

Ground-dwelling Spider Communities Respond to Changes in Riparian Vegetation Widths

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Spiders play a key role in the ecological dynamics in riparian habitats. However, most studies on the effects of changes in riparian habitats on spider communities focused the conversion of riparian forest rather than a gradient of forest widths. We assessed the community structure of ground-dwelling spiders in riparian vegetation fragments with varying widths in Southern Brazil. We selected four fragments with different riparian vegetation widths (> 40 m; < 30 m; < 15 m; < 5 m). In each fragment, spiders were seasonally collected using pitfall traps. We tested the effects of riparian vegetation widths and environmental variables (litter height, litter cover and canopy openness) on the taxonomic and guild composition of spider communities. The taxonomic and guild composition of ground-dwelling spiders varied among the widest (> 40 and < 30 m) and narrower riparian widths (< 15 m and < 5 m). While hunting spiders were associated with the narrower wider widths, web-building spiders were associated with the wider widths. Spider composition was influenced by the leaf litter height in the widest widths (> 40 and < 30 m) and by canopy openness in the narrowest width (< 15 m). Reductions in riparian vegetation were associated with significant changes in the community structure of ground-dwelling spiders, likely through top-down

mechanisms associated with the higher litter input in wider fragments. In summary, the fragmentation of the riparian forests of the Southern Brazil are negatively associated with web-building spiders.

Key words: Atlantic Forest, Edge Effect, Guild Composition, Riparian Forest, Soil Spiders

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BACKGROUND

Riparian forests are habitats with high plant biomass and biological productivity that harbor elevated levels biodiversity (Naiman et al. 1993). The riparian vegetation provides many ecological services to both the aquatic and the terrestrial biota, including the stabilization of riverbanks, energy input to the freshwater habitats, sediment filtering, among others (Rios and Bailey 2006; Lorion and Kennedy 2009). However, riparian forests have been continuously converted to several anthropogenic land uses, mainly agriculture, urban areas, and forestry (Nilsson 2005). Under this scenario, estimating adequate amounts of riparian vegetation cover are essential for policies aiming at the protection of biodiversity (Marczak et al. 2010; Moraes et al. 2014). Riparian spiders are important links in the energy flow from aquatic habitats to terrestrial environments (Collier et al. 2002; Sanzone et al. 2003; Baxter et al. 2005). Researchers demonstrated that spider communities in riparian habitats can be assembled by several structural aspects of the vegetation (Bell et al. 1999; Bonn et al. 2002; Krell et al. 2015; Hunt et al. 2020). Specifically, spider community structure in riparian habitats has been related to vegetation size, tree clearance, litter input, etc. (Laeser et al. 2005; Rodrigues et al. 2014; Hunt et al. 2020; Ramberg et al. 2020). Changes in the integrity of the riparian vegetation can affect a range of factors that influence spider establishment, e.g., microclimate, availability sites for web building, and prey availability (Bell et al. 1999; Bonn et al. 2002; Laeser et al. 2005; Rodrigues et al. 2014; Hunt et al. 2020; Ramberg et al. 2020). Riparian forests can act as dispersal routes for spiders among and within networks, however, in regions characterized by riparian loss, this flow can be stopped (Raizer et al. 2005a; Lambeets et al. 2010; Tonkin et al. 2016). Given that riparian spiders play a key role in the nutrient flux at the interface between aquatic and terrestrial environments, impacts on the riparian vegetation can propagate to higher trophic levels (e.g., the vertebrate fauna) (Nakano and Murakami 2001; Baxter et al. 2005). In this sense, spiders have been employed as model organisms in several studies to assess the

impacts of changes in riparian condition in ecological dynamics (Marczak and Richardson 2007; Hunt et al. 2020).

In relation to the knowledge on the effects of modifications of riparian vegetation on spiders, most studies focused the effects of conversion of riparian forest to other land uses or compared species composition among vegetation types (Buddle et al. 2004; Hore and Uniyal 2008; Lo-Man-Hung et al. 2011; da Rosa et al. 2019; Ramberg et al. 2020) rather than a gradient of forest widths. In addition, the relationships between the ground-dwelling spider fauna and riparian vegetation habitats are incipient in the Neotropical region (Rodrigues 2011). This is because many of those earlier studies although focused subsets of the fauna inhabiting specific microhabitats (*e.g.*, arboreal or shrub habitats) or with specific traits (*e.g.*, web-building) (Kato et al. 2003; Laeser et al. 2005; Rodrigues and Mendonça 2012; Rodrigues et al. 2014).

