Perch selection of three species of kingfishers at the Pantanal of Brazil

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Abstract

Perch selection of three species of kingfishers at the Pantanal of Brazil. Selecting a suitable perch can offer many benefits for fish–eating birds such as kingfishers. However, factors affecting perch selection in these species remain poorly studied. We studied perch selection in three species of kingfishers inhabiting the Pantanal of Brazil during the dry season: *Megaceryle torquata*, *Chloroceryle amazona,* and *Chloroceryle americana*. First, we determined the habitat use of the three species. We then assessed the perches these kingfishers used based on four ecologically relevant traits: (1) artificial or natural, (2) perch height, (3) distance to the water, and (4) plant cover. We hypothesized that artificial perches could be more likely selected as they may offer better visibility to fish. We used a resource selection function, in a case/control design, solving it by model selection of six conditional logistic regression competing models. The probability of presence was independent of the artificial origin of a perch for the three species. It was also independent of the other studied variables, except for individuals of *C. amazona*, which selected higher perches. We conclude that artificial perches do not influence perch selection of the studied kingfishers, which may indicate that these artificial structures are not altering their behavioral choices.

Key words: *Megaceryle torquata, Chloroceryle amazona, Chloroceryle americana,* Resource selection function, Neotropical birds, Wetlands

Resumen

Selección de posaderos en tres especies de martín pescador en el Pantanal de Brasil. Para las aves ictiófagas, como los martines pescadores, seleccionar un posadero apropiado puede ofrecer muchos beneficios. A pesar de ello, los factores que afectan a la selección de los posaderos en estas aves se han estudiado muy poco. Durante la estación seca, estudiamos la selección de posaderos en tres especies de martín pescador que habitan en el Pantanal de Brasil: *Megaceryle torquata*, *Chloroceryle amazona* y *Chloroceryle americana*. En primer lugar, describimos el uso del hábitat de las tres especies. Después, evaluamos cómo se produce la selección de posaderos por parte de los martines pescadores en función de cuatro características ecológicamente relevantes: (1) si es artificial o natural, (2) la altura del posadero, (3) la distancia al agua y (4) la cobertura vegetal. Teníamos la hipótesis de que se preferirían los posaderos artificiales porque podrían ofrecer más visibilidad para pescar. Utilizamos una función de selección de recursos en un diseño de caso y control, que resolvimos mediante la selección de seis modelos de regresión condicional logística como candidatos. La probabilidad de presencia fue independiente del origen artificial del posadero para las tres especies. También fue independiente de otras variables estudiadas, excepto para los individuos de *C. amazona*, que seleccionaron posaderos más elevados. Así, concluimos que los posaderos artificiales no influyen en la selección de posaderos de los martines pescadores estudiados, lo que podría indicar que estas estructuras artificiales no están alterando las decisiones conductuales de estas aves.

Palabras clave: *Megaceryle torquata*, *Chloroceryle amazona*, *Chloroceryle americana*, Función de selección de recursos, Aves neotropicales, Humedales

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Introduction

A habitat provides the conditions and resources necessary to support the population of a species (Whittaker et al., 1973). The amount and quality of resources vary in space and time, conditioning behavioral decisions and, consequently, their spatial distribution (Cody, 1985; Litvaitis and Villafuerte, 1996; Manly et al., 2007). Animals tend to select microhabitats that maximize their fitness (Chalfoun and Schmidt, 2012), depending on their specific needs, balancing the associated (energetic and non–energetic) costs and benefits (Hutto, 1985; Block and Brennan, 1993; Houston and Lang, 1998; Johnstone and Earn, 1999). It is expected that animals select –that is, use a resource in greater proportion than its availability– the microhabitats where they achieve higher reproductive success and survival (Levins, 1968; Orians, 1980). At the same time, animals should avoid (that is, use a resource in a lower proportion than its availability) those places where chances of reproduction and survival are low (Orians and Wittenberger, 1991). Here lies the importance of studying how and why animals select the different resources available (Cody, 1985). Moreover, to answer the question 'why do animals select a determined habitat?' it is important to learn about behavioral and evolutionary ecology so as to manage and preserve relevant habitats (Chalfoun and Schmidt, 2012).

For many species of birds, the structure and composition of vegetation and water bodies are key factors influencing the diversity and abundance of trophic resources, perches, and nesting sites (Cueto, 2006). Perches are important habitat elements for many bird species since they relate to multiple ecological functions (Cody, 1985). For example, birds use perches to defend their territory (Wiens 1969), and for reproduction (Krams, 2001), foraging (Wolff et al., 1999), feeding (Glinski and Ohmart, 1983) and resting (Thompson et al., 2022). Due to their relevance for many vital processes, selecting suitable perches may have important ecological consequences. For fish–eating birds, the microhabitat use is closely related to the temporal and spatial distribution of water bodies (Ferreira, 2013). Kingfishers are an important group of continental fish–eating birds. In the Pantanal wetland in Brazil, three species of kingfisher are particularly common: the ringed kingfisher *Megaceryle torquata* (Linnaeus 1766), the Amazon kingfisher *Chloroceryle amazona* (Latham 1790), and the green kingfisher *Chloroceryle americana* (Gmelin 1788). They are sympatric and differ in body size, *M. torquata* (~39.6 cm of mean body length) > *C. amazona* (~29.5 cm) > *C. americana* (~21.8 cm) (Gwynne et al., 2010; Rodrigues et al., 2019). All three three species inhabit temporary ponds of the Pantanal, sharing habitat and diet (Donatelli et al., 2014). They mainly feed on fish in shallow water, although they may occasionally eat terrestrial and aquatic arthropods, and even lizards (Rosa, 2009). At these temporary ponds, perches serve to visualize prey and prepare the attack from a certain height (Gwynne et al., 2010). Previous research pointed to perch height as an important trait partitioning the habitat of kingfishers (Remsen, 1991; Bitterman, 2012; Chodacki and Skipper, 2019). These studies compared various traits of perches used between species but did not test habitat selection by comparing the traits of used perches with those available in the habitat.

The Pantanal is a natural reserve, holding one of the highest bird abundance worldwide (Tubelis and Tomas, 2003). In the Anthropocene, however, artificial elements, such as electricity lines, wooden bridges, and traffic signs are present even at the most isolated natural reserves. These artificial structures are thus an option for fish–eating birds to use as perches, and they are commonly observed as such (Asokan and Ali, 2010). Power lines and other artificial elements may offer good visualization of prey, free of the visual obstacles of branches, for example, normally present in tropical areas (Lammers and Collopy, 2007). However, a bird perching on a power line would also be more exposed to potential predators, and may even risk electrocution (D'Amico et al., 2018). This cost–benefit relation, however, has not been tested in analyses of perch selection by kingfishers. Our study aimed to understand perch selection of three kingfisher species and elucidate the role of artificial elements in this choice. We hypothesized that artificial elements could be selected rather than natural perches because they could enhance kingfishers' fishing success, that kingfishers would select perches with greater vegetation cover to avoid predation, and that selection of perch heights and distance from the water could contribute to reducing interspecific competition among the three species (fig. 1). We did not have a priori expectations about the differences among the three species regarding perch selection.

