



Similar regional-scale survival of tropical and southern temperate birds from the New World

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Abstract

The general assumption that the survival patterns of tropical and southern temperate birds are similar lacks empirical data from higher latitudes. Regional comparisons of New World species are rare, and this assumption has been based on data from African studies. Here, we estimate the survival rates of 88 tropical and southern temperate bird populations (69 species) from eight localities in South America to evaluate the hypothesis that the survival of these populations is homogeneous at the regional scale. We estimated survival based on the Cormack-Jolly-Seber model and compared values from different environments. The survival estimates ranged from 0.30 to 0.80 (0.56 ± 0.12). Apparent survival did not differ significantly between low-latitude tropical environments (03°S) and the other sites from high-latitudes (between 22° and 34°S). Despite a predicted positive trend, body size was not significantly related to survival among passerines. On the other hand, phylogenetic relationships explained more than a third of the variation in bird survival. Based on the largest available database on South American bird species, our findings support the hypothesis that bird survival is homogeneous, at the regional scale, along the southern hemisphere. In particular, we reinforce the hypothesis that climatic variation has a limited influence on bird survival in the southern hemisphere.

Keywords Latitudinal gradient · Life history · Mortality · Population dynamic · South America

Introduction

The understanding of bird life history strategies and their implications for population dynamics has advanced considerably since the development of pioneering hypotheses on the influence of feeding resource abundance on clutch size (Lack 1947) and the seasonal regulation of mortality in adults (Ashmole 1963). Regional-scale investigations, particularly in the northern hemisphere, have revealed the existence of a slow-fast continuum in the pace-of-life that follows latitudinal-environmental gradients (Sæther 1988; Roff 1992; Ricklefs 2000; Wikelski et al. 2003; Martin 2004; Wiersma et al. 2007). In this context, the life history traits of northern temperate birds—which have a fast pace of life—contrast with those of tropical and southern temperate

species, which tend to have a slow pace of life (Stutchbury and Morton 2001; Martin 2004; Scholer et al. 2020). These patterns are determined by the covariation between life history traits that compete for energy allocation, and the adaptive responses of species to environmental factors that affect their reproductive success (Ricklefs 2000; Martin 2004). This evolutionary perspective on bird life histories has been primarily derived from data on northern temperate systems or studies that focused on clutch size (Ricklefs and Wikelski 2002; Martin 2004; Scholer et al. 2020). Despite this, less than 25% of all bird species occur in the northern temperate region and data on adult survival of birds in the southern hemisphere remain scant (Martin 2004; Robinson et al. 2010; Scholer et al. 2020).

The evidence available to date indicates only discreet variation in bird survival along the southern latitudinal gradient and suggests that survival is greater in tropical and southern temperate birds than in their northern congeners (Ricklefs 1997; Ghalambor and Martin 2001; Peach

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et al. 2001; Jansen et al. 2014; Lloyd et al. 2014). Birds in the southern hemisphere have slow reproductive investment and prioritize adult survival to increase their residual reproductive value (Ghalambor and Martin 2001; Peach et al. 2001; Ricklefs and Wikelski 2002; Lloyd and Martin 2016). This pattern may occur because longevity has the greatest impact on the individual fitness of southern hemisphere birds, which would protect themselves more than their offspring from the effects of adverse environmental factors (Ghalambor and Martin 2001).

Many environmental factors might contribute to the regional geographic uniformity of bird survival in the southern hemisphere. For instance, the low latitudinal variation in temperature and food availability, which minimize the risk of extrinsic adult mortality (Rowley and Russell 1991; Peach et al. 2001; Lloyd et al. 2014), as well as, the higher mortality risk for young (nest predation risk) compared to adults (Stutchbury and Morton 2001; Auer et al. 2007; França et al. 2016), which would favor a greater reproductive residual value (Skutch 1949; Ghalambor and Martin 2001; Martin 2014). However, while some aspects of reproductive investment by birds (e.g., clutch size) have been thoroughly investigated at a global scale, this is not the case for survival, which represents one of the most significant knowledge gaps in demographic and life history research (Ricklefs and Wikelski 2002; Martin 2004; Scholer et al. 2020). This reinforces the need to overcome existing geographic and taxonomic gaps regarding the survival of birds to better understand the global patterns of their life history strategies (Ricklefs and Wikelski 2002; Martin 2004; Robinson et al. 2010).

Most regional-scale studies of bird survival in the southern hemisphere have involved comparing pairs of sites at widely dispersed latitudes based on original field data and previously published estimates, particularly from African sites (Peach et al. 2001; Lloyd 2008; Lloyd et al. 2014; Lloyd and Martin 2016). While such studies can effectively describe extremes in the spectrum of bird survival, they fail to provide systematic insights into latitudinal gradients and suffer from analytical and sampling divergences that hamper reliable comparisons between areas. Notably, few studies have compared the survival of birds in the tropical and southern temperate environments of the New World (however, see Ricklefs 1997; Ghalambor and Martin 2001). The available evidence is mainly derived from studies at a local scale and restricted to latitudes between 10°N and 3°S, where tropical wet environments predominate (Stutchbury and Morton 2001; Muñoz et al. 2018). In the few studies conducted at higher latitudes, survival was investigated only for single populations at a local scale (15°S—França and Marini 2010; 35°S—Bulit and Massoni 2011; 15°S—Duca and Marini 2014; 41°S—Presti et al. 2018).

