partially or fully deforested and intensity of use varies, so it is possible that there is variation in the impacts of different pasture lands.

Introduction

Despite being one of the most common mammals within their geographical range, tayras (*Eira barbara*) are relatively unstudied compared to other neotropical mammal species (Konecny 1989, Oliveira 2009). Tayras are small carnivores (~2.7-7 kg) that occur across Latin America from southern Mexico to northern Argentina (Hall 1981, Presley 2000). Because the species is so widespread, the tayra is classified as a species of "Least Concern" among threatened wildlife by the IUCN Red List of Threatened Species (Cuarón et al. 2016). However, tayras may be experiencing habitat loss due to agricultural expansion and conflicts with local farmers who consider the animal a pest to their crops or domestic fowl (Oliveira 2009, Rocha et al. 2006). In fact, conversion of habitat and hunting are the biggest threat to mammal species worldwide (Hoffmann et al. 2011). Monitoring local populations becomes increasingly important in areas that are undergoing rapid change and can preemptively identify species that may be in danger due to increasing human presence on the landscape.

The ability of tayras to coexist with humans is likely the greatest contributor to their broad geographic distribution and ability to persist in a variety of different habitat types (Sunquist et al. 1989, Presley 2000). Tayras occur in close proximity to humans and use agricultural fields, orchards, and gardens as direct food sources and also benefit from the abundance of small mammals, birds and insects associated with these resources (Presley 2000, Cove et al. 2014). It is therefore possible that tayras may be able to persist in areas where habitat becomes fragmented due to agricultural expansion. For instance, in the Atlantic Forest of Brazil, tayra occupancy was negatively related to reserve size, which was attributed to the species being matrix-tolerant and able to use local agriculture at reserve boundaries as a food source; it is also possible that tayras prefer smaller reserves because they avoid predation by larger predators that do not occupy smaller forest patches (Massara et al. 2016).

There is insufficient ecological data on land cover preferences of tayras compared to other tropical mesocarnivores (Oliveira 2009). Tayras occur as low as sea level (Alberico et al. 2000) but are generally thought to occur between 1200 – 2400m (Eisenburg 1989, Emmons & Feer 1997) with the highest elevation recorded at 3379m (Jiménez et al. 2010), though they do not commonly occur ≥ 2400m (Emmons & Feer 1997). It is unclear whether the species is expanding their range to occur across a wider elevational extent, or whether individuals were previously present in these lower and higher elevation areas but went undetected due to lack of monitoring. Tayras inhabit many different ecosystems, and their association with different land cover types varies depending on geographic location of the population being studied. For example, tayra occupancy was negatively associated with dense forest cover in a forested landscape corridor in Costa Rica (Cove et al. 2014), was positively associated with forest cover in southern Brazil (Goulart et al. 2009, Bogoni et al. 2013), and exhibited no habitat relationships in Peru (Tobler et al. 2015).

Population size is an important state variable of interest for wildlife managers because many management objectives revolve around maximizing or minimizing a population size to protect imperiled species or prevent overabundance and increased wildlife conflicts (Williams et al. 2002). However, methods used to estimate abundance typically require a significant investment of time and money, and therefore can be difficult to conduct across large spatial extents (MacKenzie et al. 2002). Instead, presence-absence data can be used to estimate the proportion of sites occupied, or where the species is present across a landscape (MacKenzie 2005, Linden et al. 2017). Many methods of collecting presence-absence data such as camera-trapping surveys are relatively inexpensive, require less effort to conduct (Burton et al. 2015, De Bondi et al. 2010), and can be implemented over broad spatio-temporal extents. One of the main applications of presence-absence data is large-scale monitoring for the purposes of studying species distribution or identifying habitats that might be highly used by target species and are thus of conservation priority (MacKenzie 2005, Bailey et al. 2007).

We employ occupancy modeling as an effective method for preliminary research on the association of tayra with elevation and land use/cover types in the montane cloud forest of northern Ecuador. Our study area lies within a major biodiversity hotspot in the Andes, but unlike most of the literature that exists on tayras it is not within a reserve or other protected area. In fact, this region is highly fragmented by pasture for cattle grazing as well as subsistence agriculture. It has historically been used for these purposes by local communities and more recently is also being impacted by urban development and ecotourism. The expansion of mining into previously forested and protected areas across Ecuador is also expected to cause major biodiversity losses (Roy et al. 2018). This study provides the unique opportunity to evaluate tayra occupancy in an area where fragmentation and human impacts on the landscape are expanding.

Study Area

The study area (Figure 1.1) is within the Ecuadorian Andes, northwest of Quito, Ecuador (approximately -78.586 longitude, 0.205 latitude) within the Chocó-Andean region, which is located at the convergence of two of the world's biodiversity hotspots—the forests of Chocó and the Tropical Andes (Myers et al. 2000). This region supports a diverse group of mammalian

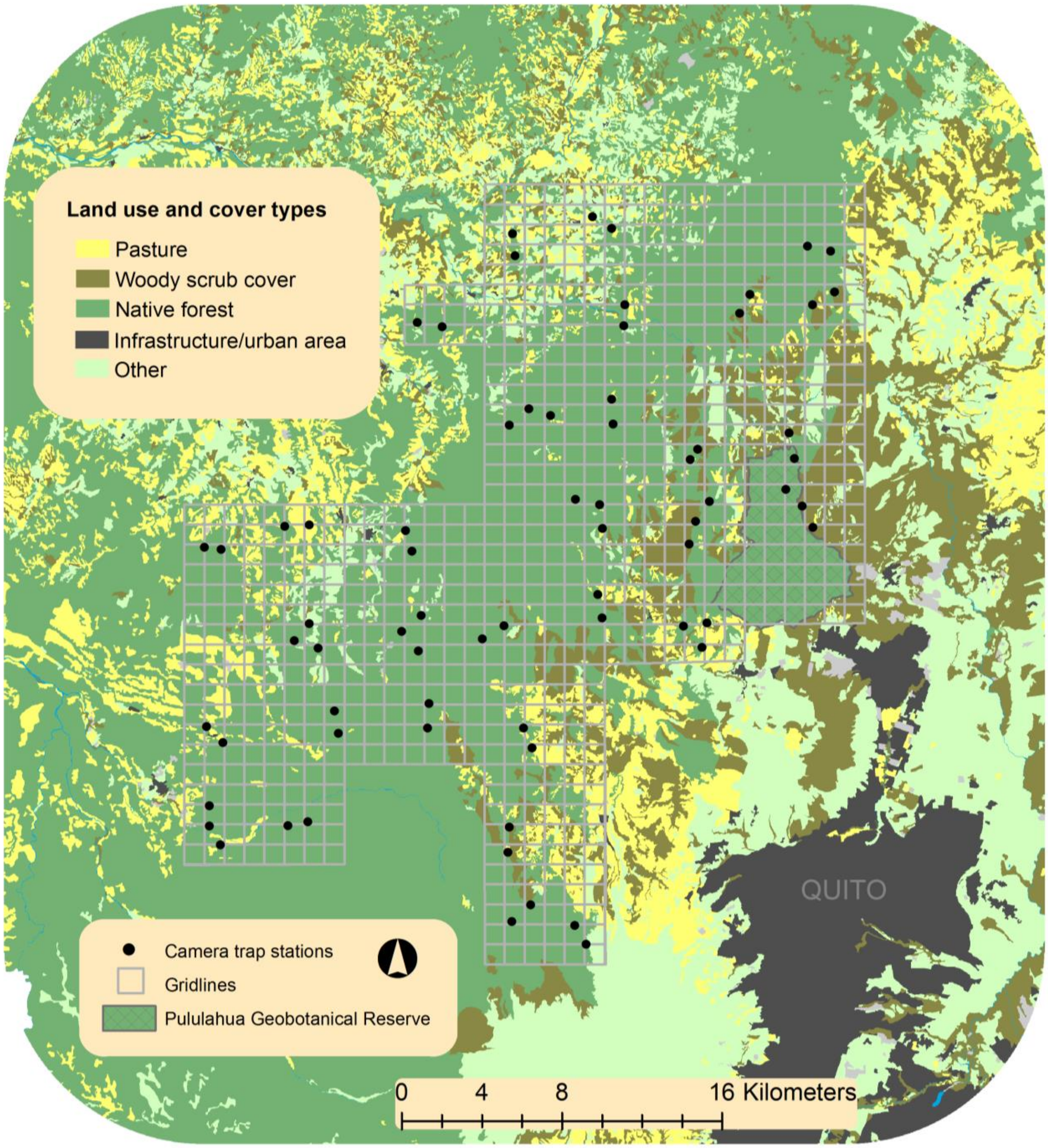

Figure 1.1. The study area northwest of Quito, Ecuador (approximately -78.586 longitude, 0.205 latitude). Map shows the survey gridlines, individual camera trap stations (n = 70) within 1 km^2 cells, and types of land use and cover.

carnivores and omnivores including the Andean bear (*Tremarctos ornatus*), puma (*Puma concolor*), jaguarundi (*Puma yagouaroundi*), ocelot (*Leopardus pardalis*), margay (*Leopardus* *wiedii*), oncilla (*Leopardus tigrinus*), culpeo fox (*Lycalopex culpaeus*), and striped hog-nosed skunk (*Conepatus semistriatus*) (Myers et al. 2000, Hodge & Arbogast 2016). It is composed mainly of montane cloud forest, where annual precipitation totals 236.8 cm with an average temperature of 17.76 °C (64.0 °F) (Jarvis & Mulligan 2011). Elevation within the study area ranges from 1,300 m to 3,800 m.

Much of the study area is within the Metropolitan District of Quito. Native and old growth forests represent approximately 66% of the study area, but this landscape also supports multiple human uses. At least 13% of the landscape has been partially or fully deforested and converted to pasture that is used for cattle grazing, as well as for growing crops that support the livelihoods of local communities. Less than 3% of the area is protected within Pululahua Geobotanical Reserve, and parts of the remaining forest are privately owned and have been developed for ecotourism. The study area incorporates the northern portion of the designated Andean Bear Ecological Corridor, which was established in July 2013 (Quito Municipal District Resolution No. 431) (Secretaría de Ambiente 2014). This corridor is central between two national ecological reserves in the region, Cotacachi-Cayapas Ecological Reserve to the north of Quito and Illinizas Ecological Reserve to the south.

Methods

Camera Trap Design

We monitored remotely activated Bushnell® Trophy Cam™ HD trail cameras from August 7, 2016 - November 22, 2016. The study area was gridded into 1 km^2 grid cells, 70 of which contained a camera trap station. This cell size and accompanying camera trap spacing is smaller than home range estimates of tayras in the literature, which fall between 2.4 km^2 and 24.44 km^2 (Konecny 1989, Sunquist et al. 1989), but large enough that detections in different grid cells are likely to be independent. Within the 804.77 km^2 sampling area (defined as the minimum convex polygon around the camera stations), 31 camera trap stations consisted of a pair of cameras and 39 stations contained one camera. Two cameras were used when possible to increase the detection and likelihood of individual identification for species like the Andean bear that have unique markings or coat patterns. The mean distance from one camera trap station to its nearest neighbor was 1.15 km (range= 0.64-1.30).

Camera sensitivity was set to “Normal” and cameras were programmed to take bursts of three photos on a 1-second interval. The cameras were strapped to trees, preferably with a diameter less than 20 cm, at 0.5 m height and placed facing either north or south to avoid direct sunlight during sunrise and sunset. We placed a 1 m tall stick 5 m in front of each camera with a vanilla scent lure taped to the top of the stick to increase wildlife detections and length of time individuals spent in front of a camera (Molina et al. 2017). Vanilla scent lure was chosen for its ease of transport and to attract as many different species as possible; it has had proven responses from cat species like ocelot and margay in captivity (Portella et al. 2013) and has been used in previous studies of Andean bears in this area (Molina et al. 2017). Stations with two cameras had a single bait stick, and the cameras were both pointed at the bait stick so that their zones of detection overlapped but the cameras were not directly facing each other. Whenever possible, cameras were placed on wildlife trails or facing trees with scratch marks or other signs of Andean bears. Cameras were checked approximately every two weeks (mean = 15 days, SD = 4.36 days) to switch memory cards, replace the scent lure, and clear vegetation.

Occupancy Analysis

We tagged photographs to species-level and metadata were written to each image using the photo management program Digikam v. 5.3.0 (https://www.digikam.org/). We used software R v. 3.4.1 (R Core Team 2017) and package camtrapR (Niedballa et al. 2018) to read and format data for occupancy modeling. The package RPresence (MacKenzie & Hines 2017) was used for occupancy analysis. We fit single-season occupancy models (MacKenzie et al. 2002) to estimate probability of tayra occurrence based on the assumption that the population is closed during the four months of the field season. We defined occasion length as 7 days to ensure independent detections, as tayras with radio-collars have been observed to be active in an area for several days before moving to different areas (Konecny 1989). We evaluated occupancy as a function of the following covariates: the percentage of native forest within a 1 km buffer of each camera trap (average value= 0.72, range= 0-1); the percentage of woody scrub cover within a 1 km buffer of each camera trap (average value = 0.10, range=0-0.56); the percentage of land used for pasture within a 1 km buffer of each camera trap (average value =0.09, range=0-0.66); and the elevation (m) at each camera trap (average value = 2200, range = 1300-3809) (Table 1.1). We used native forest and scrub cover to evaluate the possible relationship of tayra with different habitat types we expect they might use, and pasture as one measure of human presence on the landscape (pastures are areas that were once partially or entirely deforested and are now used for cattle grazing, either constantly or rotationally). Note that as the proportion of one land use/cover characteristic increases, the others must decrease and as such there is correlation between habitat covariates (Figure 1.2). The steep elevation gradient in this area is unique among previous studies, so we included elevation as a covariate. We calculated landscape covariates in ArcMap using map layers from Ecuador's National Thematic Cartography Project (2010), and sourced

Table 1.1. Covariates used for tayra (*Eira barbara*) occupancy analysis in northwest Ecuador, with a description of each covariate. Models for detection probability and occupancy were fit with combinations of the following covariates.

Covariate	**Description of covariate**
Occupancy Covariate	
Native Forest	% of native forest within a 1 km buffer zone around camera station
Woody Scrub	% woody scrub cover within a 1 km buffer zone around camera station
Pasture	% of area used for pasture within a 1 km buffer zone around camera station
Elevation	Elevation (m) at camera station
Detection Covariate	
Effort	Total number of days per 7-day occasion that cameras at camera station were operational
Scent	Number of days since the scent lure was replaced at camera station (averaged across the 7 days in each occasion)

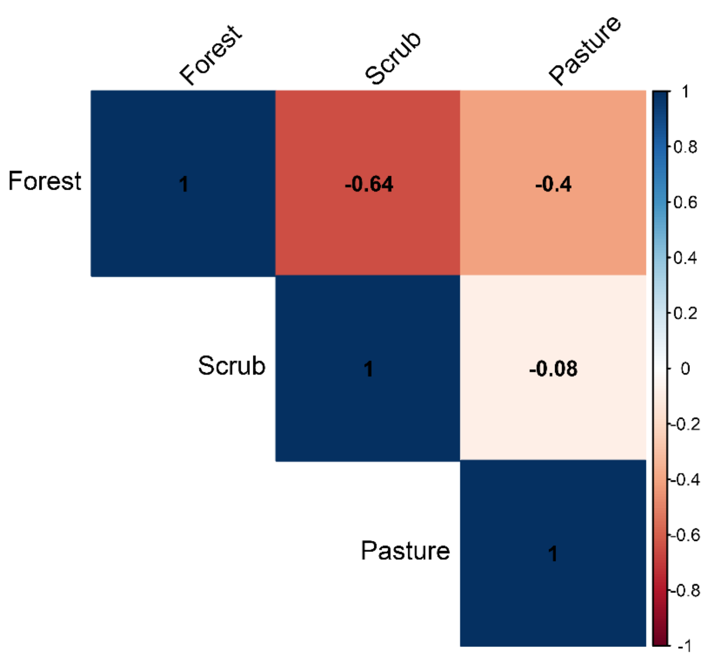

Figure 1.2. Correlation matrix for land use/cover covariates used in occupancy analysis of tayra (*Eira barbara*) northwest of Quito, Ecuador (approximately -78.586 longitude, 0.205 latitude). Correlation matrix calculated using Pearson's Correlation Coefficient (on a scale of -1 to 1, a value > 0 demonstrates positive correlation, < 0 demonstrates negative correlation, and 0 demonstrates no correlation).

elevation data from the U.S. Geological Survey's Earth Resources Observation and Science Center (2000).

We evaluated detection probability as a function of the number of days since the scent lure was replaced (averaged across the 7 days in each occasion) (average value = 7.90, range = 0-29.5), and as a function of effort (number of days out of 7 each camera at a station was operational during each occasion) (average value = 9.69, range = 1-14). We used the number of days since the scent lure was replaced as a covariate to examine the possible effect of the lure fading over time. We included the number of days each camera was operational as a measure of effort.

Despite some arguments in the literature against model sets that explore all possible covariate combinations (Burnham & Anderson 2002), we explored a full candidate model set in our analysis because it was relatively small (64 candidate models) and there was no prior expectation that any particular covariate combination would be irrelevant (Appendix 1). We preferred this strategy to a "stepwise" approach to model selection because the latter is more likely produce misleading results (Doherty et al. 2012). We used Akaike's Information Criterion (AIC) to assess model performance and conduct model selection. Models with <2 AIC units difference from the top-ranking model were considered equally best fit (Burnham & Anderson 2002). For each covariate, we calculated the summed AIC weights (w_i) of all models (i) that included that covariate as a measure of relative importance (Table 1.2) (Burnham & Anderson 2002).