Material and methods

Study area

Our study took place at the Pantanal of Miranda (Corumbá, Mato Grosso do Sul, Brazil) (19º 34' S, 57º 01' W). The Pantanal is one of the largest wetlands in the world. It covers an area of approximately 150,000 km^2, and is characterized by flooded grasslands and savannas. The climate is tropical with marked dry and wet seasons and a mean annual temperature of 25ºC (Bergier and Assine, 2016). We conducted the fieldwork during the dry season in September 2018. We sampled 13 temporary ponds located along the path named 'MS–184' (an unpaved road that crosses the Pantanal Matogrossense National Park at the municipality of Corumbá). The ponds have circular to ellipsoidal shapes of ca. 50–100 m at their widest part at this time of the year. These temporary ponds are similar: they are well preserved, maintaining the native vegetation, and abundant in fish (Alho, 2008). Although the area is well preserved, because the path crosses the ponds, each pond holds artificial elements: a wooden bridge, power lines, and traffic signs.

As we did not capture or mark the individuals, we sampled the ponds sequentially, sampling each pond just once, to avoid pseudoreplication (Millar and

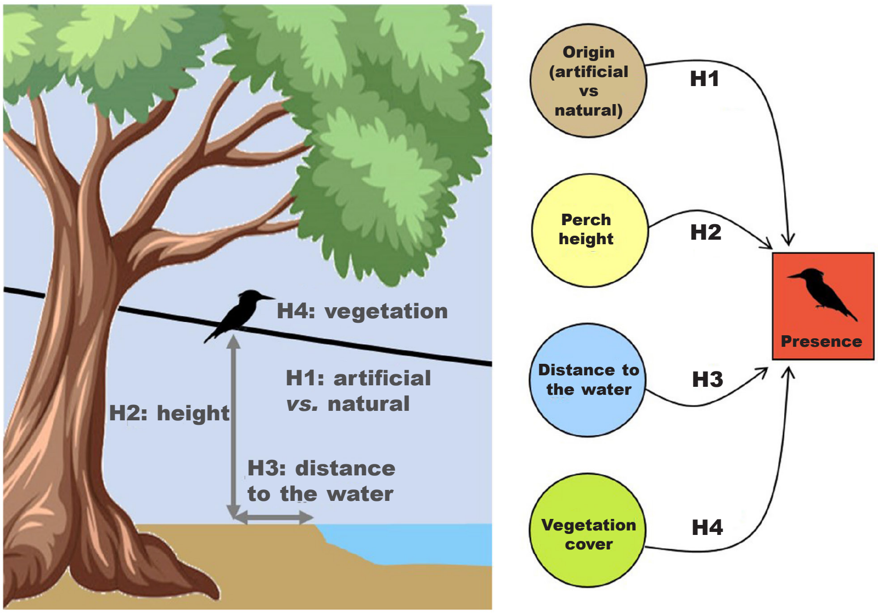

Fig. 1. Hypotheses on perch selection of three species of kingfishers (*Megaceryle torquata*, *Chloroceryle amazona*, and *C. americana*) studied at the Pantanal of Brazil: birds of the three species will select artificial over natural perches (H1), perch height (H2), distance to the water (H3), and vegetation cover above the animal (H4) will affect perch selection, probably in a different way for the different species.

*Fig. 1. Hipótesis sobre la selección de posaderos en tres especies de martín pescador (*Megaceryle torquata*, *Chloroceryle amazona *y* C. americana*) estudiadas en el Pantanal de Brasil: las aves de las tres especies preferirán los posaderos artificiales a los naturales (H1), la altura del posadero (H2), la distancia al agua (H3) y la cobertura vegetal (H4) afectarán a la selección del posadero, probablemente de forma distinta para cada especie.*

Anderson, 2004). All observations were conducted in the period of maximum activity of kingfishers, between 07.00 hrs and 11.00 hrs (pers. obs.). We visited the ponds and recorded four variables at the site where an individual kingfisher was perched. We systematically recorded available perches, noting for each used perch, and the closest four available perches (unused perches). We defined the available perches as the closest potential perch in a straight line to the perch used by the bird (i.e., > 5 cm thick, enough to support individuals of all three species), either artificial or natural. We used a case/control design, pairing the data of each perch used to data of four unused systematically sampled perches, assuming they represent the perches that are available for a given individual at a given moment (Manly et al., 2007; Duchesne et al., 2010). The studied variables were: (1) perch type (artificial vs natural), (2) perch height, (3) perch distance from the water, and (4) perch vegetation cover. Due to the difficulty in approaching the perches, the same previously trained observer (Laura C. Peinado) estimated their height and distance to the water by eye. The distance to the water was measured as the horizontal distance to the pond shore, considered zero if the perch was exactly at the shore, negative if it was within the pond border, and positive if it was outside the pond border. We quantified vegetation cover as the percentage of vegetation at the angle of view of the observed kingfisher, dividing the plane into four quadrants to facilitate the estimation. We considered this view plane as the sphere above the perch viewed through a densimeter. By simultaneously recording our four variables of interest (perch type, height, water distance and vegetation cover) for each used/unused perch for each bird and using a case/control design with the individual as a random factor, we avoided temporal and environmental variation that would confound results (Duchesne et al., 2010). We observed 34 birds using perches at these ponds: 15 *M. torquata*, 14 *C. amazona,* and 5 *C. americana*. Because we identified four unused (available) perches for each used perch, we sampled 134 unused (available) perches for the 34 used perches: 60 for *M. torquata*, 56 for *C. amazona* and 20 for *C. americana*.

Statistical analyses

First, we determined perch use of the three kingfisher species regarding the four variables of interest (perch type, height, water distance, and vegetation cover). We explored the data using univariate plots (bar plots or violin plots, depending on the variable;

Table 1. Descriptive statistics of used and unused perches of the three kingfisher species studied at the Pantanal of Miranda (Mato Grosso do Sul, Brazil). Mean and standard deviation (SD) values are provided for perch height, distance to water and vegetation cover. The variable 'type' represents the percentage of artificial perches (vs natural ones) of the total for each group. We used a paired design, with four unused perches assessed to each used perch. Sample size is 34 for used perches (15 *M. torquata*, 14 *C. amazona*, 5 *C. americana*) and 136 for unused (available) perches (60 *M. torquata*, 56 *C. amazona*, 20 *C. americana*).