The present study aimed to contribute to solving these geographic and taxonomic gaps among birds of the southern hemisphere. Specifically, we tested the hypothesis that annual survival of birds does not vary substantially along a latitudinal gradient in the Southern Hemisphere. For this, we estimated survival in 88 populations (69 species) of resident birds, at eight South American sites between latitudes 3°S and 34°S in habitats that included tropical and sub-tropical forests with high annual precipitation and temperate open woodlands with low annual precipitation.

Materials and methods

Study areas

The bird survival estimates obtained in the present study were derived from our field database, which was compiled from monitoring eight tropical, sub-tropical, and southern temperate environments in South America (Fig. 1). One of the sites was in a low-latitude tropical environment in Brazil (LLTE; 3°S), at the *Volta Grande do Xingu* (VGX—eastern Amazon basin) in *Amazônia* state. Three sites were located in high-latitude tropical environments in Brazil (HLTE; 22–24°S), which include *Reserva Biológica União* (RBU) and *Ilha Grande* (IG) in *Rio de Janeiro* state and *Parque Estadual da Serra do Mar* (PESM) in *São Paulo* state. Two other areas were located in a boundary region between tropical and temperate zones in southern Brazil (sub-tropical environments—STE; 27–30°S), which include *Estação Ecológica de Carijós* (EEC) in *Santa Catarina* state and *Floresta Nacional de Passo Fundo* (FNPf) and the *Instituto de Pesquisas Desidério Finamor* (IPDF) in *Rio Grande do Sul* state. The eighth area was located in a temperate environment (TE) at the *Reserva de Biósfera de Ñacuñán* (RBN) in Mendoza province, midwestern Argentina (34°S) (Fig. 1).

The VGX is located in the Brazilian Amazonian with vegetation of the *terra firme* forest type and low climate seasonality, with high annual rainfall (annual precipitation = 2100 mm) and temperature (mean minimum temperature of coldest month = 21 °C; mean maximum temperature of hottest month = 33 °C) throughout the year. All of the HLTE areas are located in the Brazilian Atlantic Forest and have vegetation of the dense ombrophilous forest type (DOF), which is influenced by a coastal climate. These are more seasonal environments than the low-latitude tropical environments, with high annual rainfall (RBU–DOF₁ = 1400 mm; IG–DOF₂ = 1600 mm; PESM–DOF₃ = 2200 mm) and considerable seasonal temperature variation (mean minimum temperature of coldest month: RBU–DOF₁ = 15 °C, IG–DOF₂ = 13°C, PESM–DOF₃ = 09 °C; mean maximum temperature of hottest month: RBU–DOF₁ = 30 °C, IG–DOF₂ = 30 °C,