Results

Tayras were detected at 31 of 70 camera trap stations over the 6,127 trap nights, yielding a naive occupancy estimate of 0.44. Of the 31 sites with tayra detections, only 9 had detections in more than one 7-day survey occasion; the other 22 stations had detections in only one occasion. Tayras were detected at camera stations from 1300 m to 3067 m. Elevation (w_i = 0.85) and native forest (w_i = 0.74) were important predictors of tayra occupancy, while pasture (w_i = 0.33) and woody scrub cover (w_i = 0.31) received less weight. The effort covariate on detection probability carried more weight (w_i = 0.64) than the scent lure covariate (w_i = 0.51). Model selection revealed uncertainty in the top performing model, possibly due to the number of different combinations of covariates on both occupancy and detection probability within the candidate model set. Among the top performing models (lowest AIC values), there were five models with a difference in AIC (ΔAIC) < 2 which we consider to fit the data equally well (Table 1.3). All possible covariates on both occupancy and detection probability were included within the structure of at least one out of these five models. Model-averaged across the top 5 best fitting models, the mean occupancy across sites was 0.56 (SE= 0.12). Site-specific occupancy estimates ranged from 0.05-0.87 (Figure 1.3). According to the top-ranking model, native forest positively influenced the probability of occupancy of tayra at a site (β= 3.07, SE= 1.50) while elevation had a negative effect on occupancy (β= -0.82, SE= 0.40) (Figure 1.4). In the top-ranking models that contained scrub and pasture, scrub influenced occupancy positively (β=1.85, SE=2.75) and pasture had a negative effect on occupancy (β= -0.82, SE=2.83) (Figure 1.4). Predictions of tayra occupancy using the top performing model showed occupancy is highest when % native forest is high and elevation is low (Figure 1.5). The mean estimate for detection probability across sites/surveys was 0.12 (SE=0.02). Detection probability was positively influenced by camera trap effort (β= 0.07, SE= 0.04 in top-ranked model), and negatively influenced by the number of days since the scent lure was replaced (β= -0.03, SE= 0.03 in 2nd-ranked model).

Table 1.2. Relative variable importance of each covariate on occupancy and detection probability of tayra in northwest Ecuador. The value for each covariate was calculated by summing the AIC weights (w_i) of all models (i) that included that covariate.

Covariate	w_i
Occupancy Covariate	
Elevation	0.8488
Native Forest	0.7449
Pasture	0.3299
Scrub	0.3091
Detection Covariate	
Effort	0.6423
Scent	0.5096

Table 1.3. Top ranking models (ΔAIC<2) for occupancy analysis of tayra (*Eira barbara*) in northwest Ecuador. We explored all possible covariates described in Table 1.1 on occupancy and detection probability (64 models total).

Model Parameterization	**# Parameters**	**AIC**	**AIC Weight**	**-2*log-likelihood**	**ΔAIC**	**Model likelihood**
Ψ (NativeForest+Elevation), p(Effort)	5	435.37	0.131	425.37	0	1
Ψ (NativeForest+Elevation), p(Effort+Scent)	6	436.21	0.09	424.21	0.84	0.66
Ψ (NativeForest+Elevation), p(Scent)	5	436.31	0.08	426.31	0.94	0.62
Ψ (NativeForest+Scrub+Elevation), p(Effort)	6	436.90	0.06	424.90	1.53	0.46
Ψ (NativeForest+Pasture+Elevation), p(Effort)	6	437.28	0.05	425.28	1.91	0.38

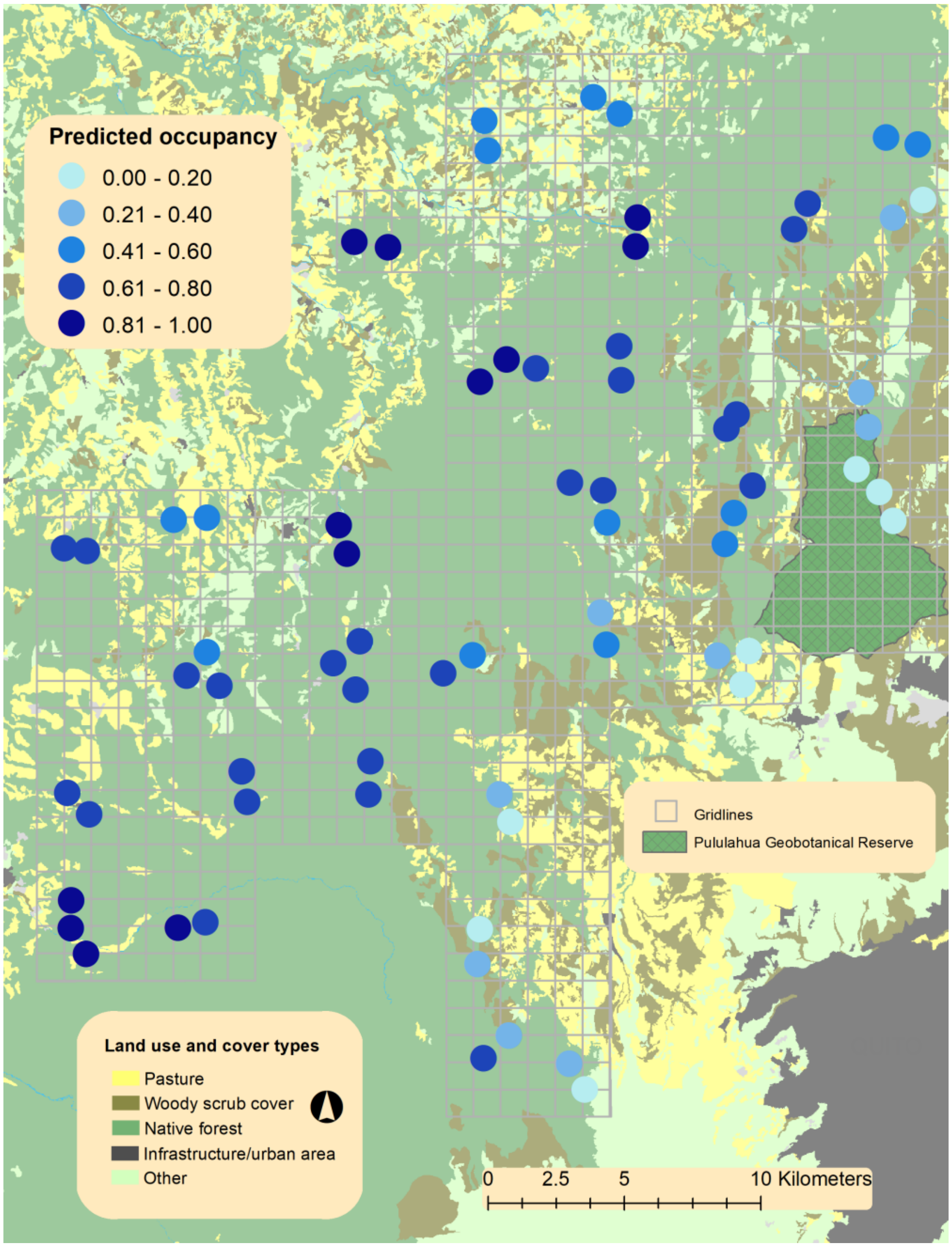

Figure 1.3. Map of the predicted occupancy (model-averaged esimates from the five top-ranking models) of tayras (*Eira barbara*) in northwest Ecuador (approximately -78.586 longitude, 0.205 latitude). Map shows the survey gridlines, camera trap stations (n = 70) as points proportional in size to predicted occupancy value, and types of land use and cover in the area.

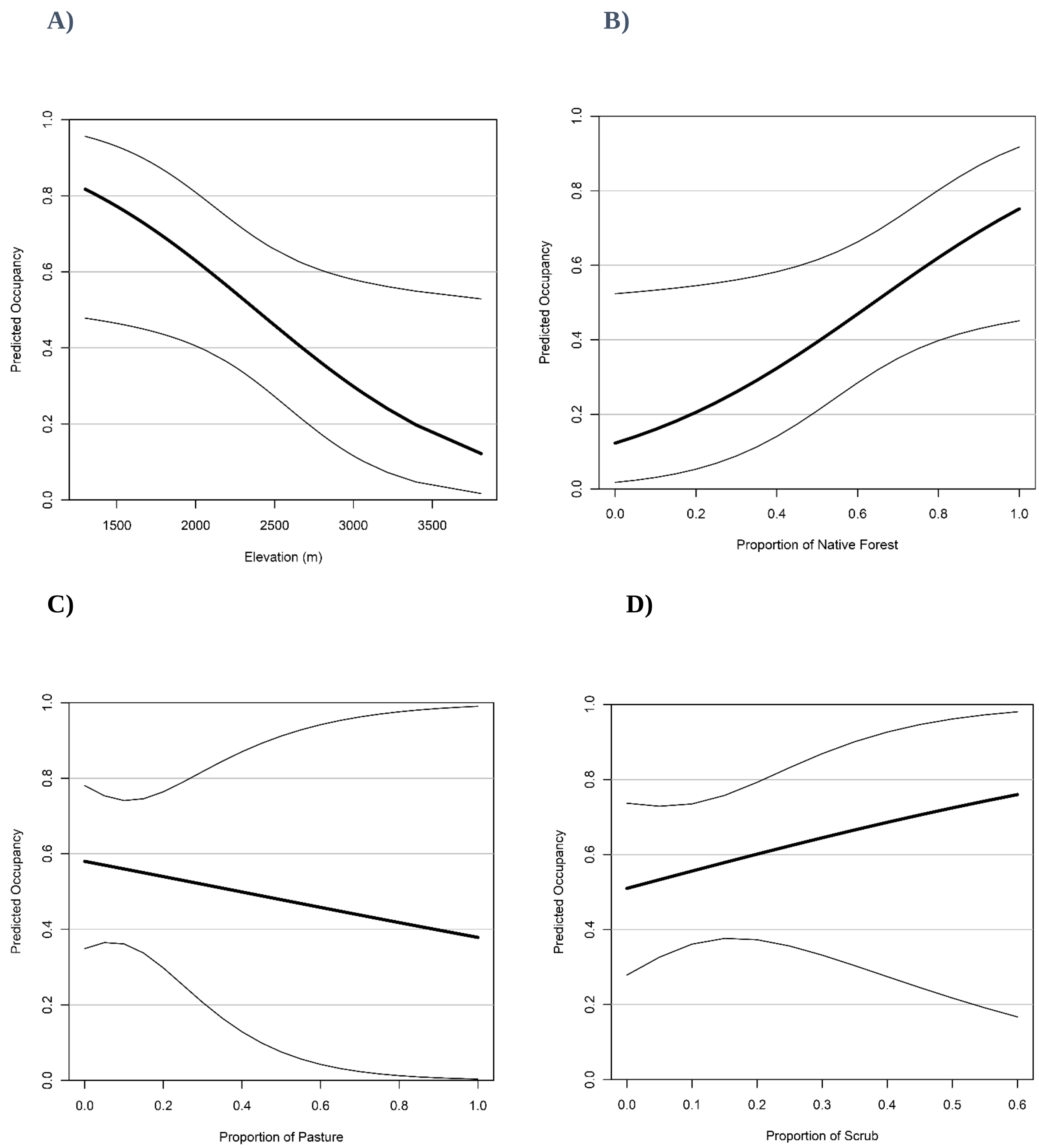

Figure 1.4. Relationship between tayra (*Eira barbara*) occupancy and four covariates in northwest Ecuador (approximately -78.586 longitude, 0.205 latitude): elevation (A) and the proportion of native forest (B), pasture (C) and scrub (D). Predicted occupancy was calculated using the top performing model that contained the particular covariate, and other model covariates were held at the average value. Lighter outer lines show the 95% confidence intervals.

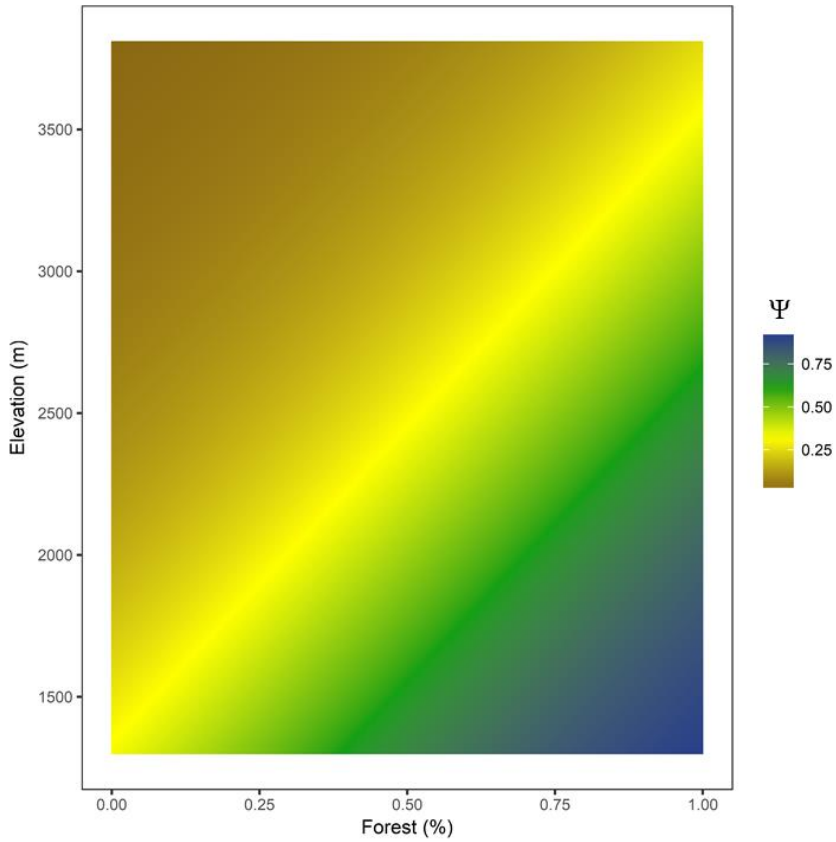

Figure 1.5. Predictions of tayra occupancy (Ψ) in northwest Ecuador (approximately -78.586 longitude, 0.205 latitude) from the top-performing model, showing the combined effect of elevation at a site and the percent of native forest within a site's buffer zone.

Discussion

Tayras have been poorly studied compared to other wildlife that are similarly widespread throughout Latin America (Konecny 1989, Oliveira 2009). Tayra occupancy in our study was negatively associated with elevation and positively associated with native forest, providing new insights into the species' relationship with land cover/use types in an area that is not protected for conservation and that is heavily impacted by humans. While we suspected that native forest—the dominant land cover in the area—would be important, this has not been the case in some studies in other countries/regions. Our study confirms the importance of native cloud forest as the primary predictor of occupancy of tayras in the Chocó-Andean region. The amount of pasture was not a strong predictor of tayra occupancy, suggesting that the disturbance by pasture as well as the human presence associated with managing pastures is not driving occupancy at this scale. Given that much of the land used for pasture in this area is at least partially forested or has some vegetative cover, it follows that this type of human land use may not have profound negative impacts on tayra, but pasture lands also lack some of the beneficial resources of other human land uses tayra have been positively associated with in past studies (specifically, the food sources of crops or raising of animals like chickens) (Presley 2000, Massara et al. 2016). A closer look at the different intensities of vegetation/cover within pasture lands, as well as the frequency of their use by humans/cattle, may yield a more complex relationship. Furthermore, our study was limited to a single-season occupancy analysis and while we were able to explore associations with different land use/cover types, a multi-season occupancy model would reveal more information on local colonization and extinction potentially due to changes on the landscape (MacKenzie et al. 2003). Notably, although tayra occupancy decreased with increased elevation, tayras were detected at 25% of sites at elevations higher than 2400 m, which is considered uncommon for the species (Emmons & Feer 1997).

Detection probabilities and repeat detections at sites were low, possibly attributable to our sampling design. Estimates of tayra home range size are varied and based on data from only a few individuals, causing uncertainty regarding tayra space use on the landscape (Konecny 1989, Sunquist et al. 1989). This lack of knowledge makes it difficult to design a species-specific study. Instead, we used data from an existing camera trap array not specifically designed for this species; this allowed us to study tayras alongside species considered of higher conservation priority (i.e., Andean bear). While many camera trapping studies are used to monitor more than one species (Burton et al. 2015), this can be problematic for species that use the landscape at different spatial scales. Here, large distances (up to 13 km) between camera stations went unsampled, making it difficult to generalize our results to areas outside of our immediate sampling area. We recommend future studies conduct a pilot study with a higher density of camera traps in a smaller area to see how this affects detection rates, as only 9 of 70 sites in our study had >1 detection within the survey. One suggestion for increasing detection probability would be to try alternative lures; while tayras did appear in photos to be interested in the vanilla scent we used in our study, we had no prior knowledge that this lure would be effective and perhaps another lure might be more effective.

There is emerging evidence that tayra individuals can be identified by their chest and neck patches (Villafañe-Trujillo et al. 2018); this could provide information on whether tayra detections are in fact independent at specific grid sizes (1 km, 2 km, or more) and within different occasion lengths (1 day vs 7 days, for example). If individual tayras can be reliably detected, camera traps could yield information on tayra abundance and density if data are analyzed using spatially explicit capture-recapture models (Royle et al. 2013) and even recently developed spatial partial identity models (Augustine et al. 2018), which are particularly useful for camera trap photos of species that cannot always be identified with complete certainty. To our knowledge, there have been no studies on tayra using any type of capture-recapture method.

