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Conservation status of the threatened and endemic Rufous-throated Dipper *Cinclus schulzi* in Argentina

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Summary

The Rufous-throated Dipper *Cinclus schulzi* is endemic to the Southern Yungas of north-western Argentina and southern Bolivia. The species is categorised as 'Vulnerable' on the IUCN Red List on the basis of small population size and restricted range. The purpose of our study was to determine the distribution of potentially suitable habitat for the Rufous-throated Dipper, estimate its population size, and assess potential distribution within strict protected areas, in north-western Argentina. We surveyed 44 rivers in the Southern Yungas of Argentina from 2010 to 2013 to determine dipper density (i.e. the number of individuals detected per km surveyed). The dipper's potential distribution was assessed using a maximum entropy modeling approach based on 31 occurrence points and eight bioclimatic and two topographic variables as predictors. The species is dependent on mountain forest rivers, so the potential distribution was restricted to rivers. We estimated dipper population size by multiplying density by the potential distribution along rivers. Finally, we calculated the extent of suitable habitat contained within the boundaries of Argentina´s National Parks. Dipper density was 0.94 ± 1.55 individuals/km. We estimate that within north-west Argentina there are ~2,815 km of river that are potential habitat, with an area of occupancy of 141 km^2 and a population size of 2,657 ± 4,355 dippers. However, of this river extent, less than 5% is within National Parks. Our results highlight the need to create new and to enlarge existing National Parks that protect the potentially suitable habitat of the species. Although more information is needed for Bolivia, the country-level area of occupancy and population size of the dipper found in Argentina provides strong evidence that the IUCN Red List classification of this species as 'Vulnerable' is warranted.

Keywords: Freshwater, IUCN, Protected Areas, Southern Yungas, Vulnerable

Introduction

Freshwater species and habitats are among the most threatened in the world as demand for water in irrigation, industrial, and domestic use continues to increase worldwide (Strayer and Dugeon 2010, Reid *et al.* 2019). Species dependent on freshwater habitats thus often have substantially higher extinction risk than terrestrial animals (Strayer and Dugeon 2010, Darwall *et al.* 2011). Creating protected areas that encompasses intact, whole-water catchment management can be an effective conservation strategy (Saunders *et al.* 2002). Unfortunately, freshwater habitats have commonly been protected only incidentally as part of their inclusion within terrestrial reserves (Saunders *et al.* 2002). Little is known about the representation of threatened freshwater species in protected areas nor the role of these protected areas to ensure the long-term persistence of species that depend on freshwater (Saunders *et al.* 2002).

The estimated areal extent of a species' distribution constitutes the core of most assessments of species global conservation status (IUCN 2014, Syfert *et al.* 2014). Reliable assessments of rare species' habitat area are difficult given that they are by definition uncommon, and often difficult to detect (Thompson 2004, Lomba *et al.* 2010). Until recently, tremendous field effort and financial support was needed to obtain key information for determining rare species' conservation status, often involving long-term studies (Thompson 2004). The development of species distribution modelling approaches reliant only on species presence data, such as maximum entropy (MAXENT; Phillips *et al.* 2006), has created new opportunities, because potential habitat can be identified even with low numbers of occurrences (Guisan *et al.* 2006, Pearson *et al.* 2007). Model predictions developed using small sample sizes can be informative concerning the location of potentially suitable habitat, which is an important criterion in creating protected areas, particularly for rare and threatened species (Pearson *et al.* 2007).

The Rufous-throated Dipper *Cinclus schulzi* is a threatened bird species categorised as 'Vulnerable' on the IUCN Red List on the basis of its small population size and restricted range (BirdLife International 2019). The population size of the species has been inferred by expert opinion based on non-systematic surveys to be 3,000–4,000 individuals of which an estimated 2,000–2,700 were thought to be mature individuals (Tyler and Ormerod 1994, Tyler and Tyler 1996, BirdLife International 2019). For Bolivia, estimates vary from 1,000 to 2,000 individuals, while in Argentina, the population size has been estimated to be no more than 2,000 individuals (Tyler 1994, Tyler and Tyler 1996, BirdLife International 2019). The Rufous-throated Dipper is endemic to the Southern Yungas of north-western Argentina and southern Bolivia, with an estimated extent of occurrence of 147,000 km^2 (BirdLife International 2019). However, the species is highly specialised in its habitat requirements, and occurs only in association with well-oxygenated, unpolluted running waters of mountain rivers (Tyler and Tyler 1996). Rufous-throated Dippers nest in narrow watercourses that have vertical rock formations (Sardina Aragón *et al.* 2015) and breeding pairs maintain year-round territories (Sardina Aragón 2016). This species' ecology is among the least known of the five dipper species of the family Cinclidae (Tyler and Ormerod 1994). Information about its distribution is vague, and information about its abundance is speculative, which hinders conservation and management efforts (Buckland *et al.* 2008).