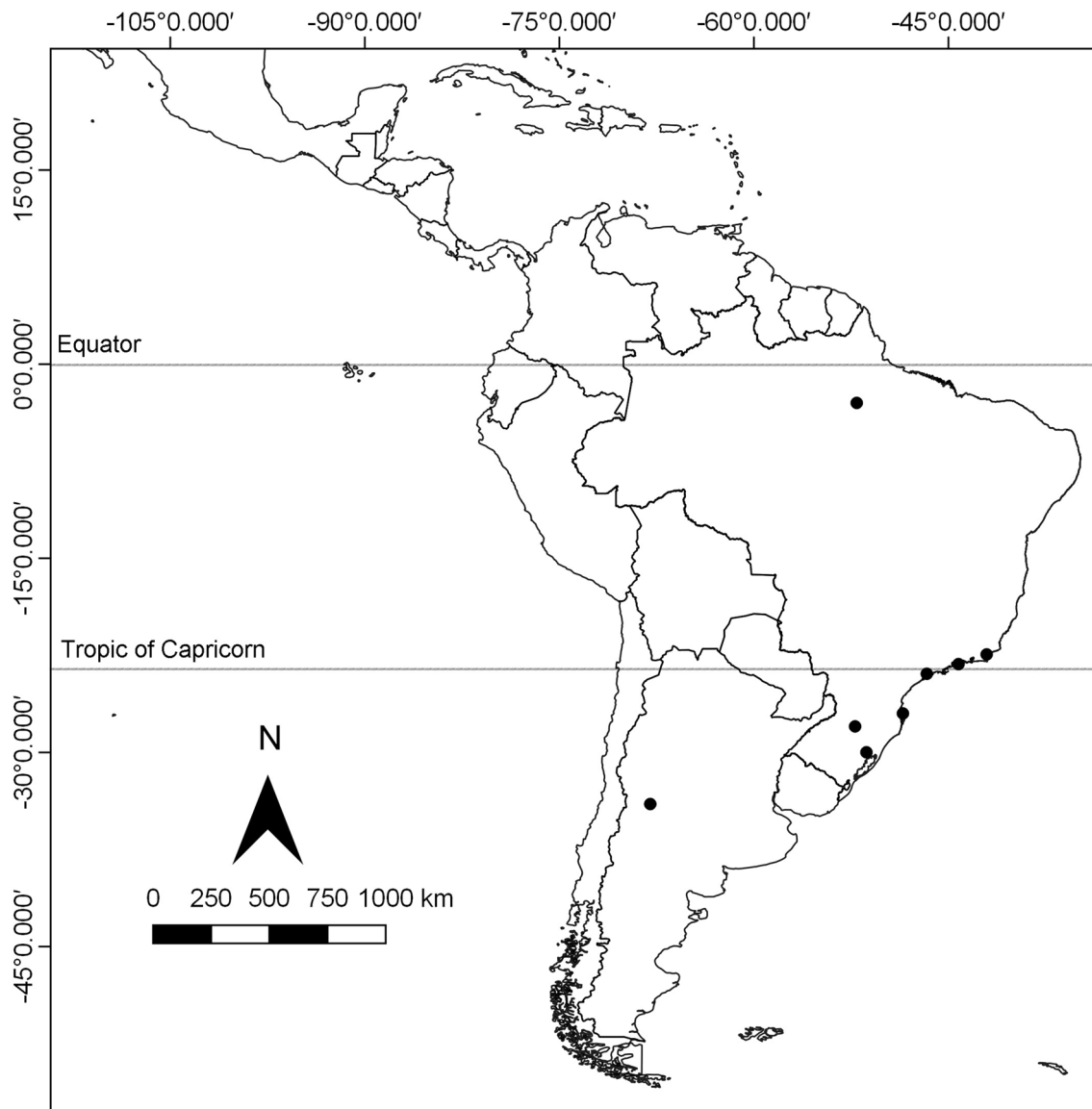


Fig. 1 Localities from which apparent survival estimates were obtained from our field data (circles)

PESM-DOF₃ = 25 °C). The STE of southern Brazil included in this study are distributed in two lowland coastal areas: the IPDF with riparian floodplain forest (RFF) and the EEC with *restinga* forest (RF); and an inland area (FNPF) with mixed montane ombrophilous forest (MMOF). These areas have a moderate temperate climate with well-defined seasonality, high annual rainfall (RFF = 1500 mm, RF = 1600 mm, MMOF = 1750 mm), high summer temperatures (mean maximum temperature of hottest month: RFF = 29 °C, RF = 29 °C, MMOF = 27 °C) and low winter temperatures (mean minimum temperature of coldest month: RFF = 11 °C, RF = 11 °C, MMOF = 7 °C). The Argentinean TE is located in the *Monte* desert, which includes open woodland vegetation (OW), low annual precipitation (280 mm), relatively

warm summers (32 °C) and cold winters (−1 °C). Climate data are historical averages between 1970 and 2000 (Fick and Hijmans 2017) and, were obtained from the WorldClim program (<http://www.worldclim.org>).

Mark-recapture data

The field dataset was compiled from the *in loco* monitoring of bird populations at the eight study localities, which followed standardized protocols to obtain survival estimates based on mark-recapture data. These protocols satisfied the following assumptions, which consider the prerequisites for reliable survival analyses (Williams et al. 2002): 1—all captured birds were marked and released; 2—birds were

permanently marked, ensuring that they could be recognized if recaptured; 3—mist-nets were deployed at the same sites throughout the study; 4—intervals between sampling sessions were appropriately spaced over time to allow for birth and death events. This database includes samples obtained over the past 22 years, with total study periods ranging from 4 to 21 years and mark-recapture data being collected in between one and six field campaigns per year (Table 1). Captured birds were weighed and then banded with metal rings provided by the Research Center for the Conservation of Wild Birds – CEMAVE/ICMBio (for birds banded in Brazil) and the Argentinian Museum of Natural Sciences (for birds banded in Argentina). The taxonomic classification of bird species followed Billerman et al. (2020).

Survival estimates

We only considered resident birds for the survival analyses due to the reduced seasonal site fidelity of migratory birds, which increases the probability of underestimating survival for these species. Only individuals with adult plumage were included in the analyses. We used the field dataset to compile individual capture histories, which we grouped by species for each locality. We used these sets of histories to generate demographic models based on the Cormack-Jolly-Seber approach (CJS; Lebreton et al. 1992), which was performed in MARK version 9.0. These models estimate the apparent survival parameter (ϕ —the probability that an individual survives between occasions i and $i + 1$ and remains in the sampled population) and the probability of recapture (p —the probability that an individual is recaptured at occasion i when first captured at occasion $i - j$). The term “apparent survival” indicates that the estimate (ϕ) is a combination of the probability that an individual remains alive and the probability that it has not permanently emigrated from the

study area. In the present study, all survival estimates based on our data refer to apparent survival.

We modeled the ϕ parameter for each population as a function of the time-since-marking (TSM) and the p parameter as a time-dependent (t) variable. TSM was used to avoid bias in the survival estimates due to the inclusion of transients (non-resident individuals who dispersed after their first capture), given that transients are common in mark-recapture studies in Neotropical environments (e.g., Muñoz et al. 2018). TSM models permit the partitioning of apparent survival into survival during the first interval after banding (ϕ^1 , supposedly transients) and in subsequent intervals (ϕ^{2+} , residents) (Pradel et al. 1997). We excluded non-informative survival estimates from each model, these coming from the first interval after banding (transients).

We adjusted the models using a Bayesian Markov chain Monte Carlo (MCMC) method rather than the more commonly used maximum likelihood approach. We chose this approach because the MCMC is more efficient when estimating parameters close to the 0 or 1 limits and because its credible interval is less confusing or biased than the confidence interval (Barry et al. 2003). We evaluated the convergence of the MCMC structure by calculating the sample size (i.e., number of interactions) and burn-in (i.e., initial samples discarded to guarantee the stabilization of the Markov chain) necessary for the generation of reliable estimates (Raftery and Lewis 1996). Based on these results, we employed models with a burn-in of the first 1000 runs and storage of 10,000 posterior iterations. We ran a second diagnostic test to evaluate the convergence of the Markov chains based on the R-hat statistic (Gelman 1996). The chains converged adequately, with R-hat ≤ 1.0 for all of the estimated parameters. We then obtained estimates of apparent survival and the 95% credible intervals. The apparent survival values resulting from the models represent infra-annual estimates and were fitted according to sample size described in the “Mark-recapture data” session. These infra-annual estimates