Although tayras are widespread, there is still little known about what habitats they use within the Chocó-Andean region, where they are part of an ecosystem that sustains multiple carnivore and generalist species and has delicate community dynamics (Myers et al. 2000, Hodge & Arbogast 2016). Many of these species which have lower abundances and smaller distributions are much more frequently studied (Oliveira 2009). Our study has provided new insight on tayra land use and cover associations in this region, where deforestation for pasture, agriculture, and other land uses is continually expanding. While tayras are generalists that may be adaptable to human-caused landscape changes and fragmentation, other species may be more vulnerable and long-term monitoring of the occupancy and distribution of a variety of species is important to fully understand ecosystem health.

CHAPTER 1 APPENDIX

A1.1. Candidate model set for occupancy analysis of tayra (*Eira barbara*) in northwest Ecuador. We evaluated occupancy as a function of the following covariates: the percentage of native forest within a 1 km buffer of each camera trap; the percentage of woody scrub cover within a 1 km buffer of each camera trap; the percentage of land used for pasture within a 1 km buffer of each camera trap; and the elevation (m) at each camera trap (standardized). We evaluated detection probability as a function of the number of days since the lure at each camera trap was last replaced (averaged across the 7 days in each occasion), and as a function of effort (number of days out of 7 cameras were operational in each occasion). We included a null model without covariates.

Model
psi(NativeForest+Scrub+Pasture+Elevation),p(.)
psi(NativeForest+Scrub+Pasture),p(.)
psi(NativeForest+Scrub+Elevation),p(.)
psi(NativeForest+Pasture+Elevation),p(.)
psi(Scrub+Pasture+Elevation),p(.)
psi(NativeForest+Scrub),p(.)
psi(NativeForest+Pasture),p(.)
psi(NativeForest+Elevation),p(.)
psi(Scrub+Pasture),p(.)
psi(Scrub+Elevation),p(.)
psi(Pasture+Elevation),p(.)
psi(NativeForest),p(.)
psi(Scrub),p(.)
psi(Pasture),p(.)
psi(Elevation),p(.)
psi(.),p(.)
psi(NativeForest+Scrub+Pasture+Elevation),p(Effort)
psi(NativeForest+Scrub+Pasture),p(Effort)

psi(NativeForest+Scrub+Elevation),p(Effort)

psi(NativeForest+Pasture+Elevation),p(Effort)

psi(Scrub+Pasture+Elevation),p(Effort)

psi(NativeForest+Scrub),p(Effort)

psi(NativeForest+Pasture),p(Effort)

psi(NativeForest+Elevation),p(Effort)

psi(Scrub+Pasture),p(Effort)

psi(Scrub+Elevation),p(Effort)

psi(Pasture+Elevation),p(Effort)

psi(NativeForest),p(Effort)

psi(Scrub),p(Effort)

psi(Pasture),p(Effort)

psi(Elevation),p(Effort)

psi(.),p(Effort)

psi(NativeForest+Scrub+Pasture+Elevation),p(Scent)

psi(NativeForest+Scrub+Pasture),p(Scent)

psi(NativeForest+Scrub+Elevation),p(Scent)

psi(NativeForest+Pasture+Elevation),p(Scent)

psi(Scrub+Pasture+Elevation),p(Scent)

psi(NativeForest+Scrub),p(Scent)

psi(NativeForest+Pasture),p(Scent)

psi(NativeForest+Elevation),p(Scent)

psi(Scrub+Pasture),p(Scent)

psi(Scrub+Elevation),p(Scent)

psi(Pasture+Elevation),p(Scent)

psi(NativeForest),p(Scent)

psi(Scrub),p(Scent)

psi(Pasture),p(Scent)

psi(Elevation),p(Scent)

psi(.),p(Scent)

psi(NativeForest+Scrub+Pasture+Elevation),p(Effort+Scent)

psi(NativeForest+Scrub+Pasture),p(Effort+Scent)

psi(NativeForest+Scrub+Elevation),p(Effort+Scent)

psi(NativeForest+Pasture+Elevation),p(Effort+Scent)

psi(Scrub+Pasture+Elevation),p(Effort+Scent)

psi(NativeForest+Scrub),p(Effort+Scent)

psi(NativeForest+Pasture),p(Effort+Scent)

psi(NativeForest+Elevation),p(Effort+Scent)

psi(Scrub+Pasture),p(Effort+Scent)

psi(Scrub+Elevation),p(Effort+Scent)

psi(Pasture+Elevation),p(Effort+Scent)

psi(NativeForest),p(Effort+Scent)

psi(Scrub),p(Effort+Scent)

psi(Pasture),p(Effort+Scent)

psi(Elevation),p(Effort+Scent)

psi(.),p(Effort+Scent)

A1.2. R code for occupancy analysis.

```
##Single species models for tayra, with scent as the orignial value in days since lure replaced
(days averaged across 7 days).
##Effort is the # of days, so from 1-14 depending on A,B, station
##Naive forest, woody scrub cover, pasture, and elevation covariates on occupancy

#load RPresence
library("RPresence", lib.loc="~/R/win-library/3.4")

# load csv detection history
Mycsv <- read.csv(file=" Tayra7dayeffort.csv", header=FALSE)
```

```
head(Mycsv)
summary(Mycsv)

#tell it how many sites and surveys
nsites=nrow(Mycsv)
nsrvys=ncol(Mycsv)

#read in UNIT covariate csv, include header, then exclude first column (camera stations)
UnitCovs<-read.csv(file=" SiteCovs1SpV2.csv", header=TRUE)
head(UnitCovs)
UnitCovs2<-UnitCovs[,-1]
head(UnitCovs2)

#read in SURVEY covs (SCENT, EFFORT)
SurvCovs<-read.csv(file="SurveyCovs1SpV5.csv", header=TRUE)
head(SurvCovs)

#Create your Pao!!
?createPao
data=createPao(Mycsv,unitcov=UnitCovs2,survcov=SurvCovs,title="Tayra.pao")


#Every combo of psi covs, no covs on P
Psi_NF_WSC_Pa_El__P_1<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Pasture+Elevation,p~1), data=data,
type="so",  psi.cov=UnitCovs2, modname = "Psi_NF_WSC_Pa_El__P_1")
Psi_NF_WSC_Pa__P_1<-occMod(model=list(psi~NativeForest+WoodyScrubCover+Pasture,p~1),
data=data, type="so",  psi.cov=UnitCovs2, modname = "Psi_NF_WSC_Pa__P_1")
Psi_NF_WSC_El__P_1<-occMod(model=list(psi~NativeForest+WoodyScrubCover+Elevation,p~1),
data=data, type="so",  psi.cov=UnitCovs2, modname = "Psi_NF_WSC_El__P_1")
Psi_NF_Pa_El__P_1<-occMod(model=list(psi~NativeForest+Pasture+Elevation,p~1), data=data,
type="so",  psi.cov=UnitCovs2, modname = "Psi_NF_Pa_El__P_1")
Psi_WSC_Pa_El__P_1<-occMod(model=list(psi~WoodyScrubCover+Pasture+Elevation,p~1),
data=data, type="so",  psi.cov=UnitCovs2, modname = "Psi_WSC_Pa_El__P_1")
Psi_NF_WSC__P_1<-occMod(model=list(psi~NativeForest+WoodyScrubCover,p~1), data=data,
type="so",  psi.cov=UnitCovs2, modname = "Psi_NF_WSC__P_1")
Psi_NF_Pa__P_1<-occMod(model=list(psi~NativeForest+Pasture,p~1), data=data, type="so",
psi.cov=UnitCovs2, modname = "Psi_NF_Pa__P_1")
Psi_NF_El__P_1<-occMod(model=list(psi~NativeForest+Elevation,p~1), data=data, type="so",
psi.cov=UnitCovs2, modname = "Psi_NF_El__P_1")
```

```
Psi_WSC_Pa__P_1<-occMod(model=list(psi~WoodyScrubCover+Pasture,p~1), data=data,
type="so",  psi.cov=UnitCovs2, modname = "Psi_WSC_Pa__P_1")
Psi_WSC_El__P_1<-occMod(model=list(psi~WoodyScrubCover+Elevation,p~1), data=data,
type="so",  psi.cov=UnitCovs2, modname = "Psi_WSC_El__P_1")
Psi_Pa_El__P_1<-occMod(model=list(psi~Pasture+Elevation,p~1), data=data, type="so",
psi.cov=UnitCovs2, modname = "Psi_Pa_El__P_1")
Psi_NF__P_1<-occMod(model=list(psi~NativeForest,p~1), data=data, type="so",
psi.cov=UnitCovs2, modname = "Psi_NF__P_1")
Psi_WSC__P_1<-occMod(model=list(psi~WoodyScrubCover,p~1), data=data, type="so",
psi.cov=UnitCovs2, modname = "Psi_WSC__P_1")
Psi_Pa__P_1<-occMod(model=list(psi~Pasture,p~1), data=data, type="so",  psi.cov=UnitCovs2,
modname = "Psi_Pa__P_1")
Psi_El__P_1<-occMod(model=list(psi~Elevation,p~1), data=data, type="so",  psi.cov=UnitCovs2,
modname = "Psi_El__P_1")
Psi_1__P_1<-occMod(model=list(psi~1,p~1), data=data, type="so", modname = "Psi_1__P_1")
#Every combo of psi covs, effort on P
Psi_NF_WSC_Pa_El__P_E<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Pasture+Elevation,p~Effort),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_NF_WSC_Pa_El__P_E")
Psi_NF_WSC_Pa__P_E<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Pasture,p~Effort), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC_Pa__P_E")
Psi_NF_WSC_El__P_E<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Elevation,p~Effort), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC_El__P_E")
Psi_NF_Pa_El__P_E<-occMod(model=list(psi~NativeForest+Pasture+Elevation,p~Effort),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_Pa_El__P_E")
Psi_WSC_Pa_El__P_E<-occMod(model=list(psi~WoodyScrubCover+Pasture+Elevation,p~Effort),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_Pa_El__P_E")
Psi_NF_WSC__P_E<-occMod(model=list(psi~NativeForest+WoodyScrubCover,p~Effort),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC__P_E")
Psi_NF_Pa__P_E<-occMod(model=list(psi~NativeForest+Pasture,p~Effort), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_Pa__P_E")
Psi_NF_El__P_E<-occMod(model=list(psi~NativeForest+Elevation,p~Effort), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_El__P_E")
Psi_WSC_Pa__P_E<-occMod(model=list(psi~WoodyScrubCover+Pasture,p~Effort), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_Pa__P_E")
Psi_WSC_El__P_E<-occMod(model=list(psi~WoodyScrubCover+Elevation,p~Effort), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_El__P_E")
```

```
Psi_Pa_El__P_E<-occMod(model=list(psi~Pasture+Elevation,p~Effort), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_Pa_El__P_E")
Psi_NF__P_E<-occMod(model=list(psi~NativeForest,p~Effort), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF__P_E")
Psi_WSC__P_E<-occMod(model=list(psi~WoodyScrubCover,p~Effort), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC__P_E")
Psi_Pa__P_E<-occMod(model=list(psi~Pasture,p~Effort), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_Pa__P_E")
Psi_El__P_E<-occMod(model=list(psi~Elevation,p~Effort), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_El__P_E")
Psi_1__P_E<-occMod(model=list(psi~1,p~Effort), data=data, type="so",  p.cov=SurvCovs,
modname = "Psi_1__P_E")
#Every combo of psi covs, effort and scent on P
Psi_NF_WSC_Pa_El__P_E_S<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Pasture+Elevation,p~Effort+Scent),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_NF_WSC_Pa_El__P_E_S")
Psi_NF_WSC_Pa__P_E_S<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Pasture,p~Effort+Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC_Pa__P_E_S")
Psi_NF_WSC_El__P_E_S<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Elevation,p~Effort+Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC_El__P_E_S")
Psi_NF_Pa_El__P_E_S<-
occMod(model=list(psi~NativeForest+Pasture+Elevation,p~Effort+Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_Pa_El__P_E_S")
Psi_WSC_Pa_El__P_E_S<-
occMod(model=list(psi~WoodyScrubCover+Pasture+Elevation,p~Effort+Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_Pa_El__P_E_S")
Psi_NF_WSC__P_E_S<-occMod(model=list(psi~NativeForest+WoodyScrubCover,p~Effort+Scent),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC__P_E_S")
Psi_NF_Pa__P_E_S<-occMod(model=list(psi~NativeForest+Pasture,p~Effort+Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_Pa__P_E_S")
Psi_NF_El__P_E_S<-occMod(model=list(psi~NativeForest+Elevation,p~Effort+Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_El__P_E_S")
Psi_WSC_Pa__P_E_S<-occMod(model=list(psi~WoodyScrubCover+Pasture,p~Effort+Scent),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_Pa__P_E_S")
Psi_WSC_El__P_E_S<-occMod(model=list(psi~WoodyScrubCover+Elevation,p~Effort+Scent),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_El__P_E_S")
Psi_Pa_El__P_E_S<-occMod(model=list(psi~Pasture+Elevation,p~Effort+Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_Pa_El__P_E_S")
```

```
Psi_NF__P_E_S<-occMod(model=list(psi~NativeForest,p~Effort+Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF__P_E_S")
Psi_WSC__P_E_S<-occMod(model=list(psi~WoodyScrubCover,p~Effort+Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC__P_E_S")
Psi_Pa__P_E_S<-occMod(model=list(psi~Pasture,p~Effort+Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_Pa__P_E_S")
Psi_El__P_E_S<-occMod(model=list(psi~Elevation,p~Effort+Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_El__P_E_S")
Psi_1__P_E_S<-occMod(model=list(psi~1,p~Effort+Scent), data=data, type="so",
p.cov=SurvCovs, modname = "Psi_1__P_E_S")
#Every combo of psi covs, only scent on P
Psi_NF_WSC_Pa_El__P_S<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Pasture+Elevation,p~Scent),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_NF_WSC_Pa_El__P_S")
Psi_NF_WSC_Pa__P_S<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Pasture,p~Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC_Pa__P_S")
Psi_NF_WSC_El__P_S<-
occMod(model=list(psi~NativeForest+WoodyScrubCover+Elevation,p~Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC_El__P_S")
Psi_NF_Pa_El__P_S<-occMod(model=list(psi~NativeForest+Pasture+Elevation,p~Scent),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_Pa_El__P_S")
Psi_WSC_Pa_El__P_S<-occMod(model=list(psi~WoodyScrubCover+Pasture+Elevation,p~Scent),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_Pa_El__P_S")
Psi_NF_WSC__P_S<-occMod(model=list(psi~NativeForest+WoodyScrubCover,p~Scent),
data=data, type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_WSC__P_S")
Psi_NF_Pa__P_S<-occMod(model=list(psi~NativeForest+Pasture,p~Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_Pa__P_S")
Psi_NF_El__P_S<-occMod(model=list(psi~NativeForest+Elevation,p~Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF_El__P_S")
Psi_WSC_Pa__P_S<-occMod(model=list(psi~WoodyScrubCover+Pasture,p~Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_Pa__P_S")
Psi_WSC_El__P_S<-occMod(model=list(psi~WoodyScrubCover+Elevation,p~Scent), data=data,
type="so",  psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC_El__P_S")
Psi_Pa_El__P_S<-occMod(model=list(psi~Pasture+Elevation,p~Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_Pa_El__P_S")
Psi_NF__P_S<-occMod(model=list(psi~NativeForest,p~Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_NF__P_S")
Psi_WSC__P_S<-occMod(model=list(psi~WoodyScrubCover,p~Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_WSC__P_S")
```

```
Psi_Pa__P_S<-occMod(model=list(psi~Pasture,p~Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_Pa__P_S")
Psi_El__P_S<-occMod(model=list(psi~Elevation,p~Scent), data=data, type="so",
psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_El__P_S")
Psi_1__P_S<-occMod(model=list(psi~1,p~Scent), data=data, type="so",  p.cov=SurvCovs,
modname = "Psi_1__P_S")

##List and AIC
TayraList<-list(
  Psi_NF_WSC_Pa_El__P_1,
Psi_NF_WSC_Pa__P_1,
Psi_NF_WSC_El__P_1,
Psi_NF_Pa_El__P_1,
Psi_WSC_Pa_El__P_1,
Psi_NF_WSC__P_1,
Psi_NF_Pa__P_1,
Psi_NF_El__P_1,
Psi_WSC_Pa__P_1,
Psi_WSC_El__P_1,
Psi_Pa_El__P_1,
Psi_NF__P_1,
Psi_WSC__P_1,
Psi_Pa__P_1,
Psi_El__P_1,
Psi_1__P_1,
Psi_NF_WSC_Pa_El__P_E,
Psi_NF_WSC_Pa__P_E,
Psi_NF_WSC_El__P_E,
Psi_NF_Pa_El__P_E,
Psi_WSC_Pa_El__P_E,
Psi_NF_WSC__P_E,
Psi_NF_Pa__P_E,
Psi_NF_El__P_E,
Psi_WSC_Pa__P_E,
Psi_WSC_El__P_E,
Psi_Pa_El__P_E,
Psi_NF__P_E,
Psi_WSC__P_E,
Psi_Pa__P_E,
Psi_El__P_E,
Psi_1__P_E,
```

```
Psi_NF_WSC_Pa_El__P_E_S,
Psi_NF_WSC_Pa__P_E_S,
Psi_NF_WSC_El__P_E_S,
Psi_NF_Pa_El__P_E_S,
Psi_WSC_Pa_El__P_E_S,
Psi_NF_WSC__P_E_S,
Psi_NF_Pa__P_E_S,
Psi_NF_El__P_E_S,
Psi_WSC_Pa__P_E_S,
Psi_WSC_El__P_E_S,
Psi_Pa_El__P_E_S,
Psi_NF__P_E_S,
Psi_WSC__P_E_S,
Psi_Pa__P_E_S,
Psi_El__P_E_S,
Psi_1__P_E_S,
Psi_NF_WSC_Pa_El__P_S,
Psi_NF_WSC_Pa__P_S,
Psi_NF_WSC_El__P_S,
Psi_NF_Pa_El__P_S,
Psi_WSC_Pa_El__P_S,
Psi_NF_WSC__P_S,
Psi_NF_Pa__P_S,
Psi_NF_El__P_S,
Psi_WSC_Pa__P_S,
Psi_WSC_El__P_S,
Psi_Pa_El__P_S,
Psi_NF__P_S,
Psi_WSC__P_S,
Psi_Pa__P_S,
Psi_El__P_S,
Psi_1__P_S)

##AIC table comparing that model set
TayraListAIC=createAicTable(TayraList, use.aicc = FALSE)
print(TayraListAIC$table)
write.csv(TayraListAIC$table, " tayraListAIC.csv")
```

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CHAPTER 2

SPATIAL CO-OCCURRENCE OF ANDEAN BEARS AND DOMESTIC DOGS ACROSS A MULTI-USE LANDSCAPE IN NORTHERN ECUADOR

Abstract

Habitat loss and fragmentation are major threats to wildlife worldwide, and remaining habitat patches often support less biodiversity and are vulnerable to edge effects. In addition to the impacts of adjacent development on wildlife in these patches, humans also bring introduced domestic carnivores that can alter community dynamics and compete with native species. In the Ecuadorian Andes, domestic dogs (*Canis familiaris*) are free-roaming but frequently associated with people who utilize the landscape for agriculture and cattle grazing. We conducted a camera trap survey and multi-species occupancy modeling to explore whether dogs and humans negatively influence the occupancy of Andean bears (*Tremarctos ornatus*)—a species of conservation concern throughout much of South America—within this multi-use landscape. Andean bear occupancy was independent of the presence of domestic dogs and humans; instead, bear occupancy was influenced most by the amount of native forest and woody scrub cover. These results contradict a recent study in and around a protected area in Ecuador, where Andean bear occupancy was negatively associated with feral dogs. The human-dominated landscape of this study has long been fragmented by human land uses and has few protected or managed areas, therefore Andean bears are likely acclimated to the presence of humans and dogs. Additionally, dogs in this area are most likely dependent on humans for food, so they may have less of an impact on wildlife than feral dogs dependent on the landscape for resources. Our research suggests that protection of remaining habitat is likely more important Andean bear conservation than reducing current impacts of humans and dogs.