Tabla 1. Estadística descriptiva de los posaderos utilizados y no utilizados para las tres especies de martín pescador estudiadas en el Pantanal de Miranda (Mato Grosso del Sur, en Brasil). En relación con la altura del posadero, la distancia al agua y la cobertura vegetal, aportamos los valores de la media y la desviación estándar. La variable 'type' representa el porcentaje de posaderos artificiales (respecto de los naturales) del total para cada grupo. Utilizamos un diseño pareado que nos permitió registrar cuatro posaderos no utilizados por cada posadero utilizado. El tamaño de la muestra es de 34 para los posaderos usados (15 M. torquata*, 14* C. amazona *y 5* C. americana*) y de 136 para los posaderos no usados (disponibles) (60* M. torquata*, 56* C. amazona *y 20* C. americana*).*

Variable	Perch	*M. torquata*	*C. amazona*	*C. americana*	Pooled
Perch height (m)	Used	4.08 ± 2.55	2.91 ± 2.53	1.38 ± 0.22	3.13 ± 2.44
	Unused	3.23 ± 2.55	1.73 ± 1.34	1.64 ± 1.01	2.35 ± 2.03
Distance to water (m)	Used	–2.12 ± 3.14	–2.73 ± 3.00	–3.05 ± 2.50	–2.53 ± 2.86
	Unused	–2.32 ± 3.83	–2.32 ± 3.39	–2.44 ± 2.22	–2.29 ± 3.36
Vegetation cover (%)	Used	6.54 ± 17.00	9.29 ± 14.78	0.00 ± 0.00	7.12 ± 14.58
	Unused	8.37 ± 17.02	9.38 ± 16.21	4.69 ± 5.61	10.53 ± 1954
Type (% of artificial perches)	Used	21.42 %	33.33 %	0 %	24.24 %
	Unused	37.50 %	30.00 %	0 %	29.55 %

see supplementary material). Data were not normally distributed, and showed no homogeneous variances between species. We tested for differences in the relative frequency of use of artificial perches (observations in artificial perches/total observations of the species) by species using Fisher's exact probability test. We tested for inter–specific differences in perch height, perch distance to water, and perch vegetation cover using Kruskal–Wallis tests. If differences were found between the three species, we used pairwise Wilcoxon rank sum tests using the Benjamini and Hochberg (1995) *p*–value correction to identify where the differences were. We then fitted a factor analysis of mixed data (FAMD) to reduce the dimensionality of the values and visualize perch use by the three species (Pagès, 2014) using the R package 'FactoMineR' (Lê et al., 2008).

To evaluate how kingfishers selected their perches, we used a resource selection function (RSF) approach. An RSF is a function of the probability that an individual uses a specific resource based on its availability in the habitat (Manly et al., 2007). In our case, the resource was the perch, and we were interested in the effect of the four studied variables (perch type, height, water distance and vegetation cover) in their probability of use (fig. 1). Here, we used conditional logistic regression (CLR) models to solve the RSF, pairing the data of used and available perches for each individual. In this way we could determine whether available perches were true absences that the bird could have selected at the moment of observation but did not (Jones, 2001; Duchesne et al., 2010; Benício et al., 2019). The response variable was the presence of the bird on the perch (1, used perch; 0, unused perch). In this way, using CLR we fitted a model on the odds ratio of the probability of a bird selecting a certain perch in relation to other available perches depending on the main effects of the explicative variables (artificial/natural perch, height, distance to water and vegetation cover) in the same probabilistic process (Liedke et al., 2018; Ortega et al., 2019). We used the function clogit of the package R 'survival' (Therneau, 2015; R Core Team, 2018). To test our ecological hypotheses (fig. 1), we fitted six competing CLR models and selected the best model(s) based on AIC using the 'AICcmodavg' R package (Mazerolle, 2017): (1) null model: presence ~ perch_type + perch_height + distance_water + veg_cover + strata (ID); (2) perch type model, to test the effect of artificial elements on perch selection: presence ~ perch_type + strata (ID); (3) perch height model: presence ~ perch_height + strata (ID); (4) accessibility to water model: presence ~ distance_water + strata (ID); (5) vegetation cover model, to test whether the kingfishers selected perches to avoid predation: presence ~ veg_cover + strata (ID);

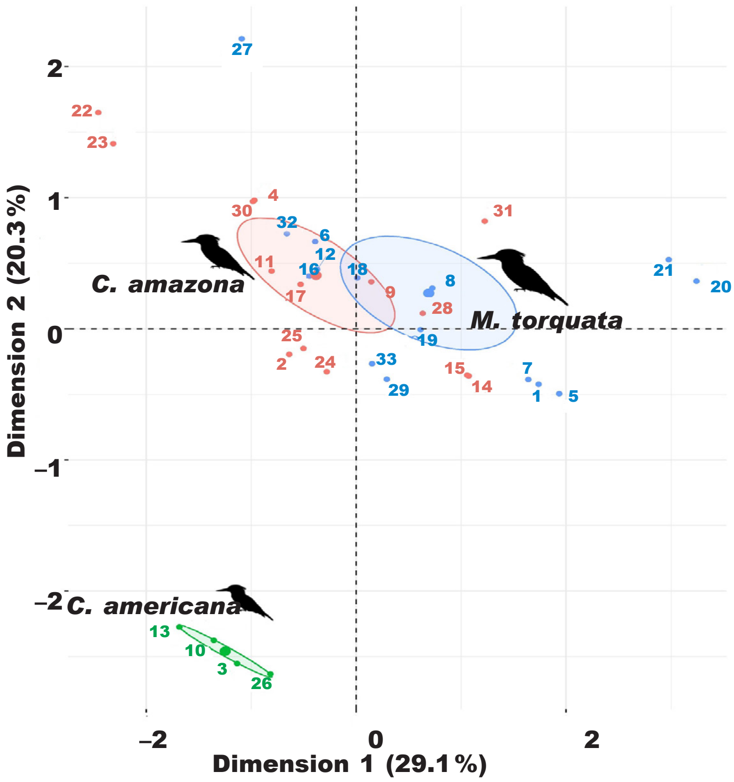

Fig. 2. Multivariate analysis (Factor Analysis of Mixed Data) of the habitat use of the three species of kingfishers studied at the Pantanal of Brazil (*Megaceryle torquata* in blue, *Chloroceryle amazona* in red, and *C. americana* in green). The first axis was mainly related to perch origin (natural vs artificial) and the second to bird species and vegetation cover.

*Fig. 2. Análisis multivariado (análisis factorial de datos mixtos) del uso de hábitat de las tres especies de martín pescador estudiadas en el Pantanal de Brasil (*Megaceryle torquata *en azul,* Chloroceryle amazona *en rojo y* C. americana *en verde). El primer eje se relaciona principalmente con el origen del posadero (natural o artificial) y el segundo, con la especie de ave y la cobertura vegetal.*

(6) height by species model, to test if the different species selected perches at different heights, as previously suggested in the literature: presence ~ perch_height + perch_height × species + strata (ID). We identified the best models as those with delta AIC_c < 2 and accumulated Akaike weights up to 0.95 (Johnson and Omland, 2004). If a clear best model was observed (AIC_c < 2 and Akaike weight > 0.95), we kept this model as the best one. If this was not the case, we averaged the coefficients of the best models. We assessed the goodness–of–fit of selected models by visually inspecting residuals (Johnson and Omland, 2004).