Table 1 Vegetation types, geographic regions and sampling schedules of the eight localities in our field database

Environment	Latitude, longitude	Field campaigns				Number of years
		First	Last	Per year	Total	
Low-latitude tropical environment (LLTE)						
<i>Terra firme</i> forest	03°13'S, 52°3'W	Apr-Jul/2013	Dec-Mar/2017	3	12	4
High-latitude tropical environments (HLTE)						
Dense ombrophilous forest-1	22°25'S, 44°02'W	Jan-Apr/2009	Jan-Apr/2016	3	22	7
Dense ombrophilous forest-2	23°10'S, 44°12'W	Jul-Aug/1999	May-Jun/2005	6	36	6
Dense ombrophilous forest-3	24°01'S, 46°47'W	May-Aug/2007	May-Aug/2011	3	13	4
Sub-tropical (STE) and temperate environments (TE)						
Mixed montane ombrophilous forest	28°16'S, 52°10'W	Jan-Dec/ 1999	Jan-Dec/2020	1	22	22
<i>Restinga</i> forest	27°28'S, 48°29'W	Jul-Dec/ 2015	Jan-Jun/2020	2	10	5
Riparian floodplain forest	30°03'S, 51°18'W	Sep-Nov/2002	Jun-Aug/2006	4	16	4
Open woodland	34°03'S, 67°54'W	Oct-Dec/2004	Jul-Sep/2009	4	20	5

were converted to annual estimates based on the product of the survival parameters estimated over the course of a year. Average annual survivals for each site were obtained using geometric means.

Comparative survival analyses

We restricted the comparative survival analyses to the order Passeriformes, since this group corresponds to 97% of the species sampled. To evaluate whether apparent bird survival is influenced by latitudinal trends and differs between environments, we fitted a Bayesian phylogenetic mixed model (Hadfield 2010). Since body mass is associated to bird lifespan and survival (Sæther 1989; Speakman 2005; Scholer et al. 2020), we included it as an explanatory variable in the model. Body mass were log-transformed (natural base) to correct inherent skewness. We used the function MCMCglmm from the package ‘MCMCglmm’ (Hadfield 2010) to create a linear mixed model using Bayesian Markov Chain Monte Carlo (Hadfield 2012). To account for phylogenetic effects, we used 100 randomly selected phylogeny trees based on the Hackett backbone (Hackett et al. 2008) obtained from the Birdtree project (< <http://birdtree.org> > ; Jetz

et al. 2012). We fitted the models to each of the trees and then extracted the mean density of the combined posterior distribution using the package mulTree (Guillerme and Healy 2014). Bird phylogeny was included as a random term in the model. To test the effects of the explanatory variables on apparent bird survival, we fitted a gaussian mixed model with identity link function. We set uninformative priors for both fixed and random effects of models. We used an uninformative inverse-Wishart prior distribution (with variance, V , set to 1 and belief parameter, ν , set to 0.002; Hadfield 2010). To ensure model convergence, we ran each model for 500 000 iterations, with burn-in set at 10 000 and stored samples every 100 iterations. The model resulted in comparable effective sample size for all factors (~ 1000). Fixed effects were considered statistically significant when the 95% credible interval did not overlap zero. We calculated the percentage of variance explained by each of the fixed effects only and the combination of fixed and random effects, using marginal and conditional R^2 , respectively (Nakagawa and Schielzeth 2013). Descriptive statistics are expressed as mean \pm standard deviation (minimum–maximum). All the comparative analyses were performed using R (version 4.2.1, www.r-project.org).

Table 2 Results from a phylogenetic linear mixed model with a Gaussian error distribution and identity link function to evaluate the effects of latitude, environment and body size in the apparent bird survival

Variable ^a	Estimate	95% CI		Posterior distribution
		Lower	Upper	
Environment (HLTE)	0.390	-0.589	1.380	
Environment (STE _{RRF})	0.536	-0.679	1.762	
Environment (STE _{MMOF})	0.499	-0.694	1.703	
Environment (TE _{OW})	0.677	-0.803	2.169	
Latitude	0.021	-0.025	0.069	
Body mass	0.048	-0.006	0.102	
Phylogenetic variance	0.007	0.001	0.025	
Residual variance	0.012	0.008	0.017	

The *Terra firme forest* at low-latitude tropical environment (LLTE) was the reference level for the environments. Black circles indicate the mean of the estimate produced by averaging 100 models and the error bars (gray shading) show the lower and upper 95% and 50% credible intervals (CI)

^aHLTE, Dense ombrophilous forests at high-latitude tropical environments; STE_{RRF}, riparian and *restinga* forests at sub-tropical environments; STE_{MMOF}, mixed montane ombrophilous forest at sub-tropical environments and; TE_{OW}, open woodland at temperate environments

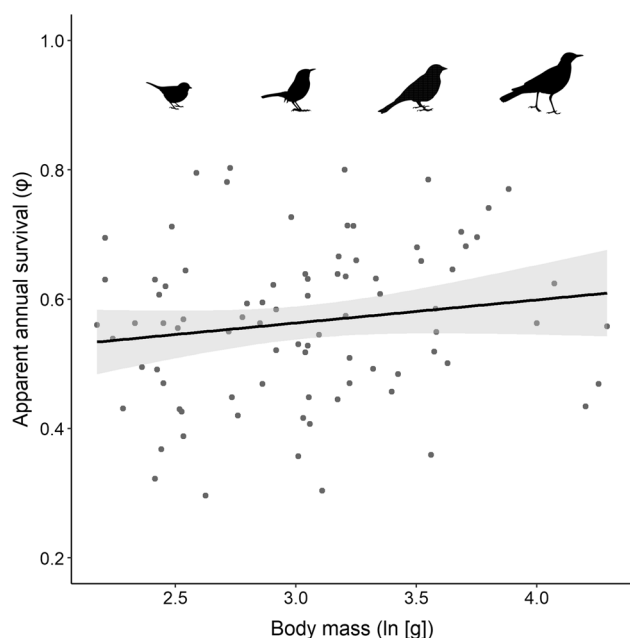


Fig. 2 Apparent annual survival with 95% confidence interval (in light gray) of passerine species according to their body mass (log-transformed) based on 85 populations sampled at eight localities in South America