Introduction

Habitat loss and fragmentation are the greatest threats to biodiversity worldwide (Hoekstra et al. 2005, Haddad et al. 2015) and have direct and indirect effects on wildlife behavior and landscape use, including increased interactions with humans and human land uses such as agriculture and urbanization. Mammalian carnivore populations are sensitive to environmental changes because of their low population densities, large home range sizes, and high energy requirements (Crooks & Soulé 1999, Cardillo et al. 2004, Ripple et al. 2014). Human-wildlife interactions increase as human presence increases, and carnivores may avoid previously used habitats, predate on domestic livestock, or be killed by humans (Balme et al. 2010, Miller et al. 2016). The consequences of human intrusion into natural areas imperil carnivore species and reduce carnivore abundances worldwide (Treves & Karanth 2003, Ripple et al. 2014). One indirect consequence of habitat fragmentation and increased human presence on the landscape is the accompanying presence of domestic species that are kept as pets, most commonly dogs (*Canis familiaris*) and cats (*Felis catus*). Both carnivore species can spread disease (e.g., canine distemper, rabies), predate on native species or compete for prey, and alter the behaviors or activity patterns of native species (Hughes & Macdonald 2013, Loss et al. 2013).

Ecological communities with a high diversity of carnivores have delicate community dynamics and may be especially vulnerable to domestic or introduced carnivores. The Chocó-Andean region of Ecuador has remarkably high biodiversity and endemism, and supports a large suite of mammalian carnivores including the Andean bear (*Tremarctos ornatus*) (Myers et al. 2000, Hodge & Arbogast 2016), an important species for conservation planning that is endangered in Ecuador and threatened throughout its range in South America. The Chocó-Andean region has also long supported human communities, resulting in deforestation of much of the region for cattle grazing, agriculture, infrastructure, and mining (Rieckmann et al. 2011). Conversion of habitat poses a threat to wildlife by separating the remaining cloud forest into isolated fragments, diminished of resources and more vulnerable to edge effects (Murcia 1995, Hoekstra et al. 2005, Dirzo et al. 2014). While there is emerging research on the impacts of domestic dogs on wildlife, much of it comes from developed countries—particularly North America—where domestic dogs are integrated into human communities and well cared for/managed by people, not free-roaming or unmanaged as they are more likely to be in less developed areas (Hughes & Macdonald 2013, Weston et al. 2014). In our study site in the Andes where dogs are free-roaming and not as closely managed, dogs may have a greater impact on wildlife by intruding into their habitat, even when accompanied by people.

Within Ecuador's Cayambe-Coca National Park and in surrounding areas, which consist of páramo or high-elevation grasslands, temporal activity patterns of Andean bears shifted when dogs were present and there was a negative relationship between occupancy of Andean bears and domestic dog presence (Zapata-Ríos & Branch 2016, 2018). Feral dogs may have caused Andean bears to use strategies to avoid dogs, but bears are still at risk of being displaced or outcompeted (Zapata-Ríos & Branch 2018). Unlike the aforementioned study, domestic dogs in our study area are not necessarily feral. Many are owned and fed by humans and are often seen accompanying people through the forest as well as roaming freely; it is unlikely that there are many feral dogs that are completely independent of humans. Because bears have persisted in this area despite the presence of local human communities—and therefore the presence of dogs—they may be able to coexist with the presence of both dogs and humans in a manner not seen in other regions.

Our study examined spatial patterns that can indicate sympatry or avoidance between Andean bears and domestic dogs and humans in a multi-use landscape within the Chocó-Andean cloud forest. While some behavioral mechanisms of carnivores that allow for co-occurrence can be studied at fine spatial and temporal scales with GPS information, diet analyses, and other methodologies, multi-species occupancy modeling can be used to evaluate co-occurrence between species at a landscape scale (MacKenzie et al. 2004 & 2006). Occupancy modeling is used to estimate the probability of a species occupying a site while accounting for imperfect detection (MacKenzie et al. 2002). While occupancy modeling was originally developed for use on a single species, it can be expanded to a multi-species framework to evaluate whether two or more species co-occur non-randomly across the landscape (MacKenzie et al. 2004 & 2006). A two-species occupancy model was first developed in MacKenzie et al. 2004 and then reparametrized by Richmond et al. 2010 to better incorporate covariates into analysis. The reparametrized model, called a conditional multi-species occupancy model, examines the relationship between two species with the assumption that one species is dominant (species A) and the other is subordinate (Species B), and that the probability of occupancy for the subordinate species is conditional upon that of the dominant (Richmond et al. 2010). We use the reparametrized model (Richmond et al. 2010) to evaluate whether Andean bears avoid areas where domestic dogs and humans are present. Due to the close relationship between dogs and people, and their shared impact on the landscape, we group them to study their joint effects on bears.

Study Area

The study area is within the Ecuadorian Andes, northwest of Quito, Ecuador (approximately -78.586 longitude, 0.205 latitude) (Figure 2.1). It lies within the Chocó-Andean region, which is at the convergence of two of the world's biodiversity hotspots—the forests of Chocó and the

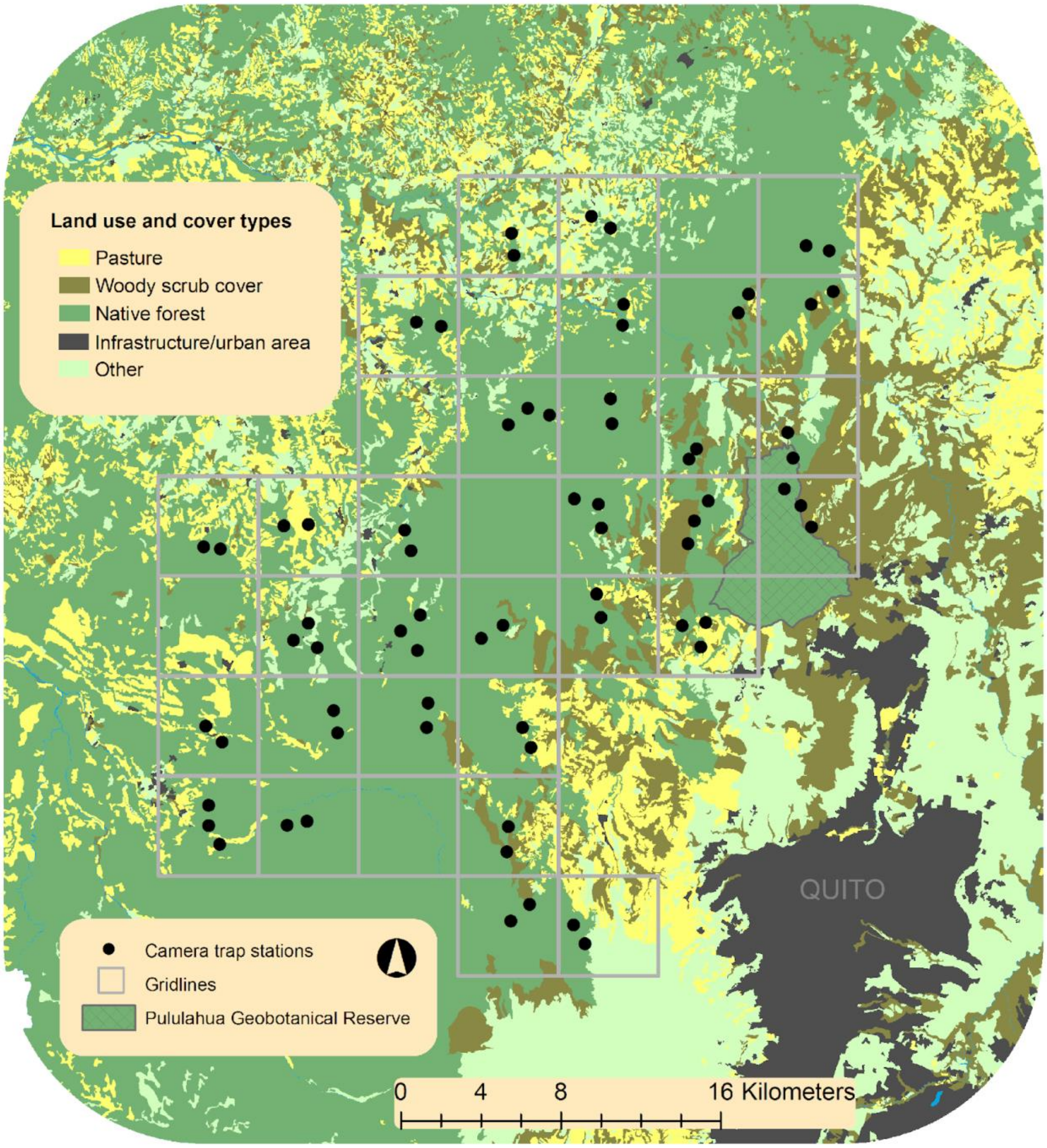

Figure 2.1. The study area northwest of Quito, Ecuador (approximately -78.586 longitude, 0.205 latitude). Map shows the 25 km^2 survey gridlines, individual camera trap stations (n = 70) within 25 km^2 cells, and types of land use and cover.

Tropical Andes (Myers et al. 2000). This region supports a diverse group of mammalian carnivores and omnivores including the Andean bear (*Tremarctos ornatus*), puma (*Puma concolor*), jaguarundi (*Puma yagouaroundi*), ocelot (*Leopardus pardalis*), margay (*Leopardus wiedii*), oncilla (*Leopardus tigrinus*), culpeo fox (*Lycalopex culpaeus*), and striped hog-nosed skunk (*Conepatus semistriatus*) (Myers et al. 2000, Hodge and Arbogast 2016). It is composed mainly of montane cloud forest, where annual precipitation totals 236.8 cm with an average temperature of 17.76 °C (64.0 °F) (Jarvis & Mulligan 2011). Elevation within the study area ranges from 1,300 m to 3,800 m.

Much of the study area is within the Metropolitan District of Quito. Native and old growth forests persist across approximately 66% of the study area, but this landscape also supports multiple human uses. At least 13% of the landscape has been partially or fully deforested and converted to pasture that is used for cattle grazing, as well as for growing crops that support the livelihoods of local communities. Much of the area lacks paved roads, and people often cross forested land on foot when traveling between communities and agricultural areas. Less than 3% of the area is protected within Pululahua Geobotanical Reserve and parts of the remaining forest are privately owned and have been developed for ecotourism. The study area incorporates the northern portion of the designated Andean Bear Ecological Corridor, which was established in July 2013 (Quito Municipal District Resolution No. 431) (Secretaría de Ambiente 2014). This corridor is central between two national ecological reserves in the region, Cotacachi-Cayapas Ecological Reserve to the north of Quito and Illinizas Ecological Reserve to the south.

Methods

Camera Trap Design

We monitored remotely activated Bushnell® Trophy Cam™ HD trail cameras from August 7, 2016 - November 22, 2016. The area was gridded into 25 km^2 cells for camera trap placement. We deployed 3-4 cameras in each grid cell, except for several that could not be surveyed due to accessibility. Within the 804.77 km^2 sampling area (defined as the minimum convex polygon around the camera stations), 31 grid cells or sites contained camera trap stations. Camera trap stations contained either one or two cameras angled to detect the same subject. Two cameras were used at a station when possible to increase the detection and likelihood of identification of individual Andean bears that have unique markings or coat patterns. Each 25 km^2 grid cell contained one central camera trap station with two cameras, and 1-2 supplemental camera trap stations with only one camera. We surveyed 31 stations with two cameras and 39 supplemental stations with only one camera. For analysis, camera stations within each grid cell were combined into one site.

Camera sensitivity was set to "Normal" and cameras were programmed to take bursts of three photos on a 1-second interval. The cameras were strapped to trees, preferably with a diameter less than 20 cm, at 0.5 m height and placed facing either north or south to avoid direct sunlight during sunrise and sunset. We placed a 1 m tall stick 5 m in front of each camera with a vanilla scent lure taped to the top of the stick to increase wildlife detections and length of time individuals spent in front of a camera (Molina et al. 2017). Vanilla scent lure was chosen for its ease of transport and to attract as many different species as possible; it has had proven responses from cat species like ocelot and margay in captivity (Portella et al. 2013) and has been used in previous studies of Andean bears in this area (Molina et al. 2017). Stations with two cameras had a single bait stick, and the cameras were both pointed at the bait stick so that their zones of detection overlapped but the cameras were not directly facing each other. Whenever possible, cameras were placed on wildlife trails or facing trees with claw marks or other signs of Andean bears. Cameras were checked every two weeks to switch memory cards, replace the scent lure, and clear vegetation.

Occupancy Analysis

We tagged photographs to species-level and metadata were written to each image using the photo management program Digikam v. 5.3.0 (https://www.digikam.org/). We used software R v. 3.4.1 (R Core Team 2017) and package camtrapR (Niedballa et al. 2018) to read and format data. The package RPresence (MacKenzie & Hines 2017) was used for occupancy analysis. We fit multi-species models (MacKenzie et al. 2004 & 2006) using the conditional model parameterization (Richmond et al. 2010), which assumes one species is dominant and the second species has an occupancy conditional on the occupancy of the dominant species. We modeled Andean bear occupancy as conditional upon domestic dog and human occupancy given that Andean bears avoided dogs spatially and temporally in previous studies in Ecuador (Zapata-Ríos & Branch 2016, 2018). However, unlike the previous research in Ecuador, dogs and humans still have a close relationship and their effects on wildlife are likely linked due to their shared use of the landscape. Given that relationship—evidenced by the fact that over 75% of dog detections included humans—we grouped domestic dogs and humans into one category for analysis. We defined occasion length as seven days to ensure independent detections.

Our candidate model set compares two different occupancy parameterizations (Table 2.1), the first where ψ^{BD} and ψ^{Bd} (the occupancy of Andean Bears *(B)* where domestic dogs/humans are *(D)* and are not *(d)* present) are both estimated, and the second where $\psi^{BD} = \psi^{Bd}$ (parameters are fixed so that the occupancy of Andean bears is independent of the occupancy of domestic dogs/humans) and only one parameter for bear occupancy (notated ψ^{B}) is estimated. In both parameterizations, domestic dog/human occupancy is notated ψ^{D}. For both occupancy parameterizations, we ran models with and without additional terms for species effects (for models with a covariate species effect, this applied to all model covariates). In our candidate model set, if ψ^{D}, ψ^{BD}, and ψ^{Bd} were all estimated separately, the occupancy covariates contained a species effect that was either conditional (the effect of a covariate on Andean bears differed dependent on presence or absence of dogs/humans) or unconditional (effect of a

Table 2.1. Description of notation used for models in analysis of domestic dog (*Canis familiaris*) and human co-occurrence with Andean bear (T*remarctos ornatus*) in northwest Ecuador. Our candidate model set compares two different occupancy parameterizations: 1) ψ^{BD} and ψ^{Bd} are both estimated (occupancy of Andean bears is dependent on the presence/absence of domestic dogs/humans), and 2) $\psi^{BD} = \psi^{Bd}$ (parameters are fixed so that the occupancy of Andean bears is independent of the presence /absence of domestic dogs/humans) and only one parameter for bear occupancy ψ^{B} is estimated. In both parameterizations domestic dog/human occupancy is ψ^{D} is estimated. For both occupancy parameterizations, we ran models with and without a species effect on occupancy (for models with a species effect, this applied to all model covariates). In our candidate model set if ψ^{D}, ψ^{BD}, and ψ^{Bd} were all estimated separately, the models contained a species effect on covariates that was either conditional (the effect of a covariate on Andean bears differed dependent on presence/absence of dogs/humans) or unconditional (effect of a covariate on Andean bears was constant with respect to dog/human presence/absence). For the $\psi^{BD} = \psi^{Bd}$ parameterization, models in our candidate set were run with and without a species effect. In all models, detection probability parameterization was fixed and when covariates were incorporated, a species effect was also always included.