Results

The three species used perches with similar traits, that is, at a height of approximately 1–4 m, 2–3 m within the pond shore (in horizontal, see Methods section), and with 5–20 % of vegetation cover within the bird's viewpoint (table 1). Most of the used perches (78.58 %) were natural elements (tree branches), and only 21.42 % were artificial. The relative frequency of use of artificial perches was similar for the three species (χ^2–test = 2.015, p = 0.365). In addition, perches used by the three species were at similar distances to water (Kruskal–Wallis' test, χ^2 = 0.307, p = 0.858) and were covered by a similar amount of vegetation (Kruskal–Wallis' test, χ^2 = 1.936, p = 0.380). However, in the height of perches used by the three species differed (Kruskal–Wallis' test, χ^2 = 7.827, p = 0.020). Pairwise post–hoc comparisons revealed significant differences in perches used by *M. torquata,* these being taller than those used by *C. americana* (p = 0.02). While the other two species used a broader range of perch heights, *C. americana* always used perches below 5 m (fig. 3). For the multivariate approach (FAMD), we retained two dimensions that explained 49.41 % of the variance in perch use of Pantanal kingfishers (fig. 1s in supplementary material). The first axis explained 29.15 % of the variance and was mainly

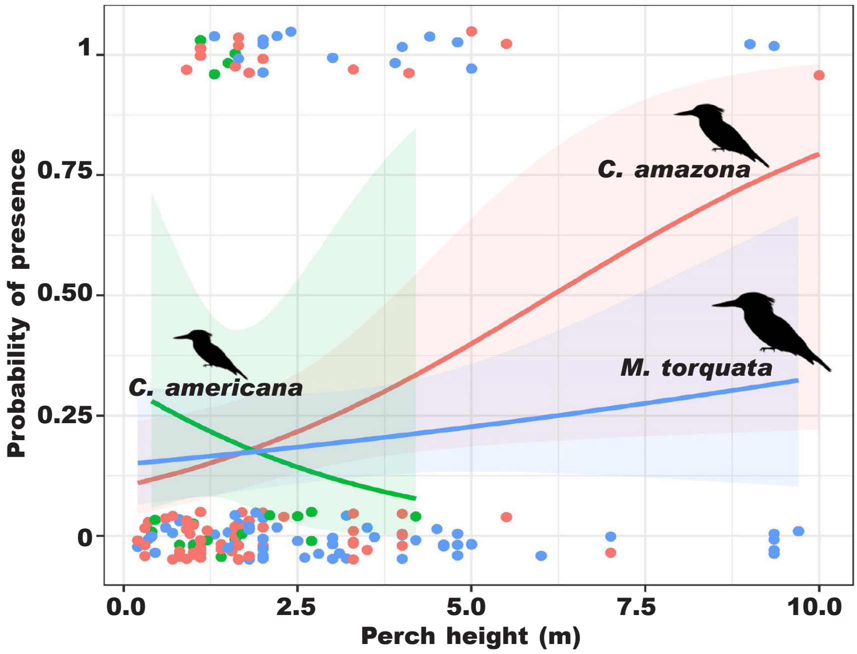

Fig. 3. Probability of presence depending on perch height for the three studied species (*Megaceryle torquata* in blue, *Chloroceryle amazona* in red, and *C. americana* in green), estimated by a logistic regression model (lines and semitransparent bands, depicting the SE; points represent the observed individual values). The influence of perch height on the presence of birds was only significant for *Chloroceryle amazona* (see more details in the text).

*Fig. 3. Probabilidad de presencia de cada una de las tres especies estudiadas (*Megaceryle torquata *en azul,* Chloroceryle amazona *en rojo y* C. americana *en verde) dependiendo de la altura del posadero, estimada a partir de un modelo de regresión logística (las líneas y bandas translúcidas representan los errores estándar y los puntos representan las observaciones individuales). La influencia de la altura del posadero en la presencia de las aves fue significativa solamente para* Chloroceryle amazona *(véase información más detallada al respecto en el texto).*

related to perch type (natural vs. artificial), and the second explained 20.26 % of the variance and was mainly related to bird species and vegetation cover (see fig. 2s and 3s in supplementary material). There was no overlap between *C. americana* and the other two species, and only minimal overlap between the other two species (fig. 2).

Selection on CLR models indicated one clear best model, the 'height by species' model, with AIC weights 0.92 (table 2). The other five models did not fit the inclusion criteria to be selected ($\Delta AIC_c < 2$ and Akaike weight > 0.95; see table 2). Thus, the kingfishers studied did not select or avoid perches depending on their type (natural or artificial; fig. 4s in supplementary material), distance to water or vegetation cover. Results from the selected CLR (fig. 6s in supplementary material) revealed that *C. amazona* selected taller perches than those available in the habitat (table 3), while *M. torquata* and *C. amazona* did not select or avoid perches depending on their height (tables 2, 3). The probability of using a perch by *C. amazona* increased considerably when the perch was above 3.2 m in height (fig. 5s in supplementary material).

Discussion

To our knowledge, this is the first study on perch selection of kingfishers. By using a resource selection function approach, assessing the traits of used perches in comparison with the available perches for each bird within a close temporal and spatial scale, we were able to determine the perch selection process beyond describing species' perch use. From our four hypotheses (fig. 1), we found support only for hypothesis 2, about different species selecting different perch heights (probably to reduce intraspecific competition). None of the three kingfisher species showed preference for artificial perches, distance to the water, or vegetation cover.

Contrary to our expectations, kingfishers from the Pantanal showed no selection preference for artificial or natural perches. The three studied species, *M. torquata*, *C. amazona,* and *C. americana*, used both artificial perches (bridges and power lines) and natural perches (tree branches) in the same relative proportion as that available in their habitat. This result suggests that artificial structures (at least at this isolated natural reserve) are not altering the behavior

Table 2. Perch selection of the three studied kingfisher species inhabiting the Pantanal of Brazil. Results of the model selection analysis of the six competing conditional logistic regression models proposed to test the different study hypotheses. Bird presence (1, presence; 0, absence) is the response variable in all models and all of them are conditioned by the individual ID.

Tabla 2. Selección de posaderos en las tres especies de martín pescador estudiadas en el Pantanal de Brasil. Resultados del análisis de selección de los seis modelos de regresión condicional logística propuestos para confirmar o rechazar las diferentes hipótesis de estudio. La presencia de aves (1, presencia; 0, ausencia) es la variable de respuesta en todos los modelos y todos ellos están condicionados por el ID del individuo.

