DIVERSITY AND SEASONALITY OF BIRDS IN PERMANENT WATERHOLES IN THE PERUVIAN NORTHWEST

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WATER HOLES IN NORTHWEST PERU

Abstract.- In arid environments, the presence of water sources is key for biological communities as they provide a vital element that is scarce. In this study we evaluated the diversity and the relative abundance of bird species in seven permanent waterholes located along an elevational gradient in mountain dry forests in northwest Peru. From January to December 2016, we analysed 114,438 photos (22,888 photo events) obtained through camera traps, and counted bird species and individuals photographed at these waterholes. We measured how bird diversity and abundance varied between waterholes during the humid (January to May) and dry seasons. In total, we made 4,137 detections of 35 bird species. Of these, 10 species were endemic to the Tumbesian area, including one that is globally Endangered (White-winged Guan -*Penelope albipennis*). Ninety-five percent of detections in all waterholes corresponded to four species of pigeons/doves (Columbidae). We also recorded two migratory species, including one that is uncommon in northwest Peru (Slaty Thrush –*Turdus nigriceps*). The number of bird detections during the dry season was almost two times higher than that during the humid season. We did not find any correlations between relative abundance/diversity at waterholes with elevation or distance to agricultural areas. We postulate that permanent waterholes are a keystone resource for bird species in the northwest Peruvian dry forests, and should be protected, as they provide a scarce resource to several range restricted species including one that is globally threatened.

Resumen. Diversidad y estacionalidad de aves en cuerpos de agua permanente en el noroeste de Perú. En ambientes áridos, la presencia de fuentes de agua es clave para las comunidades biológicas dado que proveen un elemento vital que es escaso. En este estudio, evaluamos la diversidad biológica y abundancia relativa de las especies de aves en siete cuerpos de agua permanentes localizados en una gradiente altitudinal en el bosque seco de montaña del noroeste de Perú. Analizamos 114,438 fotografías (22,888 eventos fotográficos) obtenidos a través de cámaras trampa entre enero y diciembre del 2016, y contamos las especies de aves y los individuos detectados en estos cuerpos de agua durante las épocas húmeda (enero a marzo) y seca. También evaluamos los cambios en la diversidad y abundancia entre cuerpos de agua y estaciones. En total, realizamos 4,137 detecciones de 35 especies. De estas, 10 especies fueron endémicas de la Zona de Endemismos Tumbesina, incluyendo una que está amenazada a nivel global (Pava Aliblanca – *Penelope albipennis*). El 95% de las detecciones de aves en estos cuerpos de agua correspondió a cuatro especies de Columbidae. También registramos dos especies migratorias, incluyendo una que es poco común en el noroeste de Perú (Zorzal Plomizo – *Turdus nigriceps*). Las detecciones durante la época seca fueron casi dos veces más altas que en la época húmeda. No encontramos ninguna correlación entre la abundancia relativa/diversidad en los cuerpos de agua con la elevación o la distancia a las zonas agrícolas. Postulamos que los cuerpos de agua son un recurso clave para las aves en los bosques secos del noroeste de Perú que debe ser protegido, dado que proveen un recurso escaso a varias especies de distribución restringida incluyendo una que está altamente amenazada a nivel global.

Key words: Camera traps, Dry forests, Lambayeque, Northwest Peru, Waterholes

INTRODUCTION

Small water bodies are critical for the maintenance of biodiversity, yet they remain understudied (Biggs et al. 2017). In arid ecosystems, where water is scarce and high temperatures are frequent, the existence of permanent water sources in the landscape contributes to the persistence of populations and species (Willoughby & Cade 1967, Lynn et al. 2006). In these arid areas, presence of water also determines many aspects of species behaviour and ecology and influence the aggregation of species and individuals in time and space (Ayeni 1975). This can be more pronounced in birds given that most species are diurnal and, with a few exceptions, do not build burrows to shelter from high temperatures (Fisher et al. 1972).