Model Notation	Occupancy Parameters	Species Effect
$\psi^{D}\psi^{BD}\psi^{Bd}$, Species(C)	3 parameters: ψ^{D}, ψ^{BD}, ψ^{Bd}	Yes; species effect of B is conditional on D presence/absence
$\psi^{D}\psi^{BD}\psi^{Bd}$, Species(U)	3 parameters: ψ^{D}, ψ^{BD}, ψ^{Bd}	Yes; effect of B is not conditional on D presence/absence
$\psi^{D}\psi^{B}$, Species	2 parameters: ψ^{D} and ψ^{B} ($\psi^{BD} = \psi^{Bd}$)	Yes; covariate effect differs by species
$\psi^{D}\psi^{B}$	2 parameters: ψ^{D} and ψ^{B} ($\psi^{BD} = \psi^{Bd}$)	No; covariate effect is the same across species

covariate on Andean bears was constant with respect to dog/human presence or absence). For the $\psi^{BD} = \psi^{Bd}$ parameterization, covariates in our candidate set were incorporated with and without a species effect. In all models, detection probability was fixed and when covariates were incorporated, a species effect was also always included.

We evaluated occupancy as a function of land use or cover characteristics by creating a buffer of 1 km around each cluster of 2-3 camera stations within a grid cell. The center of each buffer zone is the middle point between the two or three stations, and the buffer zone extends 1 km out from all stations in the grid cell (thus, the buffer zone shape and area differs depending on whether the grid cell has two or three stations). Land use/cover covariates used on occupancy were the percentage of native forest (average value across the 31 grid cells = 0.72, range = 0-0.99), woody scrub cover (average value = 0.09, range=0-0.42), and pasture (average value = 0.10, range = 0-0.51) within each buffer zone (Table 2.2). We also used the average elevation (m) of each cluster of 2-3 camera stations within a grid cell (average value across grid cells = 2208, range = 1329-3603) as a covariate on occupancy. Elevation values were standardized (mean = 0, standard deviation = 1). We used native forest and scrub cover to represent two different habitat types we expect to be associated with bears and considered pasture as a measure of human presence on the landscape (pastures are areas that were once partially or entirely deforested and are now used for cattle grazing, either constantly or rotationally). Note that as the proportion of one land use/cover characteristic increases, the others must decrease and as such there is correlation between habitat covariates (Figure 2.2). We included elevation as a covariate because while bears may use higher elevation areas during certain times of year (Peyton 1980, García-Rangel 2012), we did not expect humans and dogs to be present in higher elevation areas that are increasingly steep and difficult terrain for human land uses. We calculated landscape covariates in ArcMap using map

Table 2.2. Covariates used for multi-species occupancy analysis of domestic dogs (*Canis familiaris*) and Andean bears (*Tremarctos ornatus*) in northwest Ecuador, with a description of each covariate and whether it was used to predict occupancy or detection probability.

Covariate	Description of covariate
Occupancy Covariate	
Native Forest	% of native forest within a 1 km buffer zone around camera stations at a site
Woody Scrub	% woody scrub cover within a 1 km buffer zone around camera stations at a site
Pasture	% used for pasture within a 1 km buffer zone around camera stations at a site
Elevation	Elevation (m) averaged across camera stations at a site (standardized)
Detection Covariate	
Effort	Total number of days per 7-day occasion that camera stations at a site were operational
Scent	Number of days since the scent lure was replaced at the site (averaged across the 7 days in each occasion, and across camera stations at a site)

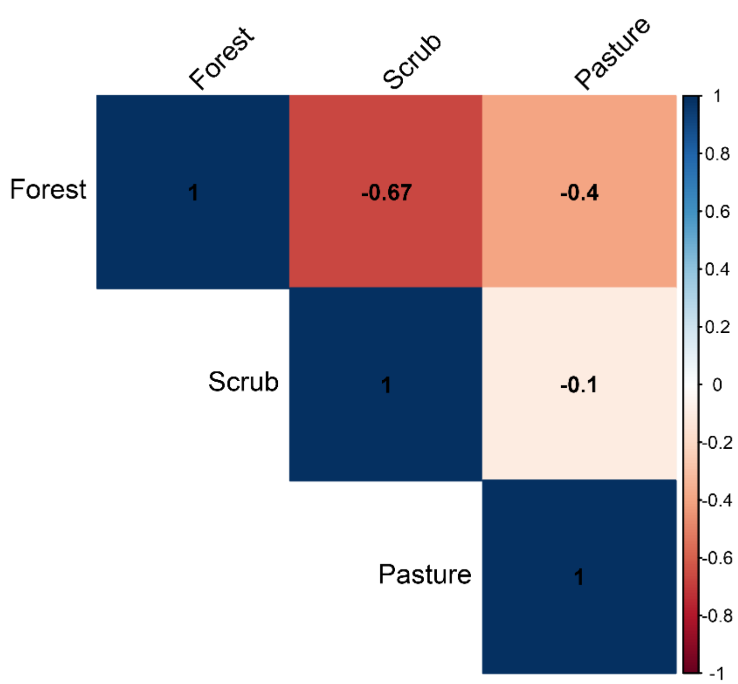

Figure 2.2. Correlation matrix for land use/cover covariates used in co-occurrence analysis of Andean bears (*Tremarctos ornatus*) domestic dogs (*Canis familiaris*) and humans (grouped) northwest of Quito, Ecuador (approximately -78.586 longitude, 0.205 latitude). Correlation matrix calculated using Pearson's Correlation Coefficient (on a scale of -1 to 1, a value > 0 demonstrates positive correlation, < 0 demonstrates negative correlation, and =0 demonstrates no correlation).

layers from Ecuador's National Thematic Cartography Project (2010) and sourced elevation data from the U.S. Geological Survey's Earth Resources Observation and Science Center (2000).

We evaluated detection probability as a function of two survey-specific covariates where the covariate value at each site is the average value across the 2-3 camera trap stations within the site. Detection probability was modeled as a function of the number of days since the scent lure was replaced at each site (averaged across the 7 days in each occasion) (average value = 8.09 days, range = 0-29.5), and as a function of effort (number of days per 7-day occasion each camera station was operational) (average value = 14.59 days, range = 1-21). We used the number of days since the scent lure was replaced as a covariate to examine the possible effect of the lure fading over time. We included the number of days each camera was operational as a measure of effort since the number of cameras varied between sites.

We explored a full candidate model set (252 models) in regards to covariates because there was no prior expectation that any particular covariate combination would be irrelevant. We preferred this strategy to a "stepwise" approach to model selection because the latter is more likely to produce misleading results (Doherty et al. 2012). We used Akaike's Information Criterion (AIC) to assess model performance and conduct model selection. Models with <2 AIC units difference from the top-ranking model were considered equally best fit (Burnham & Anderson 2002). For each covariate, we calculated the summed AIC weights (w_i) of all models (i) that included that covariate as a measure of relative importance (Burnham & Anderson 2002). We also calculated the summed AIC weights of the two occupancy parameterizations.

Results

Andean bears were detected at 19 of 31 sites, yielding a naive occupancy of 0.61. Of the 19 sites with bear detections, 11 had detections in more than one 7-day survey occasion; the other 8 stations had detections in only one occasion. Domestic dogs/humans were detected at 21 of 31 sites, yielding a naive occupancy of 0.68. Of the 21 sites with dog/human detections, 13 had detections in more than one 7-day survey occasion; the other 6 stations had detections in only one occasion (Figure 2.3). Model selection revealed uncertainty in the top performing model, likely due to the number of different parameterizations and combinations of covariates on both occupancy and detection probability within the candidate model set. Among the top performing models (lowest AIC values), there were five models with a difference in AIC (ΔAIC) < 2 which we consider to fit the data equally well (Table 2.3). These top-ranking models were all the $\psi^{D}\psi^{B}$ parameterization, where Andean bear occupancy was fixed to be independent of domestic dog and human presence/absence, and all five models included covariates with a species effect. All possible covariates on both occupancy and detection probability were included within the structure of at least one of the five models.

Across the entire candidate model set, woody scrub cover had the highest summed AIC weight (w_i =0.89) of the occupancy covariates, followed by native forest (w_i =0.72), pasture (w_i =0.57), and elevation (w_i =0.44) (Figure 2.4). Of the covariates on detection, effort was an important predictor (w_i =0.99) while scent received less weight (w_i =0.32). Models parameterized so that Andean bear occupancy was independent of dogs/humans ($\psi^{BD} = \psi^{Bd}$) carried more weight (w_i =0.82) than those with all three occupancy parameters, ψ^{D}, ψ^{BD} and ψ^{Bd} (w_i =0.18). In the top-ranking model, all land use/cover covariates on occupancy negatively influenced the occupancy of domestic dogs and humans, but positively influenced the occupancy of Andean bears. The average occupancy estimate of dogs/humans across sites was 0.74 (SE=0.13), while the average occupancy estimate of Andean bears across sites was 0.63 (SE=0.13).

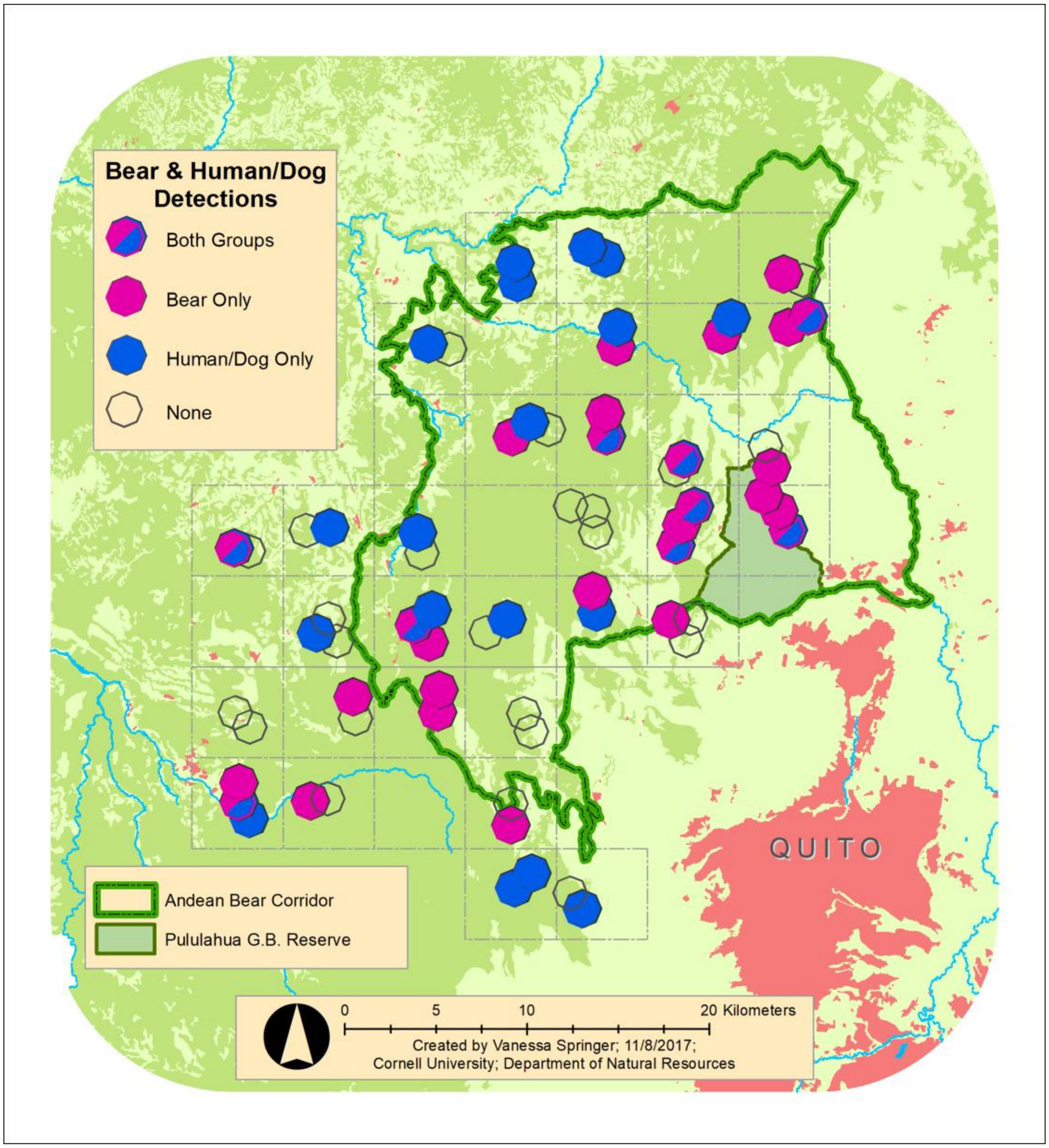

Figure 2.3. Naive detections of domestic dogs (*Canis familiaris*) and humans (grouped) and Andean bears (*Tremarctos ornatus*) on camera traps for a study northwest of Quito, Ecuador (approximately -78.586 longitude, 0.205 latitude). Map shows the survey gridlines, individual camera trap stations (n = 70) within 25 km^2 cells, and which camera stations detected one, both, or neither species.

Table 2.3. Top-ranking models (ΔAIC < 2) in co-occurrence analysis of domestic dogs (*Canis familiaris*) and humans (grouped) with Andean bears (T*remarctos ornatus*) in northwest Ecuador, where domestic dogs/humans are considered dominant in the conditional parameterization (Richmond et al 2010). All top-ranking models included a species effect on occupancy and detection covariates, meaning the listed covariates ("Model Covariates" column) were incorporated and a species effect was also included for each covariate. In all candidate models, detection probability parameterization was fixed and a species effect was also always included with covariates; models had occupancy covariates with and without species effects.

Parameterization	Model Covariates	Parameters	AIC	ΔAIC	AIC weight	-2*log-likelihood	Model likelihood
$\psi^D\psi^B$, Species	ψ(NativeForest, Scrub, Pasture, Elevation), p(Effort)	13	646.95	0	0.12	620.95	1
$\psi^D\psi^B$, Species	ψ(NativeForest, Scrub, Pasture), p(Effort)	11	647.39	0.43	0.10	625.39	0.81
$\psi^D\psi^B$, Species	ψ(NativeForest, Scrub), p(Effort)	9	647.89	0.94	0.08	629.89	0.63
$\psi^D\psi^B$, Species	ψ(NativeForest, Scrub, Pasture, Elevation), p(Effort, Scent)	14	648.38	1.43	0.06	620.38	0.49
$\psi^D\psi^B$, Species	ψ(NativeForest, Scrub, Pasture), p(Effort, Scent)	12	648.81	1.85	0.05	624.81	0.40

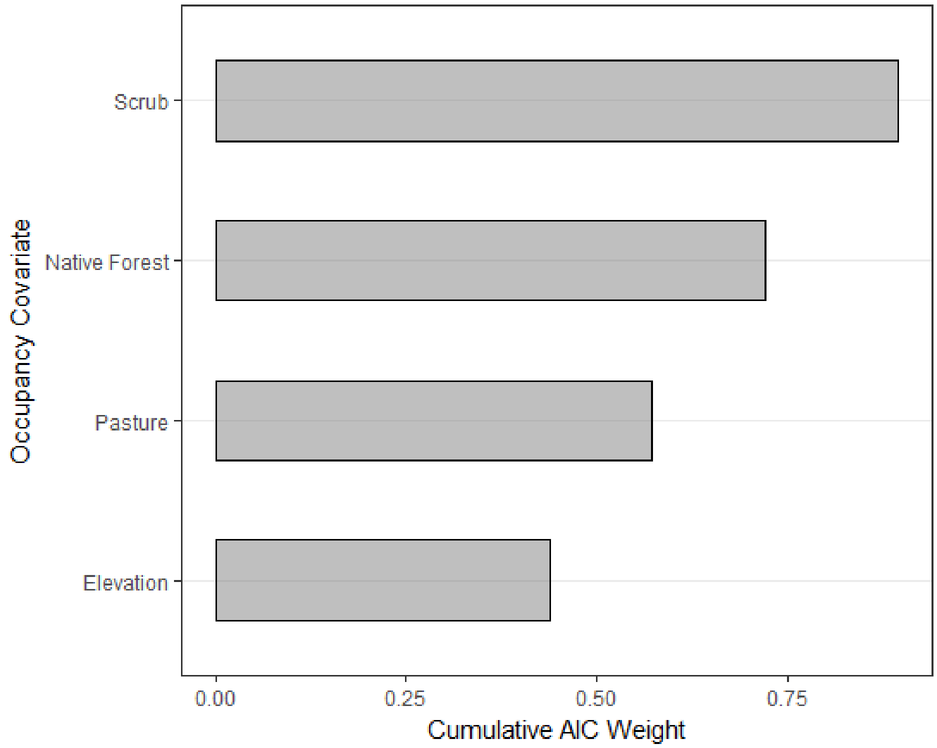

Figure 2.4. Summed AIC weights of occupancy covariates across candidate model set for multi-species occupancy analysis of domestic dogs (*Canis familiaris*)/humans and Andean bears (*Tremarctos ornatus*) northwest of Quito, Ecuador (approximately -78.586 longitude, 0.205 latitude).