Model	Predictors	AIC	ΔAIC	AIC Wt	Cum. Wt	LL
Species	Height + height × species	93.15	0.00	0.92	0.92	–43.57
Height	Height	99.29	6.15	0.04	0.97	–48.65
Water	Height + distance to water	101.18	8.03	0.02	0.98	–48.59
Null	Artificial + height + distance to water + cover	101.32	8.17	0.02	1.00	–46.66
Antipredator	Cover	106.47	13.32	0.00	1.00	–52.23
Perch type	Artificial	107.02	13.87	0.00	1.00	–52.51

of these fish–eating birds. Like kingfishers, raptors also use perches for hunting, feeding, and resting (Reinert, 1984). Perching reduces the energy required for hunting, feeding, and resting compared to flying and hovering (Collopy and Koplin, 1983). The fact that our kingfishers did not select or avoid perches regarding their type (artificial or natural) suggests that their energetic balance of costs and benefits would be similar. Moreover, artificial perches add to the natural perches available for kingfishers, increasing the available places to hunt or rest, and could even lead birds to reach some places that would be inaccessible otherwise. Other birds have been found to use artificial perches to save energy in their feeding behavior (Sheffield et al., 2001). There are also cases when the introduction of artificial structures modifies the behavior of birds, as with the introduction of artificial lights (Aubrecht et al., 2010; Kempenaers et al., 2010), or noisy elements (Polak, 2014). We think that the fact that the studied kingfishers did not select or avoid perches regarding their type (natural vs artificial) may reflect that both perch types offer similar access to food, minimizing the energy necessary for fishing (Resende, 2008). Furthermore, as the region is rather isolated and well–preserved (Junk et al., 2006), we consider the few artificial structures represent only a low level of alteration or disturbance in the ecology of kingfishers.

The literature reports *M. torquata* perching at variable or high perch height, *C. amazona* at low height and exposed perches and *C. americana* always at low perches (Remsen, 1991; Gwynne et al., 2010; Bitterman, 2012; Chodacki and Skipper, 2019). Our results show that only *C. amazona* selects for height, perching at highest sites available. For two species of kingfishers studied in Japan, differences in perching height, stream flow rate, and prey sizes were found (Kasahara and Katoh, 2008). Niche partition and a positive correlation between large body size of kingfishers with higher perches has been found in many studies (Willard, 1985; Bonnington et al., 2008; Kasahara and Katoh, 2008; Chodacki and Skipper, 2019). In our study, however, the mid–size kingfisher species (*C. amazona*) selected perches that were higher than those chosen by the largest kingfisher species (*M. torquata*). Individuals of *C. amazona* selected higher perches, while birds of the other two species did not appear to select or avoid perches based on height. Our results on perch selection do not therefore support a correlation with species' body size. Because of its concentration and abundance of wildlife, the Pantanal provides kingfishers with a diversity and abundance of prey, especially fish (Swarts, 2000; Novakowski et al., 2008; Resende, 2008). Despite this, *C. amazona* and *M. torquata* have similar diets and choose fish of similar size (Willard, 1985). Thus, it is possible that perch height segregation may relax competition between these two species. This would be the case, at least, during the dry season when our study took place. Of course, perch selection of kingfishers may change in the rainy season, when ponds are larger and deeper, and fewer prey are available. Future studies should evaluate the degree of kingfishers' perch fidelity or shift between seasons and how flooding dynamics may drive their habitat selection.

The thirteen small isolated ponds in our study are similar in depth, stream flow, turbidity, and width. Sampling was conducted in the dry season, when ponds are shallow and stream flow is low, forming rounded little ponds close to wooden bridges of the path. At these ponds, both predation risk and food availability would be similarly high for the available perches during the dry season (Holbrook and Schmitt, 1988). A perch without vegetation cover and close to the water may enhance fishing success,

Table 3. Perch selection of the three kingfisher species studied at the Pantanal of Brazil. Results from the model that best explains habitat selection of *Megaceryle torquata*, *Chloroceryle amazona* and *C. americana*, a conditional logistic regression model of bird presence explained by the perch height and the interaction between perch height and kingfisher species, and conditioned by the individual ID. The reference category for the species was *C. amazona*. (Likelihood ratio test: 19.08, df: 3, p: 0.0003; Wald test: 6.15, df: 3, p: 0.1).

Table 3. Selección de posaderos en las tres especies de martín pescador estudiadas en el Pantanal de Brasil. Resultados del modelo que mejor explica la selección de hábitat de Megaceryle torquata*,* Chloroceryle amazona *y* C. americana*, un modelo de regresión logística condicional de presencia de aves explicado por la altura del posadero y la interacción entre la altura del posadero y la especie de martín pescador, y condicionado por el ID del individuo. La categoría de referencia para las especies fue* C. amazona*. (Prueba de razón de verosimilitud: 19,08; df: 3; p: 0,0003; prueba de Wald: 6,15; df: 3; p: 0,1).*

Model parameter	Coefficient	95% CI	Odds ratio	SE	Z	*p*–value
Height	3.29	1.19–642.83	26.81	1.62	2.03	0.043
Height × species (*C. americana*)	–3.96	0.00–0.78	0.02	1.89	–2.09	0.036
Height × species (*M. torquata*)	–3.01	0–00–1.22	0.05	1.64	–1.84	0.066

while increasing predation risk. On the contrary, using a perch hidden among leaves may reduce predation risk but lower fishing success. In an environment of high availability of fishes and high predation risk such as that at the Pantanal, we would expect kingfishers to select perches with high vegetation cover. Our results, on the contrary, showed that only perch height, and not its vegetation cover or distance to the water, were selected. Further research quantifying prey availability and predation pressure could clarify why these birds neither select nor avoid perches based on vegetation cover and distance to the water, at least in the dry season.

We conclude that Pantanal kingfishers did not select or avoid perches regarding artificial/natural origin, distance to water, height above ground and vegetation cover. The exception was *C. amazona*, which selected higher perches, probably to avoid interspecific competition with *M. torquata*. The high quantity of food available and the similarity in predation risk, also high at the Pantanal, may result in similar quality (balance of costs and benefits) of the available perches for kingfishers. We think the isolation and good preservation of the Pantanal (with few artificial structures and still high numbers of quality natural perches available) may have prevented artificial structures, such as power lines, from modifying perch selection for the moment. However, bushfires are increasing dramatically in the area, fueled by climate change, and it is predicted they will worsen in future years if policies and land use remain the same. More than 14,000 km^2 of native vegetation are already predicted to be lost in the area by 2050 (Guerra et al., 2020). We consider that *C. amazona*, which selects for higher perches, could be particularly affected by the loss of native vegetation related to bushfires. We recommend using habitat selection to estimate the vulnerability of species and to prioritize conservation areas.