The purpose of our study was first, to map potentially suitable habitat of Rufous-throated Dipper in north-western Argentina; second, to estimate population size based on the potentially suitable habitat, and third, to assess the potentially suitable habitat within strict protected areas in Argentina. Together, these three elements constitute critical information for directing conservation actions for this poorly known, endemic and 'Vulnerable' species.

Methods

The Southern Yungas are mountain forests located on the eastern slopes of the Andes from southern Bolivia (14°S latitude) to north-western Argentina (29°S latitude; Figure 1) with an elevational gradient that varies between 400 and 3,000 m asl (Cabrera and Willink 1980). The Southern Yungas is a biodiversity hotspot as well as a distinct biogeographic unit that harbours

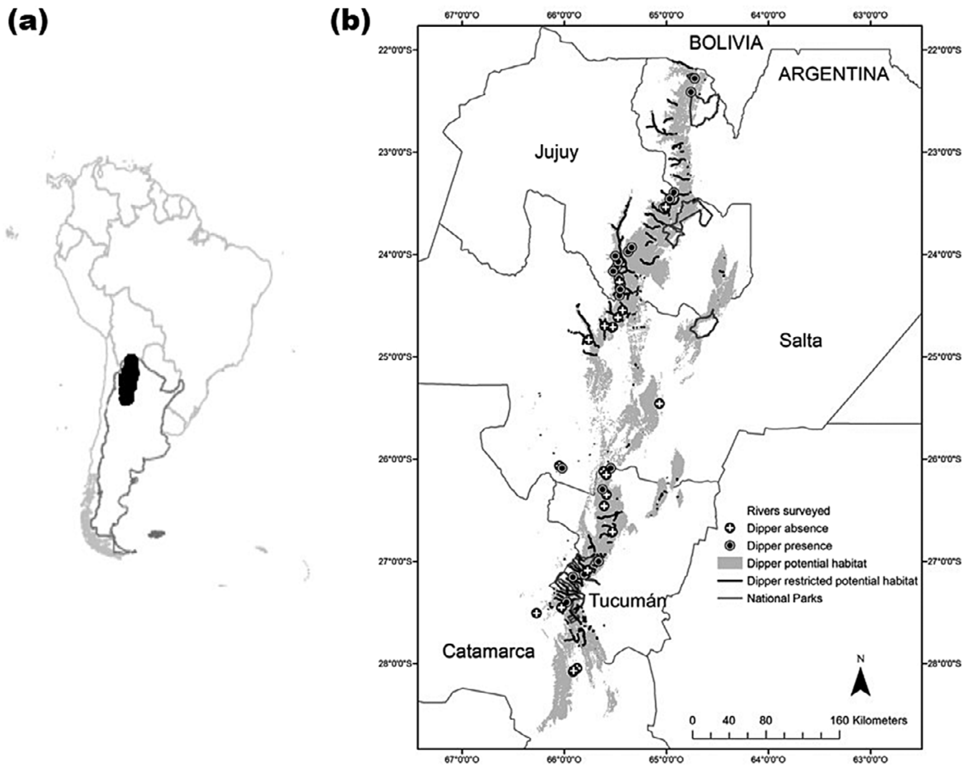

Figure 1. Distribution of Southern Yungas in north-western Argentina (a), rivers surveyed (showing presence or absence of *Cinclus schulzi*) and MAXENT species distribution using the > 10th percentile presence threshold probability value of potential habitat of *Cinclus schulzi* in permanent rivers (b).

numerous endemic species (Myers *et al.* 2000). In Argentina, the Southern Yungas has an extent of 32,000 km^2, is one of the most threatened forest ecoregions of the country and is where most of the rivers of north-western Argentina originate (Politi and Rivera 2019).