Discussion

Andean bears did not avoid domestic dogs and humans in this multi-use landscape; Andean bear occupancy was independent of the presence/absence of dogs and humans. This finding contrasts with previous findings elsewhere in Ecuador where Andean bear occupancy was lower when dogs were present, and bears shifted activity times to avoid dogs temporally (Zapata-Ríos & Branch 2016, 2018). The behavior of domestic dogs is likely an important factor influencing sympatry between bears and dogs in our study area. Dogs can have indirect impacts by causing fear or avoidance-based behavioral changes in wildlife, or direct impacts by predating on or competing with wildlife (Weston et al. 2014). These impacts vary depending on dogs' behavior and relationship with humans; if dogs are closely associated and cared for by people they are less likely to have direct impacts such as competing with carnivores for prey and other resources (Vanak & Gompper 2009). Given that in our study area dogs are usually associated with people and not feral or independent of humans, combined with the fact that there is little protected area and Andean bears have had to persist in forest patches long-surrounded by human development and land use, it is possible that Andean bears in this region are uniquely acclimated to the presence of both dogs and humans.

Furthermore, while free-roaming dogs associated with people may predate on wildlife even without depending on them as a food source (often killing but not consuming prey) (Meek 1999, Vanak & Gompper 2009), Andean bears depend much more on fruits and vegetation than they do meat for survival (García-Rangel 2012), meaning they are less likely to compete with dogs for prey animals. In fact, availability of fruit and herbaceous food sources is the main driver of Andean bear habitat use (García-Rangel 2012). In our study, increasing percentages of both native forest and scrub cover had a positive influence on Andean bear occupancy; these land cover types proved more influential to Andean bears than domestic dog/human presence. Both land cover types are associated with food sources such as epiphytic and terrestrial Bromeliad plants and fruits (Peyton 1980, Cuesta et al. 2003). While there is little research on how altitude gradients affect Andean bear ecology, seasonality and the timing of food availability varies by altitude and in our study Andean bear occupancy was positively associated with higher elevation, which in the Andes is often linked with páramo grasslands (García-Rangel 2012). Páramo habitats provide alternative food sources when Bromeliad plants in the cloud forest are not fruiting (Peyton 1980, Cuesta et al. 2003, García-Rangel 2012). Pasture also had a positive relationship with bear occupancy in our study, although this was not likely due to predation on cattle as confirmed cases of Andean bear attacks on livestock are low (Goldstein et al. 2006).

We chose to utilize camera traps and multi-species occupancy modeling to study co-occurrence of Andean bears and domestic dogs/humans at a large spatial scale, but this approach does not provide insight into the finer-scale mechanisms that are facilitating sympatry between these species. Furthermore, we are unable to examine whether the presence of domestic dogs and humans may affect the abundance of Andean bears, if not the occupancy. Information on these topics is limited; despite Andean bears being a species of major conservation concern, the first abundance estimate of Andean bears in Ecuador generated using spatial capture-recapture methods was published in 2017 (Molina et al. 2017). Additionally, we lack even basic information on the abundance of domestic dogs in the Ecuadorian Andes despite their long-term presence alongside humans. While Andean bears occupied the landscape independently of domestic dogs and humans in this study, additional research and long-term monitoring is needed to fully understand how domestic dog and human presence influence Andean bears and other wildlife. Domestic dogs alone are contributing to the extinction of over 180 vertebrate species worldwide, with predation and disturbance being their most reported impacts (Doherty et al 2017), and the consequences to carnivores of human intrusion into natural areas are well documented (Treves et al. 2003, Ripple et al. 2014). Their joint influence on Andean bears and other wildlife in the Ecuadorian Andes should not be discounted.

The Chocó-Andean region of Ecuador is at the junction of two of the world’s biodiversity hotspots, one of which contains more endemic species than anywhere else on the planet (Myers et al. 2000). Unfortunately, this biodiversity is at risk due to the alarming pace at which habitat is being converted for human use. In addition to agriculture and grazing, the expansion of mining into previously forested and protected areas across Ecuador is expected to cause major biodiversity losses (Roy et al. 2018). Our study was conducted in conjunction with ongoing research to estimate Andean bear density and design a socio-ecological corridor between Cotacachi-Cayapas and Illinizas Ecological Reserves that incorporates social, economic, and environmental objectives. The increasing presence of domestic dogs and humans on the landscape is only one of the many consequences of habitat fragmentation and human encroachment, and an understanding of how each of these factors affects wildlife is crucial to the design of a corridor that adequately prioritizes areas for conservation.

CHAPTER 2 APPENDIX

A2.1. R code for multi-species occupancy analysis.

```
####Multi-species models for bear/doghums, with effort and scent as survey level covariates.
####Native forest, woody scrub cover, pasture and elevation as site level covariates

#load RPresence
library("RPresence", lib.loc="~/R/win-library/3.4")

# load csv detection history
Mycsv <- read.csv(file="DogBearStacked.csv", header=FALSE)
head(Mycsv)
summary(Mycsv)

#####Differs from single species in the format of detection histories
#convert from stacked to collaped (these lines came from the help documention for RPresence 2
spp)

nsites=nrow(Mycsv)/2
nsrvys=ncol(Mycsv)
cov1=cov2=NULL
newMycsv=Mycsv[1:nsites,]+2*Mycsv[nsites+1:nsites,]
##Run this to look at your new, collapsed encounter histories as csv
#write.csv(newMycsv, "newMyCsvBeardog.csv")
newMycsv

#read in UNIT covariate csv, include header, then exclude first column (camera stations)
UnitCovs<-read.csv(file=" SiteCovs2Spp.csv", header=TRUE)
head(UnitCovs)
UnitCovs2<-UnitCovs[,-1]

#read in SURVEY covs (SCENT AND EFFORT)
SurvCovs<-read.csv(file=" SurveyCovs2Spp.csv", header=TRUE)
head(SurvCovs)

#Create your Pao!!
?createPao
data=createPao(newMycsv,unitcov=UnitCovs2,survcov=SurvCovs,title="Beardog06.21.2018.pao"
)

#test
```

```
TestSimpleModel<-occMod(model=list(psi~SP,p~SP), data=data,
        type="so.2sp.1",param="PsiBA", modname = "TestSimpleModel")

###START RUNNING CANDIDATE SET

#species, interaction, additive covs on psi, Effort on p
Psi_SP_Int_NF_El_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+WoodyScrubCover+Pasture,p~SP+Effort
), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El_WSC_Pa__P_SP_E")
Psi_SP_Int_NF_El_WSC__P_SP_E<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El_WSC__P_SP_E")
Psi_SP_Int_NF_El_Pa__P_SP_E<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El_Pa__P_SP_E")
Psi_SP_Int_NF_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP+INT+NativeForest+WoodyScrubCover+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_WSC_Pa__P_SP_E")
Psi_SP_Int_El_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP+INT+Elevation+WoodyScrubCover+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_WSC_Pa__P_SP_E")
Psi_SP_Int_NF_El__P_SP_E<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El__P_SP_E")
Psi_SP_Int_NF_WSC__P_SP_E<-
occMod(model=list(psi~SP+INT+NativeForest+WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_WSC__P_SP_E")
Psi_SP_Int_NF_Pa__P_SP_E<-
occMod(model=list(psi~SP+INT+NativeForest+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_Pa__P_SP_E")
Psi_SP_Int_El_WSC__P_SP_E<-
occMod(model=list(psi~SP+INT+Elevation+WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_WSC__P_SP_E")
```

```
Psi_SP_Int_El_Pa__P_SP_E<-occMod(model=list(psi~SP+INT+Elevation+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_Pa__P_SP_E")
Psi_SP_Int_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP+INT+WoodyScrubCover+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_WSC_Pa__P_SP_E")
Psi_SP_Int_NF__P_SP_E<-occMod(model=list(psi~SP+INT+NativeForest,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF__P_SP_E")
Psi_SP_Int_El__P_SP_E<-occMod(model=list(psi~SP+INT+Elevation,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El__P_SP_E")
Psi_SP_Int_WSC__P_SP_E<-occMod(model=list(psi~SP+INT+WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_WSC__P_SP_E")
Psi_SP_Int_Pa__P_SP_E<-occMod(model=list(psi~SP+INT+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_Pa__P_SP_E")
Psi_SP_Int_1__P_SP_E<-occMod(model=list(psi~SP+INT,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_1__P_SP_E")
#species, interaction, additive covs on psi, Scent on p
Psi_SP_Int_NF_El_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+WoodyScrubCover+Pasture,p~SP+Scent
), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El_WSC_Pa__P_SP_S")
Psi_SP_Int_NF_El_WSC__P_SP_S<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El_WSC__P_SP_S")
Psi_SP_Int_NF_El_Pa__P_SP_S<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El_Pa__P_SP_S")
Psi_SP_Int_NF_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP+INT+NativeForest+WoodyScrubCover+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_WSC_Pa__P_SP_S")
Psi_SP_Int_El_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP+INT+Elevation+WoodyScrubCover+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_WSC_Pa__P_SP_S")
```

```
Psi_SP_Int_NF_El__P_SP_S<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El__P_SP_S")
Psi_SP_Int_NF_WSC__P_SP_S<-
occMod(model=list(psi~SP+INT+NativeForest+WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_WSC__P_SP_S")
Psi_SP_Int_NF_Pa__P_SP_S<-
occMod(model=list(psi~SP+INT+NativeForest+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_Pa__P_SP_S")
Psi_SP_Int_El_WSC__P_SP_S<-
occMod(model=list(psi~SP+INT+Elevation+WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_WSC__P_SP_S")
Psi_SP_Int_El_Pa__P_SP_S<-occMod(model=list(psi~SP+INT+Elevation+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_Pa__P_SP_S")
Psi_SP_Int_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP+INT+WoodyScrubCover+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_WSC_Pa__P_SP_S")
Psi_SP_Int_NF__P_SP_S<-occMod(model=list(psi~SP+INT+NativeForest,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF__P_SP_S")
Psi_SP_Int_El__P_SP_S<-occMod(model=list(psi~SP+INT+Elevation,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El__P_SP_S")
Psi_SP_Int_WSC__P_SP_S<-occMod(model=list(psi~SP+INT+WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_WSC__P_SP_S")
Psi_SP_Int_Pa__P_SP_S<-occMod(model=list(psi~SP+INT+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_Pa__P_SP_S")
Psi_SP_Int_1__P_SP_S<-occMod(model=list(psi~SP+INT,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_1__P_SP_S")
#species, interaction, additive covs on psi, Scent and Effort on p
Psi_SP_Int_NF_El_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+WoodyScrubCover+Pasture,p~SP+Effort
+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs,
modname = "Psi_SP_Int_NF_El_WSC_Pa__P_SP_E_S")
```

```
Psi_SP_Int_NF_El_WSC__P_SP_E_S<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El_WSC__P_SP_E_S")
Psi_SP_Int_NF_El_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El_Pa__P_SP_E_S")
Psi_SP_Int_NF_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+INT+NativeForest+WoodyScrubCover+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_WSC_Pa__P_SP_E_S")
Psi_SP_Int_El_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+INT+Elevation+WoodyScrubCover+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_WSC_Pa__P_SP_E_S")
Psi_SP_Int_NF_El__P_SP_E_S<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_El__P_SP_E_S")
Psi_SP_Int_NF_WSC__P_SP_E_S<-
occMod(model=list(psi~SP+INT+NativeForest+WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_WSC__P_SP_E_S")
Psi_SP_Int_NF_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+INT+NativeForest+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF_Pa__P_SP_E_S")
Psi_SP_Int_El_WSC__P_SP_E_S<-
occMod(model=list(psi~SP+INT+Elevation+WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_WSC__P_SP_E_S")
Psi_SP_Int_El_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+INT+Elevation+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El_Pa__P_SP_E_S")
Psi_SP_Int_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+INT+WoodyScrubCover+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_WSC_Pa__P_SP_E_S")
Psi_SP_Int_NF__P_SP_E_S<-occMod(model=list(psi~SP+INT+NativeForest,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_NF__P_SP_E_S")
```

```
Psi_SP_Int_El__P_SP_E_S<-occMod(model=list(psi~SP+INT+Elevation,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_El__P_SP_E_S")
Psi_SP_Int_WSC__P_SP_E_S<-
occMod(model=list(psi~SP+INT+WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_WSC__P_SP_E_S")
Psi_SP_Int_Pa__P_SP_E_S<-occMod(model=list(psi~SP+INT+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_Pa__P_SP_E_S")
Psi_SP_Int_1__P_SP_E_S<-occMod(model=list(psi~SP+INT,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Int_1__P_SP_E_S")
#species, interaction, additive covs, no covs on p
Psi_SP_Int_NF_El_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+WoodyScrubCover+Pasture,p~SP),data=
data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname =
"Psi_SP_Int_NF_El_WSC_Pa__P_SP_1")
Psi_SP_Int_NF_El_WSC__P_SP_1<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+WoodyScrubCover,p~SP),data=data,typ
e="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_NF_El_WSC__P_SP_1")
Psi_SP_Int_NF_El_Pa__P_SP_1<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation+Pasture,p~SP),data=data,type="so.2sp.1
",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_NF_El_Pa__P_SP_1")
Psi_SP_Int_NF_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP+INT+NativeForest+WoodyScrubCover+Pasture,p~SP),data=data,type
="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_NF_WSC_Pa__P_SP_1")
Psi_SP_Int_El_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP+INT+Elevation+WoodyScrubCover+Pasture,p~SP),data=data,type="so
.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_El_WSC_Pa__P_SP_1")
Psi_SP_Int_NF_El__P_SP_1<-
occMod(model=list(psi~SP+INT+NativeForest+Elevation,p~SP),data=data,type="so.2sp.1",param
="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_NF_El__P_SP_1")
Psi_SP_Int_NF_WSC__P_SP_1<-
occMod(model=list(psi~SP+INT+NativeForest+WoodyScrubCover,p~SP),data=data,type="so.2sp.
1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_NF_WSC__P_SP_1")
Psi_SP_Int_NF_Pa__P_SP_1<-
occMod(model=list(psi~SP+INT+NativeForest+Pasture,p~SP),data=data,type="so.2sp.1",param="
PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_NF_Pa__P_SP_1")
Psi_SP_Int_El_WSC__P_SP_1<-
occMod(model=list(psi~SP+INT+Elevation+WoodyScrubCover,p~SP),data=data,type="so.2sp.1",p
aram="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_El_WSC__P_SP_1")
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Psi_SP_Int_El_Pa__P_SP_1<-
occMod(model=list(psi~SP+INT+Elevation+Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_El_Pa__P_SP_1")
Psi_SP_Int_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP+INT+WoodyScrubCover+Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_WSC_Pa__P_SP_1")
Psi_SP_Int_NF__P_SP_1<-
occMod(model=list(psi~SP+INT+NativeForest,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_NF__P_SP_1")
Psi_SP_Int_El__P_SP_1<-
occMod(model=list(psi~SP+INT+Elevation,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_El__P_SP_1")
Psi_SP_Int_WSC__P_SP_1<-
occMod(model=list(psi~SP+INT+WoodyScrubCover,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_WSC__P_SP_1")
Psi_SP_Int_Pa__P_SP_1<-
occMod(model=list(psi~SP+INT+Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_Pa__P_SP_1")
Psi_SP_Int_1__P_SP_1<-
occMod(model=list(psi~SP+INT,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SP_Int_1__P_SP_1")
#species, no interaction, additive covs, effort on p
Psi_SP_NF_El_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP+NativeForest+Elevation+WoodyScrubCover+Pasture,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SP_NF_El_WSC_Pa__P_SP_E")
Psi_SP_NF_El_WSC__P_SP_E<-
occMod(model=list(psi~SP+NativeForest+Elevation+WoodyScrubCover,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SP_NF_El_WSC__P_SP_E")
Psi_SP_NF_El_Pa__P_SP_E<-
occMod(model=list(psi~SP+NativeForest+Elevation+Pasture,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SP_NF_El_Pa__P_SP_E")
Psi_SP_NF_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP+NativeForest+WoodyScrubCover+Pasture,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SP_NF_WSC_Pa__P_SP_E")
Psi_SP_El_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP+Elevation+WoodyScrubCover+Pasture,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SP_El_WSC_Pa__P_SP_E")

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Psi_SP_NF_El__P_SP_E<-occMod(model=list(psi~SP+NativeForest+Elevation,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El__P_SP_E")
Psi_SP_NF_WSC__P_SP_E<-
occMod(model=list(psi~SP+NativeForest+WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_WSC__P_SP_E")
Psi_SP_NF_Pa__P_SP_E<-occMod(model=list(psi~SP+NativeForest+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_Pa__P_SP_E")
Psi_SP_El_WSC__P_SP_E<-
occMod(model=list(psi~SP+Elevation+WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El_WSC__P_SP_E")
Psi_SP_El_Pa__P_SP_E<-occMod(model=list(psi~SP+Elevation+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El_Pa__P_SP_E")
Psi_SP_WSC_Pa__P_SP_E<-occMod(model=list(psi~SP+WoodyScrubCover+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_WSC_Pa__P_SP_E")
Psi_SP_NF__P_SP_E<-occMod(model=list(psi~SP+NativeForest,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF__P_SP_E")
Psi_SP_El__P_SP_E<-occMod(model=list(psi~SP+Elevation,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El__P_SP_E")
Psi_SP_WSC__P_SP_E<-occMod(model=list(psi~SP+WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_WSC__P_SP_E")
Psi_SP_Pa__P_SP_E<-occMod(model=list(psi~SP+Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Pa__P_SP_E")
Psi_SP_1__P_SP_E<-occMod(model=list(psi~SP,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_1__P_SP_E")
#species, no interaction, additive covs, scent on p
Psi_SP_NF_El_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP+NativeForest+Elevation+WoodyScrubCover+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El_WSC_Pa__P_SP_S")
Psi_SP_NF_El_WSC__P_SP_S<-
occMod(model=list(psi~SP+NativeForest+Elevation+WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El_WSC__P_SP_S")
```

```
Psi_SP_NF_El_Pa__P_SP_S<-
occMod(model=list(psi~SP+NativeForest+Elevation+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El_Pa__P_SP_S")
Psi_SP_NF_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP+NativeForest+WoodyScrubCover+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_WSC_Pa__P_SP_S")
Psi_SP_El_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP+Elevation+WoodyScrubCover+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El_WSC_Pa__P_SP_S")
Psi_SP_NF_El__P_SP_S<-occMod(model=list(psi~SP+NativeForest+Elevation,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El__P_SP_S")
Psi_SP_NF_WSC__P_SP_S<-
occMod(model=list(psi~SP+NativeForest+WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_WSC__P_SP_S")
Psi_SP_NF_Pa__P_SP_S<-occMod(model=list(psi~SP+NativeForest+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_Pa__P_SP_S")
Psi_SP_El_WSC__P_SP_S<-
occMod(model=list(psi~SP+Elevation+WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El_WSC__P_SP_S")
Psi_SP_El_Pa__P_SP_S<-occMod(model=list(psi~SP+Elevation+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El_Pa__P_SP_S")
Psi_SP_WSC_Pa__P_SP_S<-occMod(model=list(psi~SP+WoodyScrubCover+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_WSC_Pa__P_SP_S")
Psi_SP_NF__P_SP_S<-occMod(model=list(psi~SP+NativeForest,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF__P_SP_S")
Psi_SP_El__P_SP_S<-occMod(model=list(psi~SP+Elevation,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El__P_SP_S")
Psi_SP_WSC__P_SP_S<-occMod(model=list(psi~SP+WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_WSC__P_SP_S")
Psi_SP_Pa__P_SP_S<-occMod(model=list(psi~SP+Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Pa__P_SP_S")
```

```
Psi_SP_1__P_SP_S<-occMod(model=list(psi~SP,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_1__P_SP_S")
#species, no interaction, additive covs, effort and scent on p
Psi_SP_NF_El_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+NativeForest+Elevation+WoodyScrubCover+Pasture,p~SP+Effort+Sce
nt), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El_WSC_Pa__P_SP_E_S")
Psi_SP_NF_El_WSC__P_SP_E_S<-
occMod(model=list(psi~SP+NativeForest+Elevation+WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El_WSC__P_SP_E_S")
Psi_SP_NF_El_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+NativeForest+Elevation+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El_Pa__P_SP_E_S")
Psi_SP_NF_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+NativeForest+WoodyScrubCover+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_WSC_Pa__P_SP_E_S")
Psi_SP_El_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+Elevation+WoodyScrubCover+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El_WSC_Pa__P_SP_E_S")
Psi_SP_NF_El__P_SP_E_S<-
occMod(model=list(psi~SP+NativeForest+Elevation,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_El__P_SP_E_S")
Psi_SP_NF_WSC__P_SP_E_S<-
occMod(model=list(psi~SP+NativeForest+WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_WSC__P_SP_E_S")
Psi_SP_NF_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+NativeForest+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF_Pa__P_SP_E_S")
Psi_SP_El_WSC__P_SP_E_S<-
occMod(model=list(psi~SP+Elevation+WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El_WSC__P_SP_E_S")
Psi_SP_El_Pa__P_SP_E_S<-occMod(model=list(psi~SP+Elevation+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El_Pa__P_SP_E_S")
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```
Psi_SP_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP+WoodyScrubCover+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_WSC_Pa__P_SP_E_S")
Psi_SP_NF__P_SP_E_S<-occMod(model=list(psi~SP+NativeForest,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_NF__P_SP_E_S")
Psi_SP_El__P_SP_E_S<-occMod(model=list(psi~SP+Elevation,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_El__P_SP_E_S")
Psi_SP_WSC__P_SP_E_S<-occMod(model=list(psi~SP+WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_WSC__P_SP_E_S")
Psi_SP_Pa__P_SP_E_S<-occMod(model=list(psi~SP+Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_Pa__P_SP_E_S")
Psi_SP_1__P_SP_E_S<-occMod(model=list(psi~SP,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SP_1__P_SP_E_S")
#species, no interaction, additive covs,  p
Psi_SP_NF_El_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP+NativeForest+Elevation+WoodyScrubCover+Pasture,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs3, modname =
"Psi_SP_NF_El_WSC_Pa__P_SP_1")
Psi_SP_NF_El_WSC__P_SP_1<-
occMod(model=list(psi~SP+NativeForest+Elevation+WoodyScrubCover,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs8, modname =
"Psi_SP_NF_El_WSC__P_SP_1")
Psi_SP_NF_El_Pa__P_SP_1<-occMod(model=list(psi~SP+NativeForest+Elevation+Pasture,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs9, modname =
"Psi_SP_NF_El_Pa__P_SP_1")
Psi_SP_NF_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP+NativeForest+WoodyScrubCover+Pasture,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs11, modname =
"Psi_SP_NF_WSC_Pa__P_SP_1")
Psi_SP_El_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP+Elevation+WoodyScrubCover+Pasture,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs14, modname =
"Psi_SP_El_WSC_Pa__P_SP_1")
Psi_SP_NF_El__P_SP_1<-occMod(model=list(psi~SP+NativeForest+Elevation,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs18, modname =
"Psi_SP_NF_El__P_SP_1")
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```
Psi_SP_NF_WSC__P_SP_1<-occMod(model=list(psi~SP+NativeForest+WoodyScrubCover,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs19, modname =
"Psi_SP_NF_WSC__P_SP_1")
Psi_SP_NF_Pa__P_SP_1<-occMod(model=list(psi~SP+NativeForest+Pasture,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs20, modname =
"Psi_SP_NF_Pa__P_SP_1")
Psi_SP_El_WSC__P_SP_1<-occMod(model=list(psi~SP+Elevation+WoodyScrubCover,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs22, modname =
"Psi_SP_El_WSC__P_SP_1")
Psi_SP_El_Pa__P_SP_1<-occMod(model=list(psi~SP+Elevation+Pasture,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs23, modname =
"Psi_SP_El_Pa__P_SP_1")
Psi_SP_WSC_Pa__P_SP_1<-occMod(model=list(psi~SP+WoodyScrubCover+Pasture,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs25, modname =
"Psi_SP_WSC_Pa__P_SP_1")
Psi_SP_NF__P_SP_1<-occMod(model=list(psi~SP+NativeForest,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs28, modname =
"Psi_SP_NF__P_SP_1")
Psi_SP_El__P_SP_1<-occMod(model=list(psi~SP+Elevation,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs29, modname =
"Psi_SP_El__P_SP_1")
Psi_SP_WSC__P_SP_1<-occMod(model=list(psi~SP+WoodyScrubCover,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs30, modname =
"Psi_SP_WSC__P_SP_1")
Psi_SP_Pa__P_SP_1<-occMod(model=list(psi~SP+Pasture,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs31, modname =
"Psi_SP_Pa__P_SP_1")
Psi_SP_1__P_SP_1<-occMod(model=list(psi~SP,p~SP),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs33, modname =
"Psi_SP_1__P_SP_1")
####################INTERACTIONS
#These are models with covariates interacting with BOTH SP AND INT, and Effort as cov on p
Psi_SPxINTxNF_El_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Wo
odyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxNF_El_WSC_Pa__P_SP_E")
Psi_SPxINTxNF_El_WSC__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Wo
odyScrubCover+INT*WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxNF_El_WSC__P_SP_E")
Psi_SPxINTxNF_El_Pa__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Pas
```