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Supplementary material

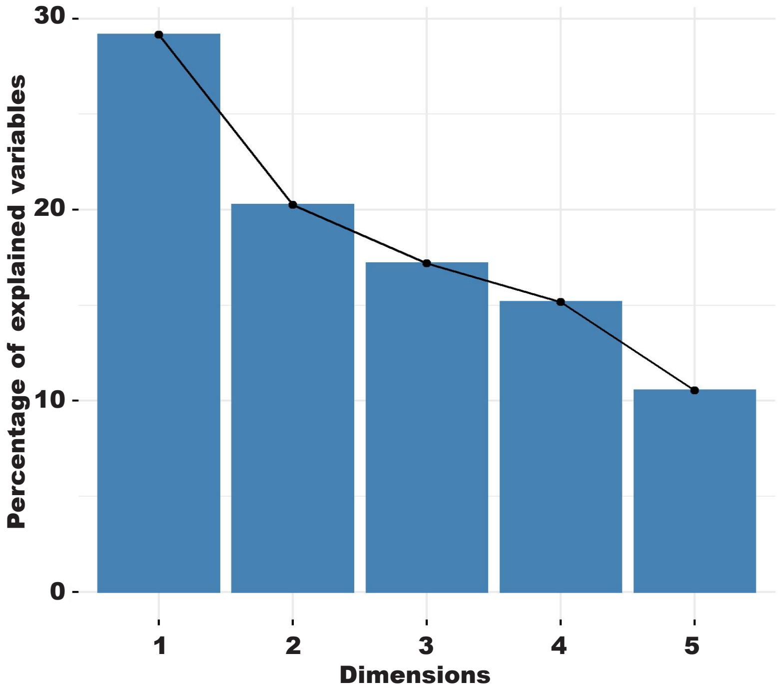

Fig. 1s. Scree plot for the multivariate exploration of perch use (Factor Analysis of Mixed Data) for the three species of kingfishers (*Megaceryle torquata*, *Chlroroceryle amazona*, and *C. americana*) studied at the Pantanal of Mato Grosso do Sul (Brazil). We retained two dimensions, that explained 49.41 % of the variance in perch use of the three species of Pantanal kingfishers regarding the four studied variables: 1, perch nature (artificial vs natural); 2, perch height (m); 3, distance to the water (m); and 4, perch vegetation cover (%).

*Fig. 1s. Gráfico de sedimentación para el estudio multivariado del uso de posaderos (análisis factorial de datos mixtos) en las tres especies de martín pescador (*Megaceryle torquata, Chlroroceryle amazona *y* C. americana*) estudiadas en el Pantanal de Mato Grosso del Sur (Brasil). Consideramos dos dimensiones que explicaban el 49,41 % de la varianza en el uso de posaderos de las tres especies de martín pescador del Pantanal en relación con las cuatro variables estudiadas: 1, tipo de posadero (artificial o natural); 2, altura del posadero (m); 3, distancia al agua (m); 4, cubierta vegetal del posadero (%).*

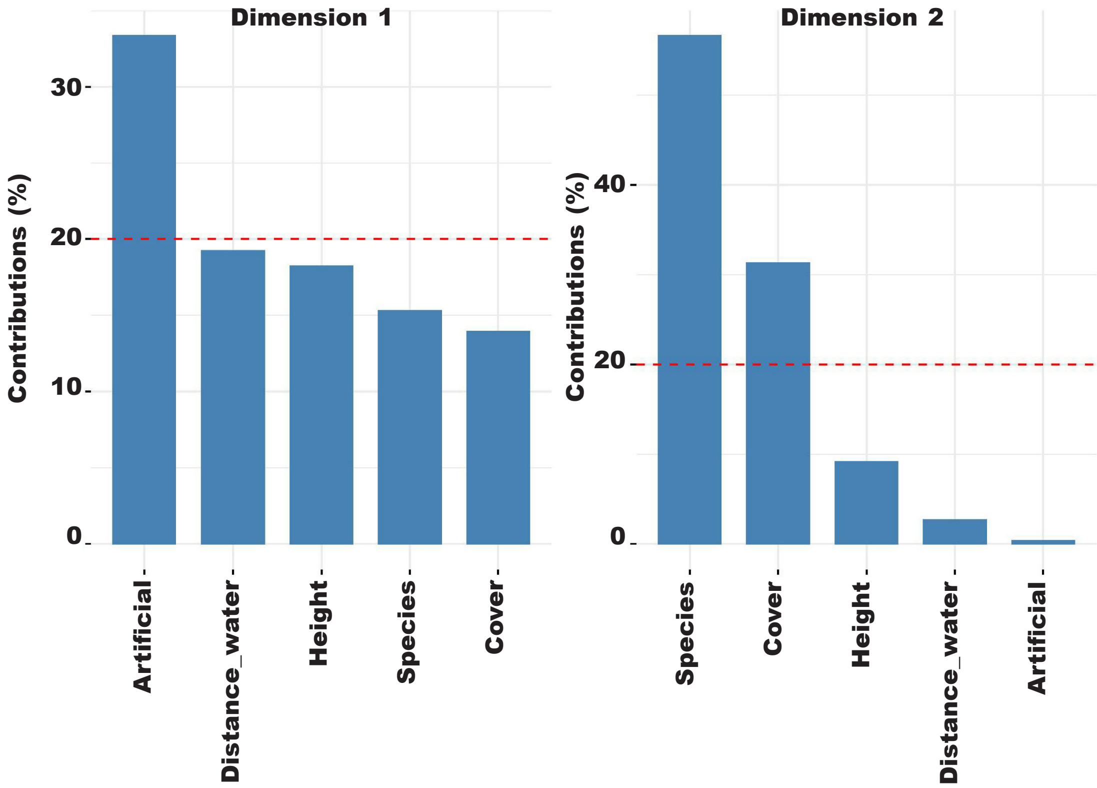

Fig. 2s. Contributions of the original variables to the two main dimensions retained by the multivariate exploration of perch use (Factor Analysis of Mixed Data) for the three species of kingfishers (*Megaceryle torquata*, *Chlroroceryle amazona*, and *C. americana*) studied at the Pantanal of Mato Grosso do Sul (Brazil). Thus, dimension 1 mainly relates to the origin of the perch (being natural vs artificial) and dimension 2 mainly relates to bird species and vegetation cover.

*Fig. 2s. Contribuciones de las variables originales a las dos principales dimensiones consideradas en el estudio multivariado del uso de posaderos (análisis factorial de datos mixtos) en las tres especies de martín pescador (*Megaceryle torquata*, *Chlroroceryle amazona* y *C. americana*) estudiadas en el Pantanal de Mato Grosso del Sur (Brasil). Así, la dimensión 1 está principalmente relacionada con el origen del posadero (natural o artificial) y la dimensión 2, con la especie de ave y la cubierta vegetal.*