Results

We estimated the apparent annual survival of 88 populations (Appendix 1) representing 69 bird species of Passeriformes (85 populations; 67 species), Apodiformes (two

populations; one species) and Piciformes (one population). The survival estimates varied from 0.30 to 0.80 (0.56 ± 0.12) and the probability of recapture ranged from 0.07 to 0.50 (0.20 ± 0.09). The presented comparisons are restricted to passerine species (for further details, see Materials and methods).

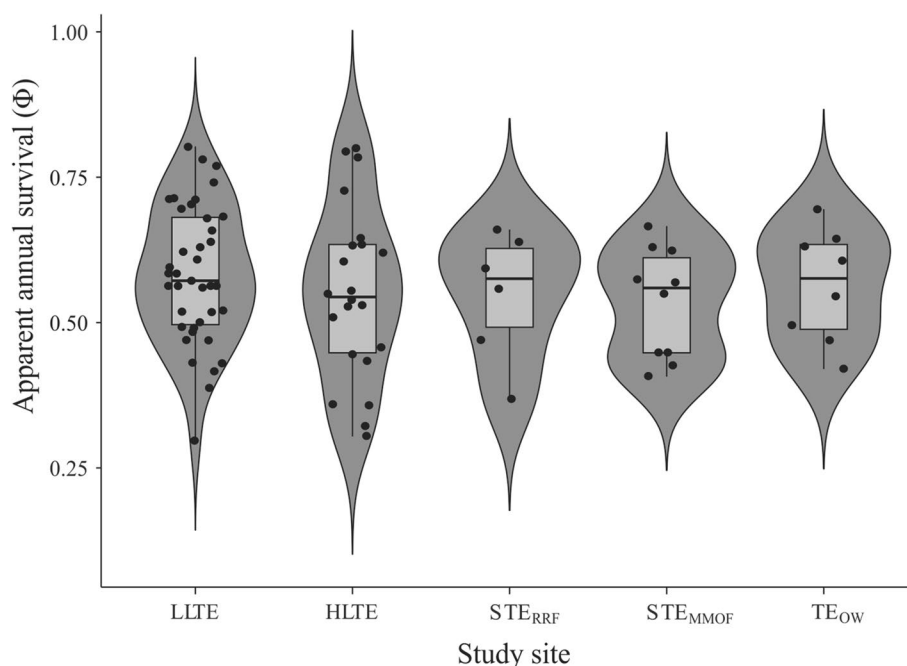
Our regional geographical scale analysis showed no latitudinal effect on the apparent annual survival of passerines in the Southern Hemisphere (Table 2). Despite the trend, body mass did not explain the variation in bird survival (marginal $R^2 = 0.06$, conditional $R^2 = 0.41$; Fig. 2). On the other hand, phylogenetic relationships between avian species explained part of the variation in bird survival (total variance explained = 35%).

When we compared the survival estimates between the studied environments (Fig. 3), we found that the survival on LLTE (39 populations; $\bar{x} = 0.57$) was not statistically different in relation to the other environments located in tropical [HLTE (22 populations; $\bar{x} = 0.53$), subtropical [RRF (6 populations; $\bar{x} = 0.54$), MMOF (10 populations; $\bar{x} = 0.53$)] and temperate regions [OW (8 populations; $\bar{x} = 0.56$)].

Discussion

The results of the present study support the hypothesis that bird survival is homogeneous at regional scale, in the Southern Hemisphere, therefore highly similar in both southern temperate and tropical environments. These findings—based on the most robust database on bird survival in South America—are consistent with the most likely pattern

Fig. 3 Distribution of annual survival estimates for passerine species in tropical and southern temperate environments. Estimates obtained from field data are arranged by environment type: *terra firme* forest at low-latitude tropical environments (LLTE), dense ombrophilous forest at high-latitude tropical environments (HLTE), riparian and *restinga* forests at humid sub-tropical environments (STE_{RRF}), mixed montane ombrophilous forest at humid sub-tropical environments (STE_{MMOF}) and open woodland at dry temperate environments (TE_{OW})



suggested for the region (Martin 2004; Scholer et al. 2020). Our dataset includes many new records, particularly for the understudied higher latitudes. We provide the first survival estimates for 49 resident populations of 34 passerine species at seven high-latitude localities in South America (22–34°S), a region known only from estimates of nine resident populations/species at two localities (Ghalambor and Martin 2001; Thomson and Estades 2012). In the current study, we minimized methodological discrepancies to ensure the reliability of comparisons extracted from the field dataset using the same sampling method (mark-recapture) at all localities, the same modeling procedures for all populations and controlling for potential underestimation caused by the presence of transient birds. In addition to investigating a pattern at the continental scale, our findings provide inferences on the relation between bird survival and the climate seasonality (Ricklefs 1997; Ghalambor and Martin 2001; Roff 2002; Robinson et al. 2010).