Ground-dwelling spiders constitute a distinct subset of the spider fauna, comprised by families with specimens that prefers actively moves over the ground layer and strongly responds to a variety of soil characteristics (Uetz 1976; Bultman and Uetz 1982; Weeks and Holtzer 2000; Hore and Uniyal 2008). Given that the ground-dwelling spider fauna is assumedly less dependent on forest traits in comparison to arboreal or shrub spiders, the composition of ground spiders can respond differently to changes in riparian vegetation. In specific, ground spiders can be related to the amount of forest cover and input of litter material by the riparian vegetation (Uetz 1976 1979; Bultman and Uetz 1982; Weeks and Holtzer 2000; Lafage et al. 2019).

In this study, we assessed the community structure of ground-dwelling spiders along a gradient of riparian vegetation width in subtropical Atlantic Forest fragments in Southern Brazil. We specifically aimed at testing the influence of classes of riparian vegetation widths (from more than 40 m to less than 5 m wide) on the taxonomic and guild composition of the spider fauna. Assuming that changes in the size and structure of the riparian vegetation affect the distribution and a range of biotic and abiotic conditions (*e.g.*, microclimate, prey availability) that influence the occurrence of spiders in these habitats (Bell et al. 1999; Laeser et al. 2005; Lambeets et al. 2010; Rodrigues et al. 2014; Hunt et al. 2020; Ramberg et al. 2020), we hypothesized that spider species and guild composition would differently vary with riparian vegetation width. We expected that spider taxa with greater mobility and active feeding habits (*e.g.*, hunting runner spiders) would predominate in the narrower classes of riparian vegetation widths, while web-building spiders would predominate in the wider classes of riparian vegetation widths.

MATERIALS AND METHODS

Study region

The study region is situated in the Sinos River basin, a 4000-km² watershed located in the state of Rio Grande do Sul, Southern Brazil (29°20'–30°10'S; 50°15'–51°20'W; Fig. 1) (COMITESINOS 2014). The original vegetation of the watershed is characterized by semi-deciduous forests ranging at the southernmost boundary of the Atlantic Forest biome (IBGE 1986). The climate of the study region is subtropical humid (Cfa according to Köppen classification system), with average annual rainfall ranging from 1200 to 2000 mm, and annual temperature of ~20°C (Maluf 2000; Alvares et al. 2013).