Waterholes play an important role in shaping bird communities in arid ecosystems and might act as a keystone resources for bird species persistence. Given the intrinsic scarcity of water in arid areas, individuals of many bird species gather around waterholes, increasing their vulnerability to predation (Cade 1965). Additionally, some species segregate in time when attending to waterholes, with some species being more abundant when temperatures are low or high (Fisher et al. 1972, Beck et al. 1973, Abdu et al. 2018).

South of the Piura river, in northwest Peru, the landscape is dominated by the Pacific desert. Here, the raising Andes isolated the humid forests to the east, resulting in the formation of a large arid zone to the west (Galán de Mera et al. 1997). Agriculture in arid ecosystems that are covered by seasonally dry tropical forests in northwest Peru is considered as the main driver of forest loss (Linares-Palomino et al. 2011, Castillo 2015). Here, water used to irrigate crops and fields are diverted from rivers and waterholes, thus diminishing the availability of this key resource to native vegetation and wildlife.

Camera trapping is a non-invasive method used for wildlife studies and is particullarly well suited for species that are shy, secretive and/or nocturnal. Camera traps allow remote and continuous collection of data for single and multiple species, and they are mainly used to obtain data on habitat use, abundance and distribution of terrestrial wildlife species. Recently they have also been used in the study of bird species, particularly ground dwelling birds like cracids and pheasants (O'Brian & Kinnaird 2008, Pettorelli et al. 2010, Rovero et al. 2013). In this study, we use information on bird presence that was collected via camera traps located in seven permanent waterholes in the dry forest of northwest Peru to quantify bird species diversity and relative abundance. The aim of this study is to establish whether small permanent waterholes in this arid ecosystem are an important feature in the landscape that congregate multiple bird species. To achieve this, we used data on the number of detections of birds attending these waterholes in dry/humid periods and derive associated diversity indexes to assess the importance of waterholes to bird species in our study area.

METHODS

Study Area. This study was conducted in a mountain range (Cerro Venado) located 14 km east from the town of Batan Grande, in the Lambayeque department in northwest

Peru (6°28’50’’S; 79°39’06’’W - Figure 1). The area is located within the southern portion of the Tumbesian endemic zone, a globally threatened conservation hotspot with a high number of endemic bird species (Myers et al. 2000, Best & Kessler 1995). Here, lowland and mountain dry forests dominate the landscape at lower and mid elevations (Galán de Mera et al. 1997, Ministerio del Ambiente 2015).

Precipitation in this highly threatened ecosystem (DRYFLOR 2016) is seasonal, with rains usually occurring from December to May (Figure 2); however, this pattern can vary with the occurrence of El Niño Southern Oscillation (ENSO) events. Adjacent to our study site, the La Leche river carries water from the Andes all year round, yet water sources are usually scarce away from the valley bottom and are virtually non-existent in mountain areas, except for a few permanent waterholes near rocky outcrops.

We located seven natural permanent waterholes in the Cerro Venado study area that on average were at 691 m a.s.l. (range: 350 – 850 m). All waterholes were in small depressions on steep mountain sides and thus were not accessed by cattle or other domestic animals. Water source for all these waterholes was underground water. Size of waterholes varied depending on water availability (and season) but on average they covered an area of ca. 2.5 m².

Our study area is classified as mountain dry forest and dominant tree species here are *Loxopterigium huasango* “hualtaco”, *Eryotheca ruizii* “pasayo” and *Bursera graveolens* “palo santo” which shed their leaves during the dry season (Ministerio del Ambiente 2015). Given the presence of water all year round, waterholes presented a highly diverse plant community with a very complex structure that facilitated their location. Around waterholes, presence of several large tree species (e.g., Higuerón – *Ficus padifolia*) provided shade and perches for birds, as has been documented in other waterholes that are close to our study area (Serván & Angulo 2006). Around waterholes, the understory was very dense while the presence of medium-sized rocks provided a smooth surface that was used by birds as perching sites when drinking.