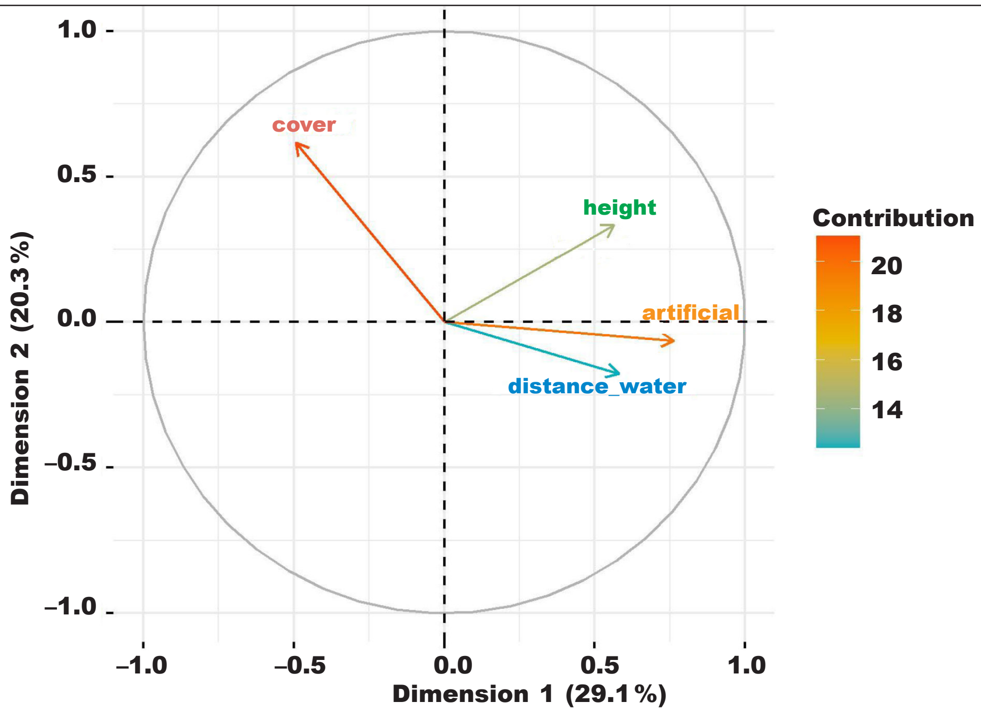

Fig. 3s. Contributions of the original variables to the two main dimensions retained by the the multivariate exploration of perch use (Factor Analysis of Mixed Data) for the three species of kingfishers (*Megaceryle torquata*, *Chlroroceryle amazona*, and *C. americana*) studied at the Pantanal of Mato Grosso do Sul (Brazil). This plot illustrates the interpretation of the two dimensions: higher values in dimension 1 mean taller perches that are more probable to be artificial and show lower vegetation cover; higher values at dimension 2 mean a higher vegetation cover.

*Fig. 3s. Contribuciones de las variables originales a las dos principales dimensiones consideradas en el estudio multivariado del uso de posaderos (análisis factorial de datos mixtos) en las tres especies de martín pescador (*Megaceryle torquata*, *Chlroroceryle amazona *y* C. americana*) estudiadas en el Pantanal de Mato Grosso del Sur (Brasil). Este gráfico ilustra la interpretación de las dos dimensiones: los valores más altos en la dimensión 1 representan posaderos más altos que es más probable que sean artificiales y presenten una cobertura vegetal menor; los valores más altos en la dimensión 2 indican mayor cobertura vegetal.*

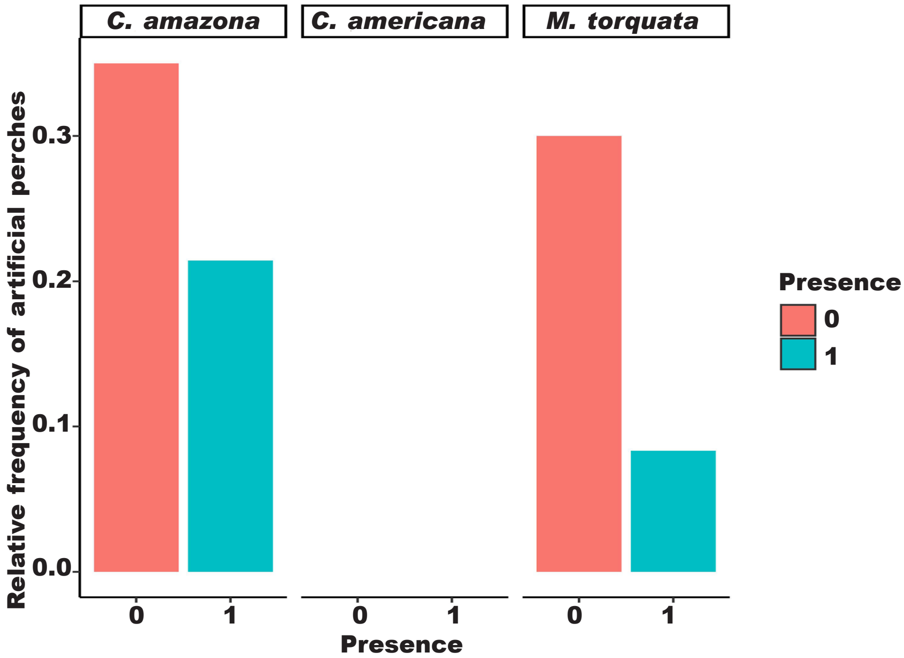

Fig. 4s. Use and availability of artificial perches for the three species of kingfishers (*Megaceryle torquata*, *Chlroroceryle amazona*, and *C. americana*) studied at the Pantanal of Mato Grosso do Sul (Brazil). The relative frequency of artificial perches (divided by sample size) is plotted for used perches (presence = 1; cyan) and available perches (presence = 0; red).

*Fig. 4s. Uso y disponibilidad de los posaderos artificiales en las tres especies de martín pescador (*Megaceryle torquata*, *Chlroroceryle amazona *y* C. americana*) estudiadas en el Pantanal de Mato Grosso del Sur (Brasil). Se representa la frecuencia relativa de los posaderos artificiales (dividida por el tamaño de la muestra) utilizados (presencia = 1; azul) y disponibles (presencia = 0, rojo).*

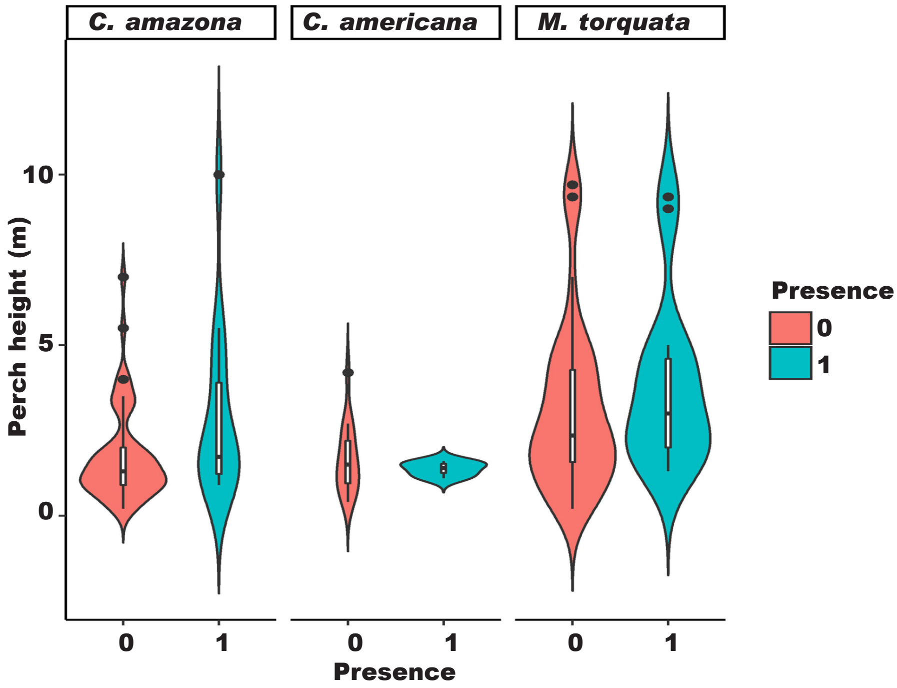

Fig. 5s. Height of used and available perches for the three species of kingfishers (*Megaceryle torquata*, *Chlroroceryle amazona*, and *C. americana*) studied at the Pantanal of Mato Grosso do Sul (Brazil). The height (in m) is plotted for used perches (presence = 1; cyan) and available perches (presence = 0; red).