We surveyed 44 rivers in the Southern Yungas of Argentina to record presence of the Rufous-throated Dipper (Table 1). Rivers studied encompassed the latitudinal gradient. Rivers selected for surveys had access from near-by roads. At each river we walked upstream transects of variable length depending on the accessibility of the river (Table 1). Surveys were conducted during the Rufous-throated Dipper non-breeding season (April to September) from 2010 to 2013. We surveyed during the non-breeding season because that it is the period when all rivers are accessible. In most rivers during the rainy season, from October to March, water levels rise and have intense flows. For each Rufous-throated Dipper sighting, we recorded the coordinates (using a global positioning system unit, GPS) and the number of individuals. We only included dippers flying upstream to avoid double counting (Osborn 1999). We determined Rufous-throated Dipper density as the number of dippers detected per km surveyed (mean ± SE). For each river, we recorded the following habitat variables at the beginning and end of each transect: 1) elevation (m asl) (determined with a GPS); 2) river width (m) (determined by measuring the distance between shores with a metric tape); 3) water depth (cm) (measured at five points along the river width using a graduated stick of 180 cm); 4) water flow (cm/sec) (determined by the time it took a Styrofoam sphere to travel downstream 10 m in the river); 5) rock cover (%) (visually estimated as

Table 1. Rivers and transect surveyed to record *Cinclus schulzi* presence in north-western Argentina.

River	Province	Latitude (S)	Longitude (W)	River lenght (km)	Transect length (km)	Dipper
Trancas	Catamarca	−28.08177	−65.91150	8.54	1.52	Present
Ambato	Catamarca	−28.04683	−65.87410	11.53	2.96	Absent
Erviti	Catamarca	−28.07123	−65.90845	7.74	2.61	Absent
Andagala	Catamarca	−27.50810	−66.26988	5.73	2.56	Absent
Potrero	Catamarca	−27.40025	−65.97650	9.70	2.45	Present
Pisavil	Catamarca	−27.45335	−66.02683	9.55	2.96	Absent
Yala	Jujuy	−24.12650	−65.48922	9.02	6.02	Present
Las Horquetas	Jujuy	−24.12261	−65.48710	5.16	4.00	Present
Morado	Jujuy	−24.32385	−65.45548	6.57	4.50	Present
Reyes	Jujuy	−24.16408	−65.52037	9.26	5.00	Present
Lozano	Jujuy	−24.07212	−65.47165	8.01	5.86	Present
León	Jujuy	−24.01605	−65.49850	8.38	6.29	Present
La Quesera	Jujuy	−24.23412	−65.46223	7.25	2.74	Present
La Caldera	Salta	−24.54655	−65.42738	8.88	2.08	Absent
Tiraxi	Jujuy	−23.97343	−65.37242	8.37	6.88	Present
Tesorero	Jujuy	−23.93215	−65.33890	10.83	5.01	Present
Yacón	Salta	−24.61650	−65.47408	9.25	4.89	Absent
San Lorenzo	Salta	−24.70985	−65.52415	8.28	2.69	Absent
El Alisal	Salta	−24.83605	−65.75853	10.59	3.33	Absent
Quebrada Grande	Salta	−24.69817	−65.60510	9.34	5.47	Absent
Morro Bola	Jujuy	−24.40260	−65.46097	9.23	2.88	Present
Noques	Jujuy	−23.54408	−65.02500	9.74	1.46	Present
Las Cañas	Jujuy	−23.53561	−65.00483	7.82	3.00	Absent
Valle Colorado	Jujuy	−23.39553	−64.92581	8.41	2.80	Present
Valle Grande	Jujuy	−23.45750	−64.96603	12.49	2.81	Present
Los Paños	Jujuy	−24.29526	−65.44559	9.97	5.86	Absent
La Almona	Jujuy	−24.27293	−65.457414	14.28	6.09	Absent
Cerro Negro	Jujuy	−24.34264	−65.45111	9.35	2.52	Present
Balderrama	Salta	−25.45962	−65.06753	10.78	3.08	Absent
Chorclalos	Salta	−26.06792	−66.04760	10.04	2.01	Absent
Colorado	Salta	−26.08962	−66.01953	14.13	2.09	Present
Lipeo	Salta	−24.34264	−65.45111	11.17	3.50	Present
Huaico Grande	Salta	−22.28136	−64.72186	19.92	2.01	Present
Tacanas	Tucumán	−26.29782	−65.62445	11.98	2.63	Present
Rearte	Tucumán	−26.35145	−65.58675	7.50	2.67	Absent
Potrero	Tucumán	−26.46103	−65.60832	10.36	2.55	Absent
Garabatal	Tucumán	−26.71455	−65.52648	6.36	2.99	Absent
Sosa	Tucumán	−27.00083	−65.66347	10.27	1.91	Present
Los Reales	Tucumán	−27.09105	−65.77110	8.68	2.78	Absent
De La Horqueta	Tucumán	−27.12835	−65.80252	7.10	2.61	Present
Del Anta	Tucumán	−26.08932	−65.54407	7.80	3.10	Present
Cochuna	Tucumán	−27.15548	−65.91438	11.86	1.62	Present
Chavarría	Tucumán	−26.15629	−65.58810	9.56	2.82	Absent
De Las Cañas	Tucumán	−26.12300	−65.61300	7.30	2.38	Absent