Data collection and analysis

Data was collected between January and December 2016 by one camera trap (Reconyx RM 45 or Reconyx MC 65) located at each waterhole. Cameras were tied to a tree trunk at approximately 40 cm above ground and at approximately 3 meters from the edge of the waterhole. Cameras were programed to take five pictures per trigger with a one second interval between triggers. These five pictures were considered as one photo event. To maximize detections, camera sensitivity was set to the highest value and operated 24 h/day for a total of 2185 camera/days. Camera traps were also programed to register the time of day at which each photo was taken. This information was later used to obtain temporal patterns of detections of birds attending waterholes. Data from cameras was retrieved once a month and batteries were replaced after changing memory cards.

Picture analysis and management was done with CameraBase 1.7 (Tobler 2015). Pictures were separated for each waterhole and all birds at each waterhole were identified to species level. To measure changes due to seasonality, we separated pictures between humid (January–May) and dry seasons (June–December) per waterhole. To minimize double counting and maximize independence of photographic events on each waterhole, pictures of individuals belonging to the same species that were taken within an hour interval were excluded from analysis. Number of individuals per photo event were obtained from pictures containing the maximum number of individuals within the same hour interval and were used as a measure of the relative abundance of species at each waterhole.

Species were identified with Birds of Peru (Schulenberg et al. 2007), and information on species diet and foraging behaviour was mainly obtained from Birds of Peru (Schulenberg et al. 2007), and the Neotropical Birds Online website (www. https://neotropical.birds.cornell.edu/Species-Account/nb/support/welcome). To measure diversity and species dominance at each waterhole and how these varied seasonally, we computed the Shannon – Weaver diversity index and built dominance curves with the accumulated percentage of individuals for each waterhole/season (Shannon & Weaver 1963, Magurran 2004). Shannon-Weaver and dominance curves were obtained with PAST 3.06 (Hammer et al. 2001). We measured the Euclidean distance from waterholes to border of agricultural areas and elevation of waterholes (with a GPS) to establish if number of species and number of detections were correlated with distance to fields, other water sources and/or elevation, as waterholes that are closer to agricultural areas might be used by a larger number of individuals, particularly of species in the family Columbidae which are known to feed in agricultural fields (Bucher 1990), while waterholes located at higher elevations might be more difficult to access. Euclidean distance from waterholes to border of agricultural areas was measured with ArcGis 10.1 (ESRI 2012).

RESULTS

We analysed 114,438 photos (22,888 photo events) and recorded 4,137 detections of 35 bird species in all seven waterholes. Ten species were endemic to the Tumbesian Endemic Area (Best & Kesler 1995), including one that is globally threatened: the White-winged Guan (*Penelope albipennis* -Endangered) (BirdLife International 2019). Endemic species comprised 2.2% of all detections. Ninety-five percent of all recorded individuals corresponded to four species of the family Columbidae (*Columbina cruziana, Zenaida meloda*, *Zenaida auriculata*, *Leptotila verreauxi*), and within this family, 3609 individuals (92% of all Columbidae records) were recorded at three waterholes (Puente, Calabozo and Dibujo). We recorded two migratory species, including one that is uncommon in northwest Peru: the Slaty Thrush (*Turdus nigriceps*) (Schulenberg et al. 2007). See Table 1 for the list of all species registered at waterholes and number of detections per species.

Sixty percent of the species registered were small diurnal species (i.e., *Columbina cruziana*, *Melanopareia elegans*, *Thamnophilus bernardi*, *Aimophila stolzmanni*, etc.) that feed on small insects and/or seeds close to the ground or amid the lower vegetation strata (Schulenberg & Kirwan 2012, 2014). We also recorded four large diurnal raptors (including three –*Parabuteo unicinctus*, *Geranoetus melanoleucus* and *Buteogallus meridionalis* that perch in the upper canopy and rocky outcrops) (Piana 2015), three small to medium sized owl species (two of them –*Glaucidium peruvianum* and *Otus roboratus* perch in the mid canopy) (Piana, pers. obs), and a few species that forage in mid to lower vegetation strata (i.e., *Cyanocorax mystacalis*, *Icterus graceannae*, *Penelope albipennis*) (Angulo 2011; Piana pers. obs). Most (94%)

species were recorded drinking water during the early morning (7:30 h to 9:30 h) and late afternoon (15:00 h to 17:00 h).