ture+INT*Pasture,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_El_Pa__P_SP_E")
Psi_SPxINTxNF_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_WSC_Pa__P_SP_E")
Psi_SPxINTxEl_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl_WSC_Pa__P_SP_E")
Psi_SPxINTxNF_El__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_El__P_SP_E")
Psi_SPxINTxNF_WSC__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_WSC__P_SP_E")
Psi_SPxINTxNF_Pa__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Pasture+INT*Pasture,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_Pa__P_SP_E")
Psi_SPxINTxEl_WSC__P_SP_E<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl_WSC__P_SP_E")
Psi_SPxINTxEl_Pa__P_SP_E<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*Pasture+INT*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl_Pa__P_SP_E")
Psi_SPxINTxWSC_Pa__P_SP_E<-
occMod(model=list(psi~SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxWSC_Pa__P_SP_E")
Psi_SPxINTxNF__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF__P_SP_E")
Psi_SPxINTxEl__P_SP_E<-occMod(model=list(psi~SP*Elevation+INT*Elevation,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl__P_SP_E")

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Psi_SPxINTxWSC__P_SP_E<-
occMod(model=list(psi~SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxWSC__P_SP_E")
Psi_SPxINTxPa__P_SP_E<-occMod(model=list(psi~SP*Pasture+INT*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxPa__P_SP_E")
Psi_SPxINT__P_SP_E<-occMod(model=list(psi~SP*INT,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA", p.cov=SurvCovs, modname = "Psi_SPxINT__P_SP_E")
#These are models with covariates interacting with BOTH SP AND INT, and Effort and Scent as covs
on p
Psi_SPxINTxNF_El_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Wo
odyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxNF_El_WSC_Pa__P_SP_E_S")
Psi_SPxINTxNF_El_WSC__P_SP_E_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Wo
odyScrubCover+INT*WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxNF_El_WSC__P_SP_E_S")
Psi_SPxINTxNF_El_Pa__P_SP_E_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Pas
ture+INT*Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxNF_El_Pa__P_SP_E_S")
Psi_SPxINTxNF_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*WoodyScrubCover+INT*WoodyS
crubCover+SP*Pasture+INT*Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxNF_WSC_Pa__P_SP_E_S")
Psi_SPxINTxEl_WSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCo
ver+SP*Pasture+INT*Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxEl_WSC_Pa__P_SP_E_S")
Psi_SPxINTxNF_El__P_SP_E_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation,p~SP+Ef
fort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs,
modname = "Psi_SPxINTxNF_El__P_SP_E_S")
Psi_SPxINTxNF_WSC__P_SP_E_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*WoodyScrubCover+INT*WoodyS
crubCover,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2,
p.cov=SurvCovs, modname = "Psi_SPxINTxNF_WSC__P_SP_E_S")
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Psi_SPxINTxNF_Pa__P_SP_E_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Pasture+INT*Pasture,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_Pa__P_SP_E_S")
Psi_SPxINTxEl_WSC__P_SP_E_S<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl_WSC__P_SP_E_S")
Psi_SPxINTxEl_Pa__P_SP_E_S<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*Pasture+INT*Pasture,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl_Pa__P_SP_E_S")
Psi_SPxINTxWSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxWSC_Pa__P_SP_E_S")
Psi_SPxINTxNF__P_SP_E_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF__P_SP_E_S")
Psi_SPxINTxEl__P_SP_E_S<-
occMod(model=list(psi~SP*Elevation+INT*Elevation,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl__P_SP_E_S")
Psi_SPxINTxWSC__P_SP_E_S<-
occMod(model=list(psi~SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxWSC__P_SP_E_S")
Psi_SPxINTxPa__P_SP_E_S<-
occMod(model=list(psi~SP*Pasture+INT*Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxPa__P_SP_E_S")
Psi_SPxINT__P_SP_E_S<-occMod(model=list(psi~SP*INT,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA", p.cov=SurvCovs, modname = "Psi_SPxINT__P_SP_E_S")
#These are models with covariates interacting with BOTH SP AND INT, andScent as cov on p
Psi_SPxINTxNF_El_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_El_WSC_Pa__P_SP_S")
Psi_SPxINTxNF_El_WSC__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Scent),
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data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_El_WSC__P_SP_S")
Psi_SPxINTxNF_El_Pa__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Pasture+INT*Pasture,p~SP+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_El_Pa__P_SP_S")
Psi_SPxINTxNF_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_WSC_Pa__P_SP_S")
Psi_SPxINTxEl_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl_WSC_Pa__P_SP_S")
Psi_SPxINTxNF_El__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation,p~SP+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_El__P_SP_S")
Psi_SPxINTxNF_WSC__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_WSC__P_SP_S")
Psi_SPxINTxNF_Pa__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Pasture+INT*Pasture,p~SP+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF_Pa__P_SP_S")
Psi_SPxINTxEl_WSC__P_SP_S<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl_WSC__P_SP_S")
Psi_SPxINTxEl_Pa__P_SP_S<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*Pasture+INT*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxEl_Pa__P_SP_S")
Psi_SPxINTxWSC_Pa__P_SP_S<-
occMod(model=list(psi~SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxWSC_Pa__P_SP_S")
Psi_SPxINTxNF__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxINTxNF__P_SP_S")

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Psi_SPxINTxEl__P_SP_S<-occMod(model=list(psi~SP*Elevation+INT*Elevation,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxEl__P_SP_S")
Psi_SPxINTxWSC__P_SP_S<-
occMod(model=list(psi~SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxWSC__P_SP_S")
Psi_SPxINTxPa__P_SP_S<-occMod(model=list(psi~SP*Pasture+INT*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxINTxPa__P_SP_S")
Psi_SPxINT__P_SP_S<-occMod(model=list(psi~SP*INT,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA", p.cov=SurvCovs, modname = "Psi_SPxINT__P_SP_S")
#These are models with covariates interacting with BOTH SP AND INT, and no covs on p
Psi_SPxINTxNF_El_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Wo
odyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP),data=data,type="so.2sp.
1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxNF_El_WSC_Pa__P_SP_1")
Psi_SPxINTxNF_El_WSC__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Wo
odyScrubCover+INT*WoodyScrubCover,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov
=UnitCovs2, modname = "Psi_SPxINTxNF_El_WSC__P_SP_1")
Psi_SPxINTxNF_El_Pa__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation+SP*Pas
ture+INT*Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname
= "Psi_SPxINTxNF_El_Pa__P_SP_1")
Psi_SPxINTxNF_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*WoodyScrubCover+INT*WoodyS
crubCover+SP*Pasture+INT*Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=Un
itCovs2, modname = "Psi_SPxINTxNF_WSC_Pa__P_SP_1")
Psi_SPxINTxEl_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCo
ver+SP*Pasture+INT*Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs
2, modname = "Psi_SPxINTxEl_WSC_Pa__P_SP_1")
Psi_SPxINTxNF_El__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Elevation+INT*Elevation,p~SP),d
ata=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname =
"Psi_SPxINTxNF_El__P_SP_1")
Psi_SPxINTxNF_WSC__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*WoodyScrubCover+INT*WoodyS
crubCover,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname =
"Psi_SPxINTxNF_WSC__P_SP_1")
Psi_SPxINTxNF_Pa__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest+SP*Pasture+INT*Pasture,p~SP),data
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=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxNF_Pa__P_SP_1")
Psi_SPxINTxEl_WSC__P_SP_1<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxEl_WSC__P_SP_1")
Psi_SPxINTxEl_Pa__P_SP_1<-
occMod(model=list(psi~SP*Elevation+INT*Elevation+SP*Pasture+INT*Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxEl_Pa__P_SP_1")
Psi_SPxINTxWSC_Pa__P_SP_1<-
occMod(model=list(psi~SP*WoodyScrubCover+INT*WoodyScrubCover+SP*Pasture+INT*Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxWSC_Pa__P_SP_1")
Psi_SPxINTxNF__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+INT*NativeForest,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxNF__P_SP_1")
Psi_SPxINTxEl__P_SP_1<-
occMod(model=list(psi~SP*Elevation+INT*Elevation,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxEl__P_SP_1")
Psi_SPxINTxWSC__P_SP_1<-
occMod(model=list(psi~SP*WoodyScrubCover+INT*WoodyScrubCover,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxWSC__P_SP_1")
Psi_SPxINTxPa__P_SP_1<-
occMod(model=list(psi~SP*Pasture+INT*Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxINTxPa__P_SP_1")
Psi_SPxINT__P_SP_1<-
occMod(model=list(psi~SP*INT,p~SP),data=data,type="so.2sp.1",param="PsiBA", modname = "Psi_SPxINT__P_SP_1")
#These are models with covariates interacting with ONLY SP , and effort on p
Psi_SPxNF_El_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*WoodyScrubCover+SP*Pasture,p~SP+Effort), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_El_WSC_Pa__P_SP_E")
Psi_SPxNF_El_WSC__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_El_WSC__P_SP_E")
Psi_SPxNF_El_Pa__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_El_Pa__P_SP_E")
Psi_SPxNF_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+SP*WoodyScrubCover+SP*Pasture,p~SP+Effort),
```

```
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_WSC_Pa__P_SP_E")
Psi_SPxEl_WSC_Pa__P_SP_E<-
occMod(model=list(psi~SP*Elevation+SP*WoodyScrubCover+SP*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl_WSC_Pa__P_SP_E")
Psi_SPxNF_El__P_SP_E<-occMod(model=list(psi~SP*NativeForest+SP*Elevation,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_El__P_SP_E")
Psi_SPxNF_WSC__P_SP_E<-
occMod(model=list(psi~SP*NativeForest+SP*WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_WSC__P_SP_E")
Psi_SPxNF_Pa__P_SP_E<-occMod(model=list(psi~SP*NativeForest+SP*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_Pa__P_SP_E")
Psi_SPxEl_WSC__P_SP_E<-
occMod(model=list(psi~SP*Elevation+SP*WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl_WSC__P_SP_E")
Psi_SPxEl_Pa__P_SP_E<-occMod(model=list(psi~SP*Elevation+SP*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl_Pa__P_SP_E")
Psi_SPxWSC_Pa__P_SP_E<-
occMod(model=list(psi~SP*WoodyScrubCover+SP*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxWSC_Pa__P_SP_E")
Psi_SPxNF__P_SP_E<-occMod(model=list(psi~SP*NativeForest,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF__P_SP_E")
Psi_SPxEl__P_SP_E<-occMod(model=list(psi~SP*Elevation,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl__P_SP_E")
Psi_SPxWSC__P_SP_E<-occMod(model=list(psi~SP*WoodyScrubCover,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxWSC__P_SP_E")
Psi_SPxPa__P_SP_E<-occMod(model=list(psi~SP*Pasture,p~SP+Effort),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxPa__P_SP_E")
#These are models with covariates interacting with ONLY SP , and scent on p
Psi_SPxNF_El_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*WoodyScrubCover+SP*Pasture,p~SP
+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs,
modname = "Psi_SPxNF_El_WSC_Pa__P_SP_S")
```