Live-encounter data (e.g., mark-recapture data) are the most reliable record type to estimate the survival for wildlife species (Sandercock 2006). However, the diversity of analytical approaches and many common sources of bias tend to hamper the systematic recognition of macroecological survival patterns (Sandercock et al. 2000; Ricklefs et al. 2011). In our approach using new estimates, we standardized both the sampling and analyses to ensure robust empirical conclusions. This is uncommon in most studies, which primarily depend on comparisons between new estimates and published data (Peach et al. 2001; Lloyd et al. 2014; Muñoz et al. 2018). Another consideration is that some intrinsic factors influence the survival estimates (Sæther 1989; Bennett and Owens 2002; Speakman 2005; Scholer et al. 2020). The survival of the South American passerines analyzed here was not influenced by body mass, but we found evidence of a phylogenetic effect. The lack influence of body size may have been due to the study species encompassing a relatively limited spectrum of variation in body mass. After controlling for these intrinsic factors, we did not find differences in bird survival between environments or across latitudinal range.

Our evidence demonstrating similar regional survival estimates of birds living in South America, indicates that the latitudinal gradient in climate does not affect bird survival in the Southern Hemisphere in the same way as it does in the Northern Hemisphere. This appears to be true at least for locations as far south as the highest latitude included in the present study (34°S), which does encompass the vast majority of the continental mass of South America. Notably, extrinsic factors may explain why northern temperate birds suffer higher mortality than southern temperate birds (Martin 2004; Scholer et al. 2020). The high mortality among northern temperate birds seems to be related to the high extrinsic cost of

climatic/food seasonality (Ricklefs 1997; Ghalambor and Martin 2001; Martin 2002; Boyce et al. 2020). In fact, the mean survival at subtropical and temperate latitudes in the current study (22–34°S; mean = 0.54, range = 0.30–0.80; $n = 49$) was higher than survival at higher latitudes in the Northern Hemisphere (data compilation by Scholer et al. 2020; 50–68°N; mean survival = 0.43, range = 0.18–0.75, $n = 116$ estimates; latitudes = 50–68°N). At the same time, the sites studied in the current study (22–34°S; mean = 09 °C, range = – 1–7 °C) have milder winters than those studied in the high latitudes of the Northern Hemisphere (50–68°N; minimum temperatures of coldest month; mean = – 07 °C, range = – 37–02 °C). In these environments from Northern Hemisphere, periods of extreme cold reduce the availability of food resources and increase the energetic costs of avoiding hypothermia, which tends to reduce individual longevity (Ashmole 1963; Ricklefs 1997; Martin 2004). In contrast, the seasonality in temperature and resources in southern temperate regions is less extreme (Rowley and Russell 1991; Schloss et al. 1999) and has a less intense impact on bird survival. The conclusions of the present study indicate that the extrinsic costs of adult mortality do not vary between tropical and southern temperate birds. Therefore, these conclusions complement those of Ghalambor and Martin (2001), who proposed that extrinsic costs were fundamental to the greater mortality of northern temperate birds in comparison to subtropical birds in the Southern Hemisphere.

The present study provides conclusive evidences that bird survival in the Southern Hemisphere does not systematically vary along a latitudinal gradient, which empirically supports an assumption of bird life history that lacked robust evidence for so long. These findings also contribute to the ongoing discussion on the mechanisms responsible for the differentiation of life history strategies among northern temperate species from those of tropical and southern temperate taxa. We suggest that factors other than latitudinal variation in climate/food seasonality (e.g., higher mortality risk for young birds compared to adults—Ghalambor and Martin 2001) may be more determinant for the survival strategies of adult birds in the Southern Hemisphere.

Appendix 1

Apparent annual survival (Φ), credible interval of survival (CI), and the probability of recapture (p) in 88 populations and 69 bird species from eight localities in South America between the latitudes of 3°S and 34°S. Estimates are derived from a field mark-recapture database.