We did not find any significant correlations between diversity or number of detections with elevation of waterholes ($r_s = 0.20$, $P = 0.63$; $r_s = -0.36$, $P = 0.38$), neither with distance from waterholes to agricultural areas ($r_s = -0.19$, $P = 0.65$; $r_s = 0.08$, $P = 0.84$).

Table 1. List of bird species and number of detections at waterholes in Cerro Venado, Lambayeque, Peru between January and December 2016.

* are Tumbesian endemic species, ** are Tumbesian endemic and globally threatened species, and *** are migratory species in Peru.

Species/Waterholes	Common name	Puente	Calabozo	Sogas	Dibujo	Venado	Mayascon	Oso
Nothoprocta pentlandii	Andean Tinamou	0	0	0	1	1	0	10
*Penelope albipennis***	White-winged Guan	3	0	0	0	0	0	0
Cathartes aura	Turkey Vulture	0	4	3	9	0	0	0
Buteogallus meridionalis	Savanna Hawk	0	1	0	0	0	0	0
Parabuteo unicinctus	Harris's Hawk	0	5	0	0	0	10	0
Geranoetus melanoleucus	Black-chested Buzzard-Eagle	0	0	0	0	0	2	0
Columbina cruziana	Croaking Ground Dove	50	1041	89	344	84	0	0
Zenaida meloda	West Peruvian Dove	46	640	24	173	2	10	0

Zenaida auriculata	Eared Dove	167	557	25	110	6	0	3
Leptotila verreauxi	White-tipped Dove	105	156	32	220	8	6	22
*Psittacara erythrogenys**	Red-masked Parakeet	0	0	1	0	0	0	0
*Forpus coelestis**	Pacific Parrotlet	9	2	22	0	0	0	0
Crotophaga sulcirostris	Groove-billed Ani	0	0	0	0	0	8	0
Glaucidium peruanum	Peruvian Pygmy-Owl	0	1	0	0	0	0	0
Megascops roboratus	Peruvian Screech-Owl	0	0	1	0	0	0	0
Athene cunicularia	Burrowing Owl	0	0	1	0	0	0	0
Furnarius leucopus	Pale-legged Hornero	0	0	1	0	0	0	0
Thamnophilus bernardi	Collared Antshrike	4	0	5	0	0	0	5
*Melanopareia elegans**	Elegant Crescentchest	0	0	2	0	0	0	1
Muscigralla brevicauda	Short-tailed Field Tyrant	0	0	1	0	0	0	0

*Cyanocorax mystacalis**	White-tailed Jay	0	0	26	0	0	4	3
*Cantorchilus superciliaris**	Superciliated Wren	0	0	2	0	0	0	0
Mimus longicaudatus	Long-tailed Mockingbird	0	3	4	0	1	0	0
*Catharus ustulatus****	Swainson´s Thrush	0	0	1	0	0	0	0
Turdus chiguanco	Chiguanco Thrush	0	0	4	0	0	0	4
*Turdus reevei**	Plumbeus-backed Thrush	0	0	2	0	0	0	0
*Turdus nigriceps****	Slaty Thrush	0	0	0	0	0	0	4
*Rhynchospiza stolzmanni**	Tumbes Sparrow	0	0	1	0	0	0	0
Poospiza hispaniolensis	Collared Warbling-Finch	0	0	3	0	0	0	0
*Atlapetes albiceps**	White-headed Brush Finch	1	0	8	0	0	0	0
Atlapetes leucopterus	White-winged Brush Finch	0	0	1	0	0	0	0
Pheucticus chrysogaster	Golden Grossbeak	0	5	0	0	1	0	0

Coereba flaveola	Bananaquit	0	0	11	0	0	0	0
*Icterus graceannae**	White-edged Oriole	0	0	5	0	0	0	0
Spinus magellanicus	Hooded Siskin	0	0	10	0	0	0	0
Total		385	2415	285	857	103	40	52