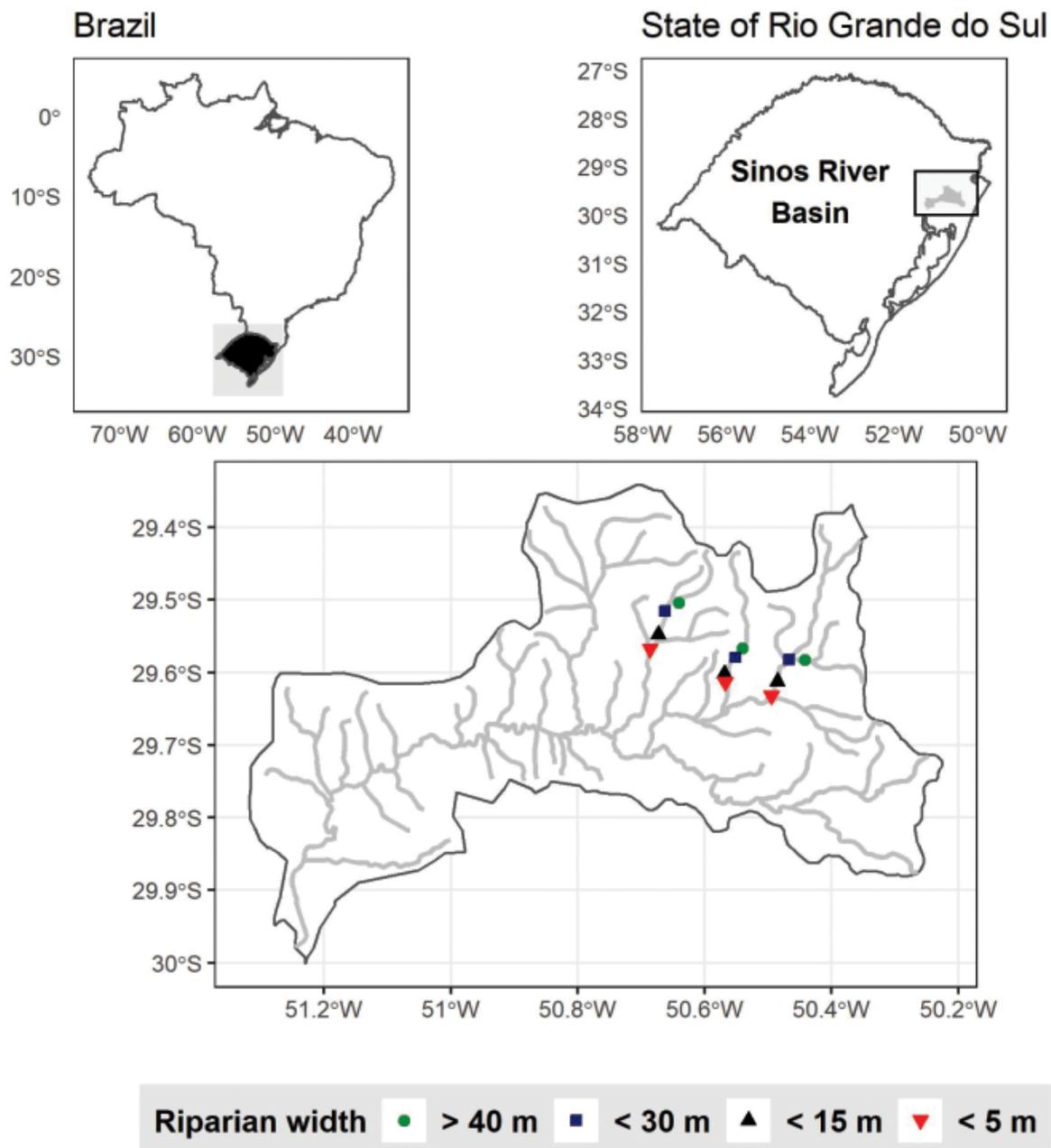


Fig. 1. Location of the studied fragments of riparian vegetation in the Sinos River basin, Southern Brazil. Adapted from: Moraes et al. (2014), Viegas et al. (2014) and Pires et al. (2020). (two-column width figure).

Sampling design

The sampling design consisted of 12 sampling sites with different riparian vegetation widths, evenly distributed in three tributaries of the watershed ($N = 4$ per tributary). We posteriorly assigned the sampling sites to four classes of riparian vegetation widths, described as follows.

(1) Fragments with riparian vegetation widths wider than 40 m on both stream margins (< 40 m). (2) Fragments with riparian vegetation widths ranging between 15 and 30 m on both stream margins (< 30 m). (3) Fragments with riparian vegetation widths ranging between 5 and 15 m on both stream margins (< 15 m). (4) Fragments with riparian vegetation widths not wider than 5 m wide on both stream margins (area < 5 m) (Fig. 1).

Collection methods

Each sampling site was located along ~100-m long fragments of riparian vegetation in each tributary. The selected fragments were non-contiguous, and in the first class (area > 40 m), the riparian vegetation width prolonged up to 1000 m along one of the stream margin, and from 210 to 440 m on the other stream margin. The minimum distance between sampling sites within each tributary was 1 km (Moraes et al. 2014). Forest species composition and the land use in the surrounding areas was similar across sampling sites, represented by small-sized rural properties which make use of croplands and livestock (Oliveira et al. 2013; Moraes et al. 2014; Viegas et al. 2014).

Four sampling events were carried out seasonally between 2010 and 2011. Ground-dwelling spiders were collected using pitfall traps that were active for 72 h. The pitfall traps consisted of plastic containers (dimensions: 30 cm in diameter; 20 cm in depth) buried in the soil up to the top and covered by a plastic dome suspended by 10-cm long sticks. A 300mL water solution and 2% neutral detergent was added to the traps. Traps were set 15 days before the first sampling period (Spring 2010) to avoid the effects of disturbance caused by establishment of the traps, and remained at each sampling site over entire study period.