Locality/Family	Species (synonym)	Mark/recapture	Mass (g)	Survival (Φ)			Recapture (p)
				Estimate	- CI	+ CI	
Low-latitude tropical environment (HLLE)							
<i>Terra firme forest</i>							
Passerellidae	<i>Arremon taciturnus</i>	449/174	25.5	0.713	0.577	0.861	0.199
Furnariidae	<i>Automolus paraenses</i> ^a	114/23	35.7	0.519	0.292	0.877	0.142
Troglodytidae	<i>Cantorchilus leucotis</i> (<i>Thryothorus leucotis</i>)	68/10	18.3	0.622	0.330	0.967	0.149
Thamnophilidae	<i>Cercomacroides nigrescens</i> (<i>Cercomacra nigrescens</i>)	155/20	18.5	0.584	0.337	0.921	0.072
Cardinalidae	<i>Cyanoloxia rothschildii</i> (<i>Cyanocompsa cyanoides</i>)	145/26	24.9	0.714	0.512	0.953	0.165
Furnariidae	<i>Dendrocincla fuliginosa</i>	190/42	40.7	0.682	0.493	0.947	0.106
Furnariidae	<i>Dendrocincla merula</i>	167/50	39.9	0.704	0.495	0.946	0.131
Furnariidae	<i>Dendroplex picus</i>	82/17	37.7	0.501	0.239	0.844	0.243
Formicariidae	<i>Formicarius analis</i>	62/10	54.6	0.563	0.282	0.965	0.109
Formicariidae	<i>Formicarius colma</i>	76/18	42.6	0.696	0.452	0.963	0.189
Thamnophilidae	<i>Formicivora grisea</i>	47/15	11.6	0.563	0.290	0.918	0.186
Parulidae	<i>Geothlypis aequinoctialis</i>	110/19	13.8	0.296	0.115	0.616	0.260
Furnariidae	<i>Glyphorhynchus spirurus</i>	555/226	16.1	0.572	0.480	0.674	0.266
Thamnophilidae	<i>Hypocnemis striata</i>	129/25	12.6	0.430	0.253	0.689	0.275
Thamnophilidae	<i>Hylophylax naevius</i>	57/14	12.4	0.388	0.156	0.718	0.288
Thamnophilidae	<i>Isleria hauxwelli</i> (<i>Myrmotherula hauxwelli</i>)	158/59	11.3	0.491	0.336	0.679	0.287
Troglodytidae	<i>Microcerculus marginatus</i>	58/16	18.5	0.521	0.264	0.934	0.200
Tyrannidae	<i>Mionectes oleagineus</i>	519/68	10.3	0.563	0.391	0.756	0.080
Onychorhynchidae	<i>Miobius barbatus</i>	82/27	12.0	0.712	0.494	0.975	0.162
Thamnophilidae	<i>Myrmelastes ruffacies</i> (<i>Schistocichla ruffacies</i>)	59/11	25.1	0.470	0.198	0.902	0.148
Thamnophilidae	<i>Myrmoborus leucophrys</i>	147/42	20.9	0.518	0.317	0.805	0.200
Thamnophilidae	<i>Myrmoborus myotherinus</i>	141/21	17.5	0.469	0.254	0.772	0.150
Thamnophilidae	<i>Myrmotherula axillaris</i>	218/38	8.8	0.560	0.359	0.823	0.091
Onychorhynchidae	<i>Onychorhynchus coronatus</i>	145/52	15.1	0.781	0.600	0.965	0.182
Troglodytidae	<i>Pheugopedius coraya</i> (<i>Thryothorus coraya</i>)	123/23	20.7	0.416	0.208	0.746	0.112
Thamnophilidae	<i>Phlegopsis nigromaculata</i>	569/99	44.7	0.741	0.580	0.912	0.087
Pipridae	<i>Pipra fasciicauda</i>	1116/375	15.3	0.803	0.715	0.912	0.164
Tyrannidae	<i>Platyrrinchus coronatus</i>	25/10	9.8	0.431	0.179	0.838	0.324
Thamnophilidae	<i>Pyriglena leuconota</i>	391/76	33.2	0.680	0.507	0.912	0.139
Thraupidae	<i>Ramphocelus carbo</i>	401/41	23.9	0.639	0.457	0.882	0.090
Thamnophilidae	<i>Rhegmatorhina gymnops</i>	103/18	27.7	0.492	0.261	0.825	0.161
Tityridae	<i>Schiffornis turdina</i>	41/13	28.5	0.608	0.345	0.920	0.193
Furnariidae	<i>Sclerurus caudacutus</i>	42/10	35.9	0.585	0.356	0.857	0.500
Thamnophilidae	<i>Thamnomanes caesius</i>	259/46	17.3	0.563	0.355	0.855	0.096
Turdidae	<i>Turdus albicollis</i>	144/36	48.6	0.770	0.570	0.992	0.169
Thamnophilidae	<i>Willisornis vidua</i> (<i>Willisornis poecilinotus</i>)	158/42	17.5	0.595	0.384	0.903	0.156
Furnariidae	<i>Xenops minutus</i>	156/52	11.2	0.630	0.453	0.849	0.253
Furnariidae	<i>Xiphorhynchus obsoletus</i>	58/15	30.7	0.484	0.236	0.871	0.250
Furnariidae	<i>Xiphorhynchus spixii</i>	67/17	33.8	0.659	0.422	0.960	0.122
High-latitude tropical environment (HLTE)							
<i>Dense ombrophilous forest—site 1</i>							