Shannon-Weaver diversity indexes varied widely between waterholes during each season (%CV $_{humid}$ = 57.3; %CV $_{dry}$ = 51.1) and in three waterholes (Puente, Calabozo and Dibujo) bird diversity was higher during the dry season, while in the other waterholes it was higher in the humid season (Table 2). Number of bird detections in six waterholes were higher during the dry season yet a pairwise comparison of bird detections in all waterholes between the dry and the wet season was not statistically significant (Student´s t-test, t = 1.76, df = 7, P = 0.13).

Table 2. Shannon-Weaver diversity indexes for seven waterholes in Cerro Venado, Lambayeque, Peru during the dry and humid seasons between January and December 2016.

Season/Waterholes	Puente	Calabozo	Sogas	Dibujo	Venado	Mayascon	Oso
Humid season	0	1.228	2.114	1.17	0.7235	1.392	1.673
Dry season	1.422	1.251	2.06	1.232	0	1.106	1.346

During the humid season, number of detections varied from 14 (Oso) to 660 (Calabozo), while during the dry season it varied from 20 (Mayascon) to 1751 (Calabozo). Considering all waterholes, more detections were made during the dry season than during the humid season (2749 vs 1388), and, except for two waterholes (Mayascon and Venado) more species were recorded during the dry season than during the humid season. Species from the family Columbidae dominated in most waterholes, and in Puente, Calabozo, Dibujo and Venado waterholes, they accounted for more than 90% of the total number of detections (Figure 3).

DISCUSSION

During this study, we detected 35 bird species drinking water at waterholes; of these, 10 were endemic to the Tumbesian area. Bird detections at waterholes were widely dominated by four granivorous species belonging to the family Columbidae. Although no detailed studies on bird diversity and abundances have been conducted in our study area, the number of bird species registered at Pomac Historical Sanctuary –PHS (approximately 25 km west of our study site) is 119 and in Laquipampa Wildlife Refuge –LWR (14 km north of our study site) is 187 (Angulo et al. 2012, Angulo & Sanchez 2016), hence the proportion of species using the waterholes we studied, and that were detected by camera traps is low. However, except for the Swainson´s Thrush, all species registered in the waterholes we studied are present in LWR, while nine species are not present in the PHS (White-headed and White-winged Brush Finches, White-winged Guan, Plumbeus-backed Thrush, etc.). Hence, it is possible that these waterholes are particularly important for bird species associated to mountain dry forests like those that are present in LWR (Schulenberg et al. 2007, Ministerio del Ambiente 2015).

Although across all waterholes included in this study, the difference in the number of bird detections between the dry and wet season was not statistically significant, it was nevertheless higher in six waterholes during the dry season. This was not the case in the Dibujo waterhole which is less than 3 km from agricultural fields where water is available all year round. It is possible that in our study area, bird species that perform large daily movements like doves (Bucher 1990) regularly visit the La Leche river which might be acting as a permanent water source, somewhat reducing the impact of water scarcity on birds during the dry season. The use of camera traps did not allow us to differentiate between bird individuals revisiting waterholes, and due to the high mobility of some of the species detected (i.e., the four species in the Columbidae –Bucher 1990), we acknowledge that some individual might have been counted more than once at each waterhole. Thus, our number of bird detections could only be used as an estimator of the relative abundance of birds and species at each waterhole and should be interpreted with care (Rovero & Marshal 2009, Burton et al. 2015).

Bird species attending waterholes during humid and dry seasons were very similar, indicating that in our study area, there is not much seasonal variation in species composition that attend waterholes, and perhaps its use is related to the availability of other critical resources besides water (i.e., food, cover, nesting sites, etc.), as has been determined for other taxa (Hamilton et al. 2015). Our findings are similar to those obtained by Cade (1965) when studying bird attendance at open waterholes in the Namib desert, in southwest Africa, to those obtained by Lynn et al. (2006) in the Arizona dessert, USA and by Fisher et al. (1972) in many study sites within the Australian desert. In all these studies, bird attendance at waterholes was dominated by species from the Columbidae family. Given that dry seeds contain a small amount of water, permanent waterholes like those we studied might be particularly relevant for granivorous species than for other birds (Fisher et al. 1972).