the percentage of a 2 x 2 m plot covered with emergent rocks); and 6) slope (%) (measured with a clinometer). We compared river characteristics between reaches with and without Rufous-throated Dipper presence using Kolmogorov-Smirnov tests (Quinn and Keough 2002).

We assessed the potential distribution of Rufous-throated Dipper using maximum entropy modeling of species geographic distributions (MAXENT; Phillips *et al.* 2006). To minimise sample bias, we included records along the latitudinal range surveyed, but only included records of Rufous-throated Dipper that were at least 2 km apart, so the map was based on the occurrence of 31 Rufous-throated Dipper records from data collected. This number of records is sufficient for MAXENT modelling (Guisan *et al.* 2006, Pearson *et al.* 2007, Wisz *et al.* 2008). As predictors, we used eight 1-km resolution bioclimatic variables that have proved useful for mapping species distributions in this region (Pidgeon *et al.* 2015; Martinuzzi *et al.* 2018), including: annual precipitation (BIO12), annual mean temperature (BIO1), seasonality of precipitation (BIO15) and temperature (BIO4), extreme data for precipitation of wettest quarter (BIO16), precipitation of driest quarter (BIO17), maximum temperature of warmest month (BIO5) and minimum temperature of coldest month (BIO6); representing conditions of the years 1950 to 2000 (Hijmans *et al.* 2005). We also included two topographic variables: elevation (DEM2) and slope (DEM3), since the species occurs in a mountainous region. We generated 10,000 pseudo-absences as background data for model training in MAXENT and selected 100 km as the universe of pseudo-absence locations, because it produced the most accurate and biologically meaningful results after testing different buffer sizes (VanDerWal *et al.* 2009). To run MAXENT, we set all other options to default and assessed model performance with a 10-fold cross-validation and the area under the receiver operating curve (AUC) (Phillips 2017). We transformed predictions from MAXENT using the 10th percentile presence logistic threshold (i.e. we use that value as the threshold probability) into a binary map of suitable versus unsuitable habitat to create a map of the species' potential distribution (McFarland *et al.* 2013). Given that the Rufous-throated Dipper is restricted to fast-flowing, rocky mountain, forested rivers (Ormerod and Tyler 2005), we refined the species distribution map by including only pixels that overlapped with rivers. We used the river layer available from the governmental Geographic Information System datasets including rivers classified as permanent (i.e. watercourse that have year-long water) (IGN 2014).

We estimated the Rufous-throated Dipper population size by multiplying the number of individuals detected per km surveyed by the extent of the species' restricted potential distribution. We estimated the area of occupancy by considering a watercourse width of 50 m (Sardina Aragón *et al.* 2015) multiplied by the extent of the species restricted potential distribution. We could have been more restrictive in estimating the area of occupancy if we had only included river width (i.e. 4–8 m), but that would represent only the foraging habitat and we would have not incorporated the breeding habitat. Nests are located in watercourse cliffs that may up to 20 m from the water (Sardina Aragón *et al.* 2015).