```
Psi_SPxNF_El_WSC__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_El_WSC__P_SP_S")
Psi_SPxNF_El_Pa__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_El_Pa__P_SP_S")
Psi_SPxNF_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+SP*WoodyScrubCover+SP*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_WSC_Pa__P_SP_S")
Psi_SPxEl_WSC_Pa__P_SP_S<-
occMod(model=list(psi~SP*Elevation+SP*WoodyScrubCover+SP*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl_WSC_Pa__P_SP_S")
Psi_SPxNF_El__P_SP_S<-occMod(model=list(psi~SP*NativeForest+SP*Elevation,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_El__P_SP_S")
Psi_SPxNF_WSC__P_SP_S<-
occMod(model=list(psi~SP*NativeForest+SP*WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_WSC__P_SP_S")
Psi_SPxNF_Pa__P_SP_S<-occMod(model=list(psi~SP*NativeForest+SP*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF_Pa__P_SP_S")
Psi_SPxEl_WSC__P_SP_S<-
occMod(model=list(psi~SP*Elevation+SP*WoodyScrubCover,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl_WSC__P_SP_S")
Psi_SPxEl_Pa__P_SP_S<-occMod(model=list(psi~SP*Elevation+SP*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl_Pa__P_SP_S")
Psi_SPxWSC_Pa__P_SP_S<-
occMod(model=list(psi~SP*WoodyScrubCover+SP*Pasture,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxWSC_Pa__P_SP_S")
Psi_SPxNF__P_SP_S<-occMod(model=list(psi~SP*NativeForest,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF__P_SP_S")
Psi_SPxEl__P_SP_S<-occMod(model=list(psi~SP*Elevation,p~SP+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl__P_SP_S")
```

Psi_SPxWSC__P_SP_S<-occMod(model=list(psi~SP*WoodyScrubCover,p~SP+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxWSC__P_SP_S")
Psi_SPxPa__P_SP_S<-occMod(model=list(psi~SP*Pasture,p~SP+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxPa__P_SP_S")
#These are models with covariates interacting with ONLY SP , and effort and scent on p
Psi_SPxNF_El_WSC_Pa__P_SP_E_S<-occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*WoodyScrubCover+SP*Pasture,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_El_WSC_Pa__P_SP_E_S")
Psi_SPxNF_El_WSC__P_SP_E_S<-occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*WoodyScrubCover,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_El_WSC__P_SP_E_S")
Psi_SPxNF_El_Pa__P_SP_E_S<-occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*Pasture,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_El_Pa__P_SP_E_S")
Psi_SPxNF_WSC_Pa__P_SP_E_S<-occMod(model=list(psi~SP*NativeForest+SP*WoodyScrubCover+SP*Pasture,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_WSC_Pa__P_SP_E_S")
Psi_SPxEl_WSC_Pa__P_SP_E_S<-occMod(model=list(psi~SP*Elevation+SP*WoodyScrubCover+SP*Pasture,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxEl_WSC_Pa__P_SP_E_S")
Psi_SPxNF_El__P_SP_E_S<-occMod(model=list(psi~SP*NativeForest+SP*Elevation,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_El__P_SP_E_S")
Psi_SPxNF_WSC__P_SP_E_S<-occMod(model=list(psi~SP*NativeForest+SP*WoodyScrubCover,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_WSC__P_SP_E_S")
Psi_SPxNF_Pa__P_SP_E_S<-occMod(model=list(psi~SP*NativeForest+SP*Pasture,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxNF_Pa__P_SP_E_S")
Psi_SPxEl_WSC__P_SP_E_S<-occMod(model=list(psi~SP*Elevation+SP*WoodyScrubCover,p~SP+Effort+Scent), data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname = "Psi_SPxEl_WSC__P_SP_E_S")

```
Psi_SPxEl_Pa__P_SP_E_S<-occMod(model=list(psi~SP*Elevation+SP*Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl_Pa__P_SP_E_S")
Psi_SPxWSC_Pa__P_SP_E_S<-
occMod(model=list(psi~SP*WoodyScrubCover+SP*Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxWSC_Pa__P_SP_E_S")
Psi_SPxNF__P_SP_E_S<-occMod(model=list(psi~SP*NativeForest,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxNF__P_SP_E_S")
Psi_SPxEl__P_SP_E_S<-occMod(model=list(psi~SP*Elevation,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxEl__P_SP_E_S")
Psi_SPxWSC__P_SP_E_S<-occMod(model=list(psi~SP*WoodyScrubCover,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxWSC__P_SP_E_S")
Psi_SPxPa__P_SP_E_S<-occMod(model=list(psi~SP*Pasture,p~SP+Effort+Scent),
data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, p.cov=SurvCovs, modname =
"Psi_SPxPa__P_SP_E_S")
#These are models with covariates interacting with ONLY SP , and no covs on p
Psi_SPxNF_El_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*WoodyScrubCover+SP*Pasture,p~SP)
,data=data,type="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname =
"Psi_SPxNF_El_WSC_Pa__P_SP_1")
Psi_SPxNF_El_WSC__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*WoodyScrubCover,p~SP),data=data,t
ype="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxNF_El_WSC__P_SP_1")
Psi_SPxNF_El_Pa__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation+SP*Pasture,p~SP),data=data,type="so.2s
p.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxNF_El_Pa__P_SP_1")
Psi_SPxNF_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+SP*WoodyScrubCover+SP*Pasture,p~SP),data=data,ty
pe="so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxNF_WSC_Pa__P_SP_1")
Psi_SPxEl_WSC_Pa__P_SP_1<-
occMod(model=list(psi~SP*Elevation+SP*WoodyScrubCover+SP*Pasture,p~SP),data=data,type=
"so.2sp.1",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxEl_WSC_Pa__P_SP_1")
Psi_SPxNF_El__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+SP*Elevation,p~SP),data=data,type="so.2sp.1",param=
"PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxNF_El__P_SP_1")
Psi_SPxNF_WSC__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+SP*WoodyScrubCover,p~SP),data=data,type="so.2sp.1
",param="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxNF_WSC__P_SP_1")
```

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Psi_SPxNF_Pa__P_SP_1<-
occMod(model=list(psi~SP*NativeForest+SP*Pasture,p~SP),data=data,type="so.2sp.1",param="P
siBA",psi.cov=UnitCovs2, modname = "Psi_SPxNF_Pa__P_SP_1")
Psi_SPxEl_WSC__P_SP_1<-
occMod(model=list(psi~SP*Elevation+SP*WoodyScrubCover,p~SP),data=data,type="so.2sp.1",pa
ram="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxEl_WSC__P_SP_1")
Psi_SPxEl_Pa__P_SP_1<-
occMod(model=list(psi~SP*Elevation+SP*Pasture,p~SP),data=data,type="so.2sp.1",param="PsiB
A",psi.cov=UnitCovs2, modname = "Psi_SPxEl_Pa__P_SP_1")
Psi_SPxWSC_Pa__P_SP_1<-
occMod(model=list(psi~SP*WoodyScrubCover+SP*Pasture,p~SP),data=data,type="so.2sp.1",par
am="PsiBA",psi.cov=UnitCovs2, modname = "Psi_SPxWSC_Pa__P_SP_1")
Psi_SPxNF__P_SP_1<-
occMod(model=list(psi~SP*NativeForest,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.co
v=UnitCovs2, modname = "Psi_SPxNF__P_SP_1")
Psi_SPxEl__P_SP_1<-
occMod(model=list(psi~SP*Elevation,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=U
nitCovs2, modname = "Psi_SPxEl__P_SP_1")
Psi_SPxWSC__P_SP_1<-
occMod(model=list(psi~SP*WoodyScrubCover,p~SP),data=data,type="so.2sp.1",param="PsiBA",
psi.cov=UnitCovs2, modname = "Psi_SPxWSC__P_SP_1")
Psi_SPxPa__P_SP_1<-
occMod(model=list(psi~SP*Pasture,p~SP),data=data,type="so.2sp.1",param="PsiBA",psi.cov=Uni
tCovs2, modname = "Psi_SPxPa__P_SP_1")


#make list of models
modelset<-list(
 Psi_SP_Int_NF_El_WSC_Pa__P_SP_E,
 Psi_SP_Int_NF_El_WSC__P_SP_E,
 Psi_SP_Int_NF_El_Pa__P_SP_E,
 Psi_SP_Int_NF_WSC_Pa__P_SP_E,
 Psi_SP_Int_El_WSC_Pa__P_SP_E,
 Psi_SP_Int_NF_El__P_SP_E,
 Psi_SP_Int_NF_WSC__P_SP_E,
 Psi_SP_Int_NF_Pa__P_SP_E,
 Psi_SP_Int_El_WSC__P_SP_E,
 Psi_SP_Int_El_Pa__P_SP_E,
 Psi_SP_Int_WSC_Pa__P_SP_E,
 Psi_SP_Int_NF__P_SP_E,
 Psi_SP_Int_El__P_SP_E,
 Psi_SP_Int_WSC__P_SP_E,
 Psi_SP_Int_Pa__P_SP_E,
 Psi_SP_Int_1__P_SP_E,
```

Psi_SP_Int_NF_El_WSC_Pa__P_SP_S,
Psi_SP_Int_NF_El_WSC__P_SP_S,
Psi_SP_Int_NF_El_Pa__P_SP_S,
Psi_SP_Int_NF_WSC_Pa__P_SP_S,
Psi_SP_Int_El_WSC_Pa__P_SP_S,
Psi_SP_Int_NF_El__P_SP_S,
Psi_SP_Int_NF_WSC__P_SP_S,
Psi_SP_Int_NF_Pa__P_SP_S,
Psi_SP_Int_El_WSC__P_SP_S,
Psi_SP_Int_El_Pa__P_SP_S,
Psi_SP_Int_WSC_Pa__P_SP_S,
Psi_SP_Int_NF__P_SP_S,
Psi_SP_Int_El__P_SP_S,
Psi_SP_Int_WSC__P_SP_S,
Psi_SP_Int_Pa__P_SP_S,
Psi_SP_Int_1__P_SP_S,
Psi_SP_Int_NF_El_WSC_Pa__P_SP_E_S,
Psi_SP_Int_NF_El_WSC__P_SP_E_S,
Psi_SP_Int_NF_El_Pa__P_SP_E_S,
Psi_SP_Int_NF_WSC_Pa__P_SP_E_S,
Psi_SP_Int_El_WSC_Pa__P_SP_E_S,
Psi_SP_Int_NF_El__P_SP_E_S,
Psi_SP_Int_NF_WSC__P_SP_E_S,
Psi_SP_Int_NF_Pa__P_SP_E_S,
Psi_SP_Int_El_WSC__P_SP_E_S,
Psi_SP_Int_El_Pa__P_SP_E_S,
Psi_SP_Int_WSC_Pa__P_SP_E_S,
Psi_SP_Int_NF__P_SP_E_S,
Psi_SP_Int_El__P_SP_E_S,
Psi_SP_Int_WSC__P_SP_E_S,
Psi_SP_Int_Pa__P_SP_E_S,
Psi_SP_Int_1__P_SP_E_S,
Psi_SP_Int_NF_El_WSC_Pa__P_SP_1,
Psi_SP_Int_NF_El_WSC__P_SP_1,
Psi_SP_Int_NF_El_Pa__P_SP_1,
Psi_SP_Int_NF_WSC_Pa__P_SP_1,
Psi_SP_Int_El_WSC_Pa__P_SP_1,
Psi_SP_Int_NF_El__P_SP_1,
Psi_SP_Int_NF_WSC__P_SP_1,
Psi_SP_Int_NF_Pa__P_SP_1,
Psi_SP_Int_El_WSC__P_SP_1,
Psi_SP_Int_El_Pa__P_SP_1,
Psi_SP_Int_WSC_Pa__P_SP_1,
Psi_SP_Int_NF__P_SP_1,

Psi_SP_Int_El__P_SP_1,
Psi_SP_Int_WSC__P_SP_1,
Psi_SP_Int_Pa__P_SP_1,
Psi_SP_Int_1__P_SP_1,
Psi_SP_NF_El_WSC_Pa__P_SP_E,
Psi_SP_NF_El_WSC__P_SP_E,
Psi_SP_NF_El_Pa__P_SP_E,
Psi_SP_NF_WSC_Pa__P_SP_E,
Psi_SP_El_WSC_Pa__P_SP_E,
Psi_SP_NF_El__P_SP_E,
Psi_SP_NF_WSC__P_SP_E,
Psi_SP_NF_Pa__P_SP_E,
Psi_SP_El_WSC__P_SP_E,
Psi_SP_El_Pa__P_SP_E,
Psi_SP_WSC_Pa__P_SP_E,
Psi_SP_NF__P_SP_E,
Psi_SP_El__P_SP_E,
Psi_SP_WSC__P_SP_E,
Psi_SP_Pa__P_SP_E,
Psi_SP_1__P_SP_E,
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  Psi_SPxEl_Pa__P_SP_1,
  Psi_SPxWSC_Pa__P_SP_1,
  Psi_SPxNF__P_SP_1,
  Psi_SPxEl__P_SP_1,
  Psi_SPxWSC__P_SP_1,
  Psi_SPxPa__P_SP_1
)

#AIC table of results
##AIC table comparing that model set
modelsetAIC=createAicTable(modelset, use.aicc = FALSE)
print(modelsetAIC$table)
write.csv(modelsetAIC$table, "BeardogmodelsetAIC.csv")

#Take a look at top model's estimates
Psi_SPxNF_WSC_Pa__P_SP_E
Psi_SPxNF_WSC__P_SP_E
Psi_SPxNF_El_WSC_Pa__P_SP_E_S
Psi_SPxNF_WSC_Pa__P_SP_E_S

##try AICc for comparison
AICcTable=createAicTable(modelset, use.aicc = TRUE)
print(AICcTable$table)
write.csv(AICcTable$table, "BeardogmodelsetAICcorrected.csv")
```

A2.2. Results of multi-species occupancy analysis with species pairing switched so that Andean bears (*Tremarctos ornatus*) are dominant and humans/dogs are subordinate. Analysis was performed in R as shown in A2.1, with an updated encounter history reflecting that the species pairing was switched.

Table A2.2.1. Top-ranking models (ΔAIC < 2) in co-occurrence analysis of domestic dogs (*Canis familiaris*) and humans (grouped) with Andean bears (*Tremarctos ornatus*) in northwest Ecuador. Andean bears are considered dominant in the conditional parameterization (Richmond et al 2010). Candidate model set compared two different occupancy parameterizations: 1) ψ^{DB} and ψ^{Db} are both estimated (occupancy of domestic dogs/humans is dependent on the presence/absence of Andean bears), and 2) $\psi^{DB} = \psi^{Db}$ (parameters are fixed so that the occupancy of domestic dogs/humans is independent of the presence /absence of Andean bears) and only one parameter for dog/human occupancy ψ^{D} is estimated. In both parameterizations Andean bear occupancy is ψ^{B} is estimated. For both occupancy parameterizations, we ran models with and without a species effect on occupancy (for models with a species effect, this applied to all model covariates). In our candidate model set if ψ^{B}, ψ^{DB}, and ψ^{Db} were all estimated separately, the models contained a species effect on covariates that was either conditional (C) (the effect of a covariate on dogs/humans differed dependent on presence/absence of Andean bears) or unconditional (effect of a covariate on dogs/humans was constant with respect to Andean bear presence/absence). For the $\psi^{DB} = \psi^{Db}$ parameterization, models in our candidate set were run with and without a species effect. In all models, detection probability parameterization was fixed and when covariates were incorporated, a species effect was also always included.

Parameterization	**Model Covariates**	**Parameters**	**AIC**	**ΔAIC**	**AIC weight**	**-2*log-likelihood**	**Model likelihood**
$\psi^{B}\psi^{D}$, Species	ψ(NativeForest, Scrub), p(Effort)	9	646.952	0	0.1036	628.952	1
$\psi^{B}\psi^{D}$, Species	ψ(NativeForest, Scrub, Pasture, Elevation), p(Effort)	13	646.954	0.002	0.1035	620.954	0.999
$\psi^{B}\psi^{D}$, Species	ψ(NativeForest, Scrub, Pasture), p(Effort)	11	647.3872	0.4352	0.0834	625.3872	0.8044
$\psi^{B}\psi^{DB}\psi^{Db}$, Species(C)	ψ(NativeForest, Scrub, Pasture), p(Effort)	15	647.6317	0.6797	0.0738	617.6317	0.7119
$\psi^{B}\psi^{D}$, Species	ψ(NativeForest, Scrub), p(Effort, Scent)	10	648.3639	1.4119	0.0512	628.3639	0.4936
$\psi^{B}\psi^{D}$, Species	ψ(NativeForest, Scrub, Pasture, Elevation), p(Effort, Scent)	14	648.3827	1.4307	0.0507	620.3827	0.489
$\psi^{B}\psi^{D}$, Species	ψ(NativeForest, Scrub, Pasture), p(Effort, Scent)	12	648.8086	1.8566	0.041	624.8086	0.3952

CHAPTER 2 REFERENCES

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