Lynn et al. (2006) found that abundance of resident species in waterholes located in the Arizona desert was many times higher than those of migratory species. In northwest Peru, diversity and relative abundance of migratory species in the waterholes we studied was also very low, yet it is possible that the methods we used for the detection of birds precluded us from recording more migratory (and resident) species and individuals. However, in our study area these waterholes were also visited by several range restricted species including one of high conservation concern (the White-winged Guan). Hence, further research on bird diversity, including habitat use by migratory and endangered species should be conducted through direct observations and mark-recapture studies in these waterholes to obtain more precise abundance estimates. This information will help to better assess the conservation value of waterholes in northwest Peru and to fine-tune measures to protect them.

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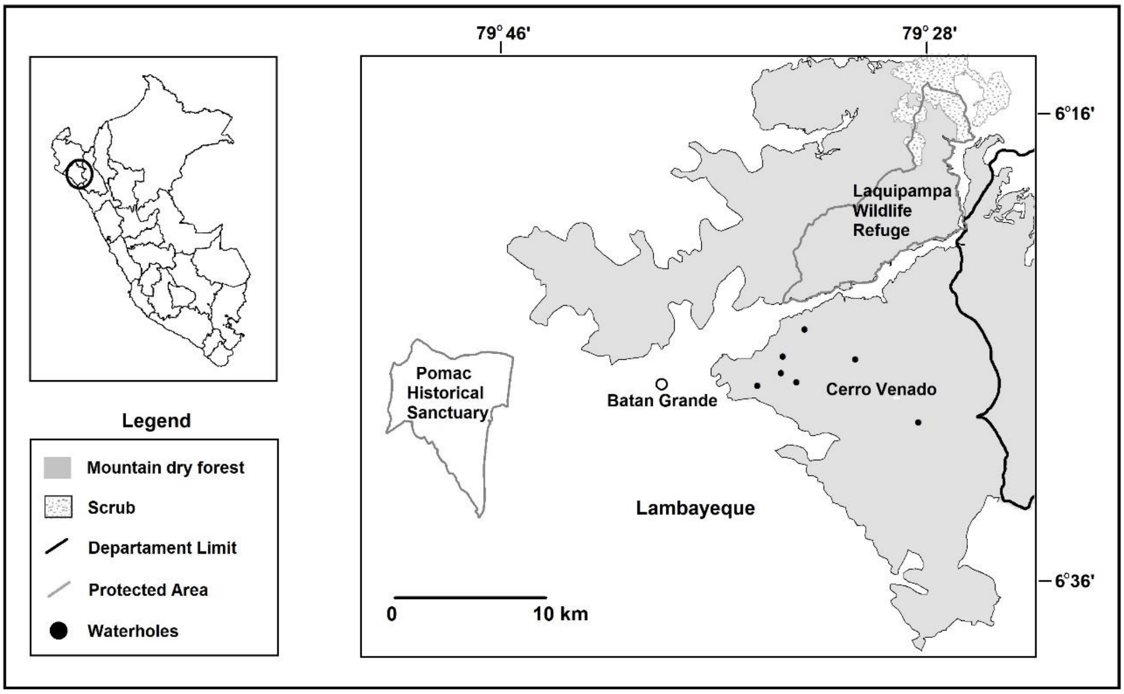
Figure legends

Figure 1. Map of waterholes in Cerro Venado, Lambayeque department in north west Peru.