We placed eight traps in each fragment, distributed in two transects (four traps per transect) (Fig. 2). Within each transect, we distributed the traps at 10-m intervals progressively away from the riverbank. The distance between each pair of transects was 40 m. Trap placement varied with the classes of the riparian vegetation width. In fragments with riparian vegetation wider than 40 m, all traps were placed within the forest habitats. In fragments with riparian vegetation not wider than 30 m, the three pairs of traps closest to the riverbank were placed within the forest fragments, while the remaining pair was placed in the adjacent field (Fig. 2b). In fragments with riparian vegetation

not wider than 15 m, only the pair of traps closest to the riverbank was placed in riparian vegetation. In the fragments with riparian vegetation width narrower than 5 m, all pairs of traps were placed in the adjacent field (Fig. 2). (Viegas et al. 2014). In the laboratory, the adult specimens were determined to the lowest level possible (species or morphospecies), while juveniles were determined to family level. Spiders were preserved in 80% ethanol.

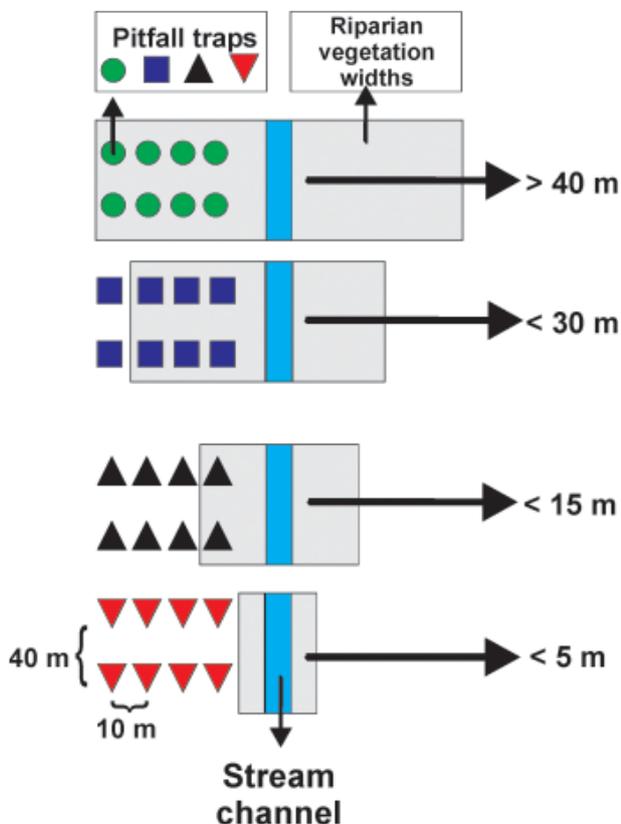


Fig. 2. Schematic figure showing the disposition of the traps across the classes of riparian vegetation width. Adapted from Viegas et al. (2014) and Pires et al. (2020). (one-column width figure).

Spider guild composition

For the assessment of guild composition, we assigned each spider taxa into functional categories based on their hunting strategies and web type using a family-based approach (*i.e.*, family affiliation) (Uetz et al. 1999; Höfer and Brescovit 2001; Rodrigues et al. 2009; Rodrigues and Mendonça 2012). Spider taxa were classified into the four following guilds: (1) orb weavers (ORB; spiders that build bi-dimensional webs); (2) space-web sheet builders (SPW; spiders that build tridimensional webs); (3) hunting runners (HRU; spiders that actively search for prey); and (4) hunting ambushers (HAS; spiders that make use of the sit-and-wait strategy in their search for prey) (Table S1).

Environmental variables

Within the three widest fragments of riparian vegetation width (> 40 m; < 30 m; < 15 m), we measured the amount of leaf litter (coverage and height) as well as canopy cover in the study region. Leaf litter was measured in 50 cm × 50 cm plots (divided into twenty-five 10 cm × 10 cm grids). Leaf litter cover was measured in three 1-m points (one in the middle and two at each end of each fragment). Leaf litter height (cm) was measured in four vertices and at the center of each grid with a ruler. Canopy openness was measured with hemispherical photographs (taken at chest height with a fisheye lens). We estimated the percent canopy cover with the Gap Light Analyzer v.2.0 program (Frazer et al. 1999).