*Fig. 5s. Altura de los posaderos utilizados y disponibles para las tres especies de martín pescador (*Megaceryle torquata, Chlroroceryle amazona *y* C. americana*) estudiadas en el Pantanal de Mato Grosso del Sur (Brasil). Se representa la altura (en m) de los posaderos utilizados (presencia = 1; azul) y los disponibles (presencia = 0, rojo).*

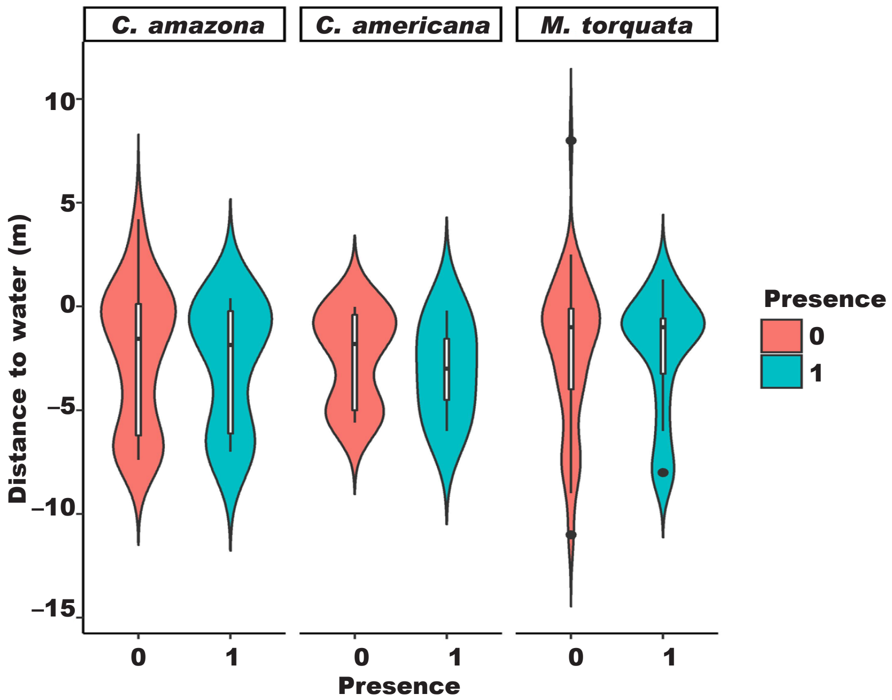

Fig. 6s. Distance to water shore of used and available perches for the three species of kingfishers (*Megaceryle torquata*, *Chlroroceryle amazona*, and *C. americana*) studied at the Pantanal of Mato Grosso do Sul (Brazil). Distance to the water was measured as the horizontal distance to the pond shore, considered zero if the perch was exactly at the shore, negative if it was within the pond border and positive if it was outside the pond border. The distance to water shore (in m) is plotted for used perches (presence = 1; cyan) and available perches (presence = 0; red).

*Fig. 6s. Distancia a la orilla de los posaderos utilizados y disponibles para las tres especies de martín pescador (*Megaceryle torquata*,* Chlroroceryle amazona *y* C. americana*) estudiadas en el Pantanal de Mato Grosso del Sur (Brasil). La distancia al agua se midió como la distancia horizontal a la orilla del estanque; se consideró nula si el posadero se encontraba exactamente en la orilla, negativa si estaba dentro del estanque y positiva si estaba fuera. Se representa la distancia a la orilla (en m) de los posaderos utilizados (presencia = 1; azul) y los disponibles (presencia = 0, rojo).*

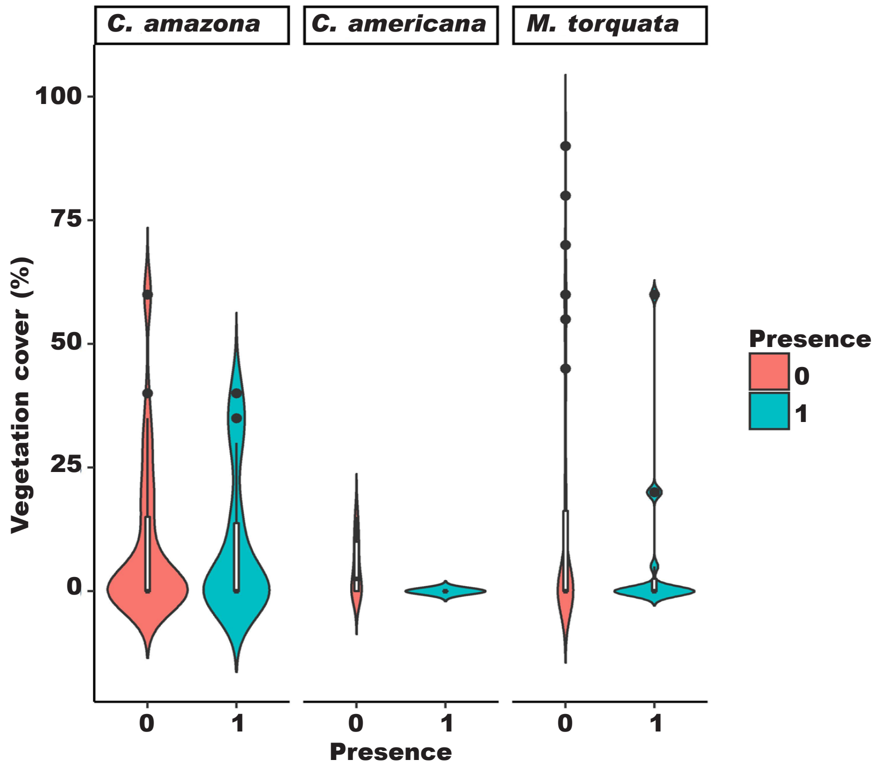

Fig. 7s. Vegetation cover of used and available perches for the three species of kingfishers (*Megaceryle torquata*, *Chlroroceryle amazona*, and *C. americana*) studied at the Pantanal of Mato Grosso do Sul (Brazil). The percentage of vegetation cover is plotted for used perches (presence = 1; cyan) and available perches (presence = 0; red).

*Fig. 7s. Cobertura vegetal de los posaderos utilizados y disponibles para las tres especies de martín pescador (*Megaceryle torquata*, *Chlroroceryle amazona* y *C. americana*) estudiadas en el Pantanal de Mato Grosso del Sur (Brasil). Se representa el porcentaje de cobertura vegetal de los posaderos utilizados (presencia = 1; azul) y los disponibles (presencia = 0, rojo).*