Finally, we estimated the extent of potential habitat of the Rufous-throated Dipper inside National Parks, using shapefiles of protected areas under the National Park Administration (e.g. Calilegua, El Rey, El Nogalar, Baritú, and Aconquija) obtained from the Biodiversity Information System (https://sib.gob.ar/). We used protected areas of the National Park Administration because these areas have the highest protection level in the region, restrict most human economic activities, and are adequately enforced.

Results

In total we surveyed 148 km of river, apportioned as 3.36 ± 1.45 km/river; min 1.46 km, max 6.88 km (Table 1). We recorded 131 Rufous-throated Dippers in 24 of the 44 rivers surveyed. The density of Rufous-throated Dipper in the rivers surveyed was 0.94 ± 1.55 individuals/km. Rivers with Rufous-throated Dippers were significantly deeper and had more rock cover than rivers without Rufous-throated Dippers (Table 2).

The AUC value of the species distribution model was 0.94. Elevation (DEM2: 32% contribution) and extreme precipitation during the wettest quarter (BIO16: 22% contribution) were the two most important predictors of Rufous-throated Dipper habitat. The threshold probability value > 0.34 results in 2,815 km of potentially suitable habitat for Rufous-throated Dippers of rivers with year-round water (Figure 1), which corresponds to an estimate of 2,657 ± 4,355 individuals.

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Table 2. River characteristics in north-western Argentina with *Cinclus schulzi* presence and absence. Kolmogorov-Smirnov test statistic (KS) and resulting *P*-value are shown.

Variables	Presence	Absence	KS	*P*
Elevation (m)	1,627±258	1,452±359	1.94	0.07
River width (cm)	569±173	614±241	0.75	0.46
River depth (cm)	**34±8**	**28±7**	**2.46**	**0.02**
Water flow (cm/s)	13±8	15±5	1.01	0.32
Rock cover (%)	**23±10**	**14±7**	**3.61**	**0.01**
Slope (°)	7±6	5±4	1.26	0.21

Table 3. *Cinclus schulzi* potential suitable habitat within National Parks and on unprotected river catchments of north-western Argentina.

		Potential suitable habitat	
		km	%
National Park	Aconquija	196	3
	El Rey	22	<1
	Calilegua	63	1
	Baritú	4	<1
	El Nogalar	9	<1
Unprotected		5669	95

The suitable potential habitat in Argentina suggests an estimated area of occupancy of 141 km² for permanent rivers. Of the rivers with potential suitable habitat for Rufous-throated Dippers, less than 5% are within National Parks (Table 3).

Discussion

Rufous-throated Dipper extent of occurrence covers the entire latitudinal range along the Southern Yungas of Argentina. Our estimated area of occupancy in Argentina (141 km²) is considerably below the threshold established by IUCN's Red List criteria to classify a species as 'Vulnerable' (< 2,000 km²; BirdLife International 2019). However, our analysis of Rufous-throated Dipper population size in Argentina suggests that if potential habitat is occupied, the population size may well be larger (2,657 ± 4,355 Dippers) than previously suggested for Argentina based on expert opinion (< 2,000 individuals; Tyler and Ormerod 1994).

We are confident that we adequately detected Rufous-throated Dippers if they were present during our surveys. This is because the species is restricted to rivers, and in these discrete linear entities the dipper is easily detected, as it does not flush easily, and is highly territorial (Tyler and Ormerod 1994). However, we might have overpredicted the area of potential habitat with our distribution model based on bioclimatic and topographic variables, given that we found significant differences in river depth and rock cover in rivers with and without Rufous-throated Dipper. Quantification of these two variables requires field measurement, and it was not possible for us to assess these variables in all rivers. Therefore, it is highly likely that that not all the rivers mapped contain adequate suitable habitat for the species. Future studies should attempt to validate Rufous-throated Dipper presence on inaccessible rivers with suitable potential habitat. Furthermore, we surveyed 35% of the total river length (~140/418 km) of the 44 rivers we studied; a more rigorous approach would be to fully assess the extent of potential suitable habitat that each river harbours. Finally, a more refined model of the species' potential suitable habitat would include factors not assessed here, but that can influence habitat quality (Van Horne 1983, Thorn *et al.* 2009, Sousa-