Data analysis

Spider community diversity, taxonomic composition and indicator species

To account for the undetected diversity in the study region, we used the first-order Jackknife1 richness estimator (incidence-based) to calculate the extrapolated richness of spider taxa. For illustration purposes, we built an interpolation-extrapolation curve (and their respective 95% upper and lower confidence intervals) for the total number of sampling units (12). To test for differences in the taxonomic composition of spider communities among riparian vegetation widths and seasons, we use a two-way Permutational Multivariate Analysis of Variance (PERMANOVA) with interaction ('riparian vegetation widths' and 'seasons' as main effects; 9999 permutations) and the tributary identity as blocking factor. This analysis was performed on a resemblance matrix (Sørensen coefficient) of the incidence-based matrix of spider composition. Given that PERMANOVA is sensitive to differences in group dispersion (Anderson and Walsh 2013), we checked the assumption of homogeneity of variance-covariance among groups a priori (*i.e.*, the levels of the main factors) using a permutation-based approach for multivariate datasets (PERMDISP) (Anderson 2006). We ruled out differences in the multivariate dispersion among groups ($P > 0.05$ for each factor) before proceeding to PERMANOVA. We also carried out an indicator species analysis (Dufrene and Legendre 1997) to assess whether frequency and abundance of specific spider taxa would be related with the classes of riparian vegetation widths. We validated the results of the indicator species analysis with a randomization-based approach (999 permutations).

Guild composition

For the assessment of spider guild composition, we calculated the community-weighted means of trait values (CWM). The CWM of a specific trait corresponds to the average values of each trait (i.e., guild) weighted by the relative abundance of each taxon. We ran a one-way PERMANOVA ('riparian vegetation widths' as main effect; 9999 permutations) using the tributary identity as blocking factor to test for differences in spider guild composition among riparian vegetation widths. This analysis was performed on a resemblance matrix (Euclidean distance) of the CWM matrix of spider guilds. Posteriorly, we fitted the values of the CWM matrix to the PCoA ordination diagram. We visually assessed the variation in the taxonomic and guild composition of spider communities among riparian vegetation widths through ordination diagrams based on principal coordinates analysis (PCoA).

Influence of environmental variables on spider communities

We tested the effect of leaf litter coverage, leaf litter height and canopy openness on spider composition across the three wider classes of riparian vegetation widths (> 40 m; < 30 m; < 15 m) through distance-based redundancy analysis (db-RDA). Prior to the analysis, we removed the highly correlated variables ($r > 0.8$; i.e., leaf litter coverage) to avoid collinearity in the explanatory dataset. The environmental variables were standardized (zero mean and unit variance). We thus fitted the db-RDA using leaf litter height and canopy openness as explanatory variables. The response dataset used in the db-RDA was the resemblance matrix (Euclidean distance) of the spider taxa (incidence-based composition and Hellinger-transformed). The significance of the db-RDA was tested using a randomization approach (999 permutations).

In the indicator species analysis and in the assessment of taxonomic composition, we used the subset of adult spiders (i.e., species and morphospecies). For the assessment of guild composition, we used the total number of specimens (adults and juveniles). We carried out all statistical procedures in the R environment v. 3.6.0 (R Core Team 2020). We used the functions available in the packages *FD* (Laliberté and Legendre 2010), *labdsv* (Roberts 2019) and *vegan* (Oksanen et al. 2019).

RESULTS

Spider communities

We collected 1504 specimens (847 adults + 657 juveniles) from 30 families and 85 species and morphospecies (Table S1). Thirty-four species (48%) occurred as singletons and six species (8.4%) as doubletons over the study period. The estimated richness as calculated by the first-order Jackknife estimator suggested that the sampling effort achieved approximately 51.1% of the richness in the region (166.23; SE = 33.74), and the rarefaction=extrapolation curve of taxa did not reach the asymptote (Fig. 3).