Locality/Family	Species (synonym)	Mark/recapture	Mass (g)	Survival (Φ)			Recapture (p)
				Estimate	- CI	+ CI	
Pipridae	<i>Dixiphia pipra</i> (<i>Pseudopipra pipra</i>)	113/44	13.3	0.795	0.658	0.920	0.147
Tyrannidae	<i>Mionectes oleagineus</i>	68/23	12.3	0.555	0.387	0.760	0.132
<i>Dense ombrophilous forest—site 2</i>							
Pipridae	<i>Chiroxiphia caudata</i>	107/58	25.1	0.509	0.371	0.661	0.155
Conopophagidae	<i>Conopophaga melanops</i>	97/59	21.1	0.605	0.466	0.769	0.137
Furnariidae	<i>Dendrocincla turdina</i>	43/34	34.8	0.785	0.619	0.959	0.193
Furnariidae	<i>Philydor atricapillus</i>	47/29	20.3	0.357	0.191	0.571	0.208
Furnariidae	<i>Sclerurus scansor</i>	59/33	36.0	0.549	0.380	0.750	0.147
Trochilidae	<i>Thalurania glaucopis</i> ^b	86/37	4.8	0.386	0.233	0.581	0.138
Thraupidae	<i>Trichothraupis melanops</i>	139/46	24.7	0.635	0.487	0.810	0.083
Furnariidae	<i>Xiphorhynchus fuscus</i>	64/88	21.1	0.528	0.390	0.691	0.348
<i>Dense ombrophilous forest—site 3</i>							
Conopophagidae	<i>Conopophaga melanops</i>	80/35	19.7	0.727	0.523	0.961	0.187
Furnariidae	<i>Dendrocincla turdina</i>	89/47	38.5	0.646	0.481	0.821	0.185
Pipridae	<i>Chiroxiphia caudata</i>	95/29	24.6	0.800	0.619	0.976	0.128
Cardinalidae	<i>Habia rubica</i>	58/30	35.2	0.359	0.206	0.569	0.279
Onychorhynchidae	<i>Myiobius barbatus</i>	47/25	11.7	0.620	0.405	0.875	0.452
Furnariidae	<i>Philydor atricapillus</i>	58/22	22.4	0.304	0.140	0.545	0.334
Tyrannidae	<i>Platyrrinchus mystaceus</i>	50/37	9.4	0.539	0.347	0.763	0.337
Thamnophilidae	<i>Pyriglena leucoptera</i>	77/11	29.9	0.457	0.214	0.848	0.145
Thamnophilidae	<i>Rhopias gularis</i> (<i>Myrmotherula gularis</i>)	34/21	11.2	0.322	0.147	0.589	0.389
Tityridae	<i>Schiffornis virescens</i>	31/25	28.0	0.632	0.396	0.919	0.253
Trochilidae	<i>Thalurania glaucopis</i> ^b	76/25	4.7	0.515	0.304	0.832	0.238
Thraupidae	<i>Trichothraupis melanops</i>	84/14	23.9	0.445	0.224	0.795	0.174
Turdidae	<i>Turdus albicollis</i>	82/13	66.9	0.434	0.188	0.798	0.135
Furnariidae	<i>Xiphorhynchus fuscus</i>	60/40	20.3	0.530	0.345	0.729	0.312
Humid subtropical environment							
<i>Mixed montane ombrophilous forest (MMOF)</i>							
Pipridae	<i>Chiroxiphia caudata</i>	234/37	24.7	0.574	0.457	0.694	0.230
Parulidae	<i>Myiothlypis leucoblephara</i> (<i>Basileuterus leucoblepharus</i>)	395/84	15.2	0.550	0.458	0.641	0.285
Tyrannidae	<i>Platyrrinchus mystaceus</i>	183/44	9.1	0.630	0.524	0.740	0.181
Thraupidae	<i>Thlypopsis pyrrhocomma</i> (<i>Pyrrhocomma ruficeps</i>)	439/63	15.4	0.448	0.337	0.540	0.248
Furnariidae	<i>Sittasomus griseicapillus</i>	178/32	12.6	0.569	0.437	0.698	0.269
Furnariidae	<i>Syndactyla rufosuperciliata</i>	80/20	24.0	0.666	0.532	0.806	0.264
Thraupidae	<i>Trichothraupis melanops</i>	189/22	21.2	0.448	0.283	0.592	0.307
Turdidae	<i>Turdus albicollis</i>	335/31	58.7	0.624	0.503	0.737	0.099
Passerellidae	<i>Zonotrichia capensis</i>	323/36	21.3	0.407	0.274	0.546	0.236
Furnariidae	<i>Synallaxis cinerascens</i>	158/19	12.5	0.426	0.256	0.602	0.143
<i>Restinga forest (RF)</i>							
Tyrannidae	<i>Elaenia obscura</i>	80/28	25.8	0.660	0.434	0.947	0.201
Parulidae	<i>Geothlypis aequinoctialis</i>	162/42	11.5	0.368	0.217	0.548	0.456
Passerellidae	<i>Zonotrichia capensis</i>	51/18	20.9	0.639	0.376	0.962	0.223
<i>Riparian floodplain forest (RFF)</i>							
Parulidae	<i>Myiothlypis leucoblephara</i> (<i>Basileuterus leucoblepharus</i>)	31/09	16.4	0.593	0.317	0.974	0.116

Locality/Family	Species (synonym)	Mark/recapture	Mass (g)	Survival (Φ)			Recapture (p)
				Estimate	- CI	+ CI	
Parulidae	<i>Geothlypis aequinoctialis</i>	118/23	11.6	0.470	0.261	0.824	0.102
Turdidae	<i>Turdus rufiventris</i>	117/30	73.1	0.558	0.332	0.869	0.098
Dry temperate environment							
<i>Open woodland</i>							
Furnariidae	<i>Asthenes baeri</i>	101/43	15.8	0.420	0.272	0.615	0.271
Furnariidae	<i>Cranioleuca pyrrhophia</i>	27/19	11.4	0.607	0.385	0.875	0.259
Furnariidae	<i>Leptasthenura platensis</i>	41/18	9.1	0.695	0.477	0.948	0.164
Picidae	<i>Melanerpes cactorum</i> ^b	34/22	34.9	0.341	0.160	0.626	0.341
Thraupidae	<i>Microspingus torquatus</i> (<i>Poospiza torquata</i>)	334/44	12.7	0.644	0.466	0.886	0.121
Furnariidae	<i>Pseudoseisura lophotes</i>	23/11	70.6	0.469	0.222	0.918	0.215
Thraupidae	<i>Saltatricula multicolor</i>	165/73	22.1	0.545	0.396	0.723	0.353
Tyrannidae	<i>Stigmatura budytoides</i>	127/78	10.6	0.495	0.372	0.642	0.293
Passerellidae	<i>Zonotrichia capensis</i>	608/61	21.1	0.631	0.479	0.802	0.138

^a*Automolus infuscatus* was used as a replacement for *Automolus paraensis* when obtaining the phylogenetic tree

^bNon-passerine birds. Synonymies reported in the phylogenetic tree (Jetz et al. 2012) are spelled within parentheses

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Code availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no competing interests.

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