Silva *et al.* 2014). For example, food availability and water quality have been shown to influence habitat quality in other dipper species (Ormerod *et al.* 1991, Ormerod and Tyler 1991, 1992), but this information is still lacking for Rufous-throated Dipper. Although nesting sites for Rufous-throated Dipper have been described (Sardina Aragón *et al.* 2015) there is no association of the availability of nesting sites with nesting success and habitat quality. Knowledge of the ecological requirements and potential factors limiting Rufous-throated Dipper population size should be addressed in future studies.

The potential suitable habitat map for the Rufous-throated Dipper that we developed indicates areas with suitable habitat in Argentina that we did not survey, making these areas priority localities for survey (e.g. south-western Salta Province and eastern Jujuy Province). In eastern Jujuy Province, the Santa Bárbara mountain range is isolated from the western mountain range, resulting in a discontinuous distribution of the Southern Yungas forest (Bellis *et al.* 2014). We speculate that the Rufous-throated Dipper has not been able to colonise this eastern mountain range and is probably absent, but future research is needed to confirm this. Furthermore, systematic surveys in Bolivia are needed to estimate the species' global population size and extent of occurrence, however some surveys of Bolivian localities have been carried out (Martínez *et al.* 2011, Flores Bedregal *et al.* 2015).

The non-breeding season is probably an adequate period to conduct dipper surveys. We obtained similar dipper density to previous results found in other studies (Tyler and Tyler 1996, Sardina Aragón *et al.* 2015). Based on previous knowledge of the species, breeding pairs are highly territorial year-round, therefore we assume that non-breeding season habitat probably adequately represents suitable potential habitat in the breeding season (Sardina Aragón 2016). However, it would be good to confirm this by resampling accessible rivers during the breeding season.

Another key finding from our study is that the Rufous-throated Dipper potential suitable habitat in Argentina is not adequately represented within existing National Parks (< 5% is protected). For some species or habitats, a 10% representation might be sufficient, but for species with very limited distribution range the proposed conservation target is up to 100% (Kukkala and Moilanen 2012, Pidgeon *et al.* 2015). Our results highlight the need to create new National Parks that protect the species' potential suitable habitat (i.e. south-west of Salta Province) and to enlarge existing protected areas to encompass entire river catchments (e.g. Calilegua and Baritú National Parks). In north-western Argentina, unprotected river catchments are threatened primarily by reservoir construction, hydroelectric and irrigation schemes, and eutrophication that modify and reduce water flow (Tyler and Tyler 1996). Conservation planning in the region has generally not been systematic, and our maps of suitable dipper habitat can guide discussions of where new protected areas can be created to contribute to the conservation of this vulnerable and endemic species (Margules and Pressey 2000). We are aware that protected areas may not be the only solution for all the challenges that freshwater rivers and its biodiversity face and that other conservation options may need to be employed. For example, BirdLife International´s Important Bird and Biodiversity Areas (IBAs) are a strategy to link policy and local engagement to bird conservation (Waliczky *et al.* 2019). However, at the global scale, IBAs inside protected areas are in better condition, with lower pressures, than those outside protected areas (Butchart *et al.* 2012). In order to have a successful conservation programme, protected areas are a central pillar, but other considerations should also be taken into account, such as economic, sociocultural, political, and enforcement components (Flores Bedregal *et al.* 2015, Waliczky *et al.* 2019).

Our study expanded the scientific knowledge of a little known, and endemic species in Argentina. Overall, our country-level analysis of occupancy and population size of the Rufous-throated Dipper suggests that the IUCN Red List classification of the Rufous-throated Dipper as 'Vulnerable' is warranted. We hope that our study will stimulate surveys in Bolivia to obtain a global assessment, and that it promotes new research in Argentina to fill in gaps in knowledge about this species (e.g. how well connected are populations among rivers). The underrepresentation of Rufous-throated Dipper potential habitat in strict protected areas, and its small population size, require that urgent efforts be taken to ensure the long-term conservation of this species.

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