Figure 2. Average maximum and minimal monthly temperature (^{0}C) and average monthly precipitation (mm) in Cerro Venado, Lambayeque department in north west Peru from 1964 to 2014 (www.senhami.gob.pe). Tmin and Tmax are minimum and maximum temperature, Pp is precipitation

Figure 3. Species rank per waterhole and season (humid vs dry) in Cerro Venado, Lambayeque, Peru, from January to December 2016. The Y axis shows the relative abundance of species at each waterhole/season (% of the total number of detections) and the X axis shows species ranks in decreasing order from left to right. AS *Rhynchospiza stolzmanni*, AC *Athene cunicularia*, AA *Atlapetes albiceps*, AL *Atlapetes leucopterus*, BM *Buteogallus meridionalis*, CS *Cantorchilus superciliaris*, CA *Cathartes aura*, CU *Catharus ustulatus*, CF *Coereba flaveala*, CC *Columbina cruziana*, CS *Crothophaga sulcirostris*, CM *Cyanocorax mystacalis*, FC *Forpus coelestis*, FL *Furnarius leucopus*, GM *Geranoaetus melanoleucus*, GP *Glaucidium peruanum*, IG *Icterus graceannae*, LV *Leptotila verreauxi*, MR *Megascops roboratus*, ME *Melanopareia elegans*, ML *Mimus longicaudatus*, MB *Muscigralla brevicauda*, NP *Nothoprocta pentlandii*, PU *Parabuteo unincinctus*, PA *Penelope albipennis*, PC *Pheuticus chrysogaster*, PH *Poospiza hispaniolensis*, PE *Psittacara erythrogenys*, SM *Spinus magellanica*, TB *Thamnophilus bernardi*, TC *Turdus chiguanco*, TN *Turdus nigriceps*, TR *Turdus reevei*, ZA *Zenaida auriculata*, ZM *Zenaida meloda*.

Figure 1.



79° 46'
79° 28'
6°16'
6°36'
Laquipampa
Wildlife
Refuge
Pomac
Historical
Sanctuary
Batan Grande
Cerro Venado
Lambayeque
0
10 km
Legend
Mountain dry forest
Scrub
Departament Limit
Protected Area
Waterholes

Figure 2.

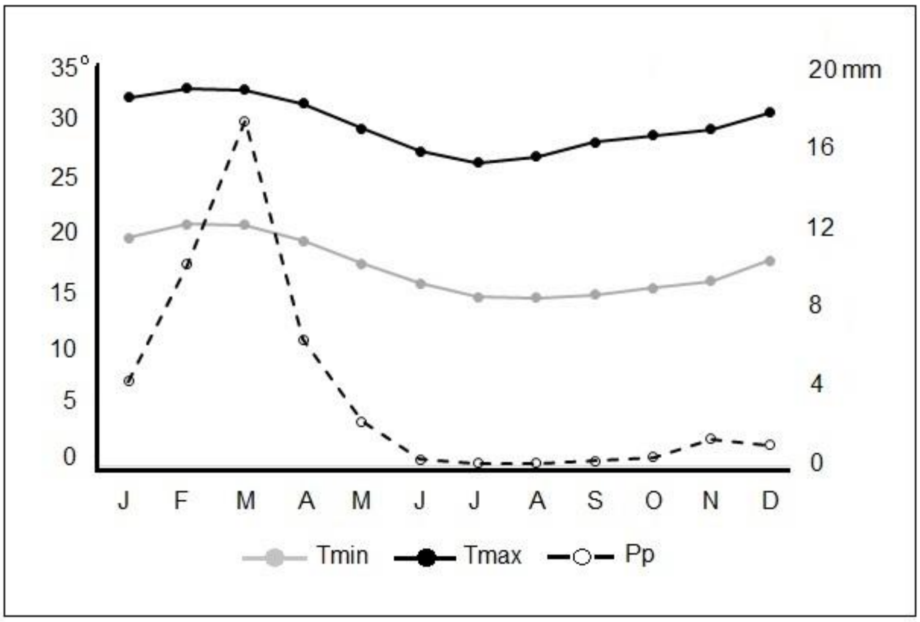
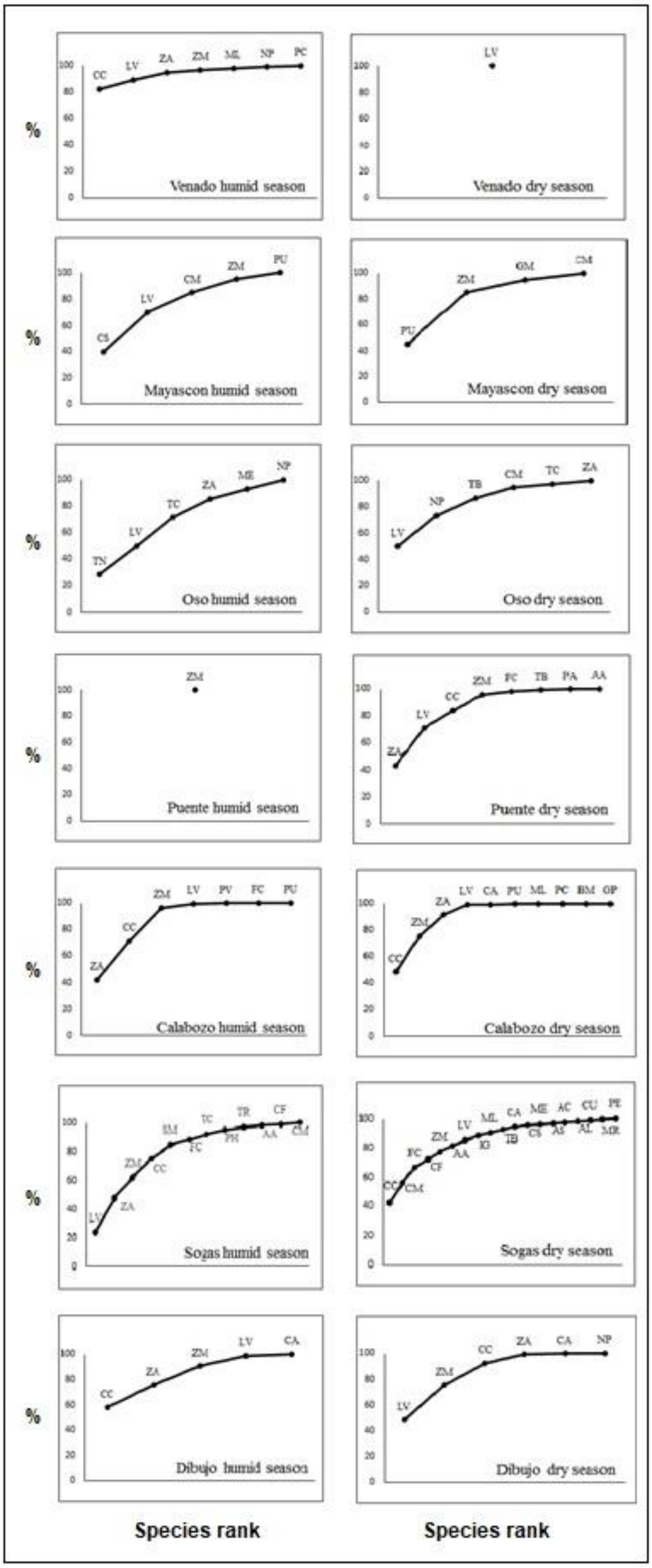


Figure 3.


%
CC LV ZA ZM ML NP PC
Venado humid season
LV
Venado dry season
CS LV CM ZM PU
Mayascon humid season
PU ZM GM CM
Mayascon dry season
TN LV TC ZA ME NP
Oso humid season
LV NP TB CM TC ZA
Oso dry season
ZM
Puente humid season
ZA LV CC ZM FC TB PA AA
Puente dry season
ZA CC ZM LV PV FC PU
Calabozo humid season
CC ZM ZA LV CA PU ML PC BM OP
Calabozo dry season
Sogas humid season
Sogas dry season
CC ZA ZM LV CA
Dibujo humid season
LV ZM CC ZA CA NP
Dibujo dry season
Species rank
Species rank