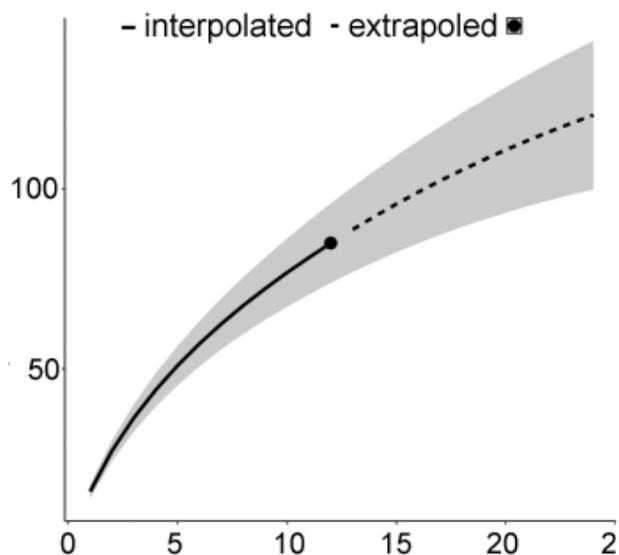


Fig. 3. Sample-size-based interpolation-extrapolation sampling curve of spider taxonomic richness in the study region (based on 500 randomizations). (one-column width figure).

Lycosidae was the most abundant family with 661 specimens (adults and juveniles; 44% of the total number of collected specimens), followed by Linyphiidae (380 specimens; 25.3%) and Tetragnathidae (127 specimens; 8.5%). We collected 816 specimens (adults and juveniles) in fragments with riparian vegetation width wider than 40 m, 329 in fragments with riparian vegetation width of 15–30 m, 177 in fragments with riparian vegetation width < 15 m and 180 in fragments with riparian vegetation width < 5 m (Table 1). Among adults, we collected 34 specimens in Autumn, 51 in the Winter, 374 in the Spring and 225 in the Summer (Table S1).

Table 1. Spider composition (species and morphospecies) in the fragments with different riparian vegetation widths in the study region

	Riparian width	> 40 m	< 30 m	< 15 m	< 5 m	Total
Family (Guild)	Species/Morphospecies					
Araneidae (ORB)	<i>Alpaida leucogramma</i>				1	1
	<i>Alpaida venilae</i>				1	1
	<i>Alpaida versicolor</i>				1	1
Corinnidae (HRU)	<i>Castianeira</i> sp.1	1	2	1		4
	<i>Castianeira</i> sp.2		1	5	4	10
	<i>Castianeira</i> sp.3		1	1		2
	<i>Meriola cetiformis</i>			1		1
Ctenidae (HAS)	Ctenidae sp.1	20	1			21
	Ctenidae sp.2	5	3			8
Gnaphosidae (HRU)	Gnaphosidae sp.1			1		1
	Gnaphosidae sp.2	1				1
	Gnaphosidae sp.3				1	1
	Gnaphosidae sp.4		1			1
	Gnaphosidae sp.5			1		1
	<i>Guaraniella mahnerti</i>		2	3	1	6
Hahniidae (SPW)	Hahniidae sp.1			1		1
Linyphiidae (ORB)	<i>Exocora ribeiroi</i>	2				2
	<i>Laminacauda ignobilis</i>			1		1
	<i>Lepthyphantes</i> sp.		1	2	1	4
	Linyphiidae sp.		1			1
	<i>Meioneta</i> sp.1	48	22	22		92
	<i>Meioneta</i> sp.2	3	18	28	7	56
	<i>Meioneta</i> sp.3	6	6	24	11	47
	<i>Mermessus</i> sp.1		4	6	16	26
	<i>Mermessus</i> sp.2			2	12	14
	<i>Mermessus</i> sp.3		1	3	22	26
	<i>Mermessus</i> sp.4		1			1
	<i>Pseudotyphistes</i> sp.		2	1		3
	<i>Psilocymbium lineatum</i>				1	1
	<i>Scolecuroa</i> sp.	1	4	5		10
	<i>Sphecozone castanea</i>	3				3
	<i>Sphecozone</i> sp.	2				2
	<i>Tutaibo</i> sp.				1	1
	<i>Vesicapalpus serranus</i>	2	6			8
	<i>Vesicapalpus simplex</i>	3		5	2	10
Lycosidae (HRU)	Lycosidae sp.1			5	17	22
	Lycosidae sp.2			3	110	113
	Lycosidae sp.3			7	55	62
	Lycosidae sp.4			2	4	6
	Lycosidae sp.5		1	8	4	13
	Lycosidae sp.6				3	3
	Lycosidae sp.7				1	1
Miturgidae	<i>Teminius insularis</i>		1	2	1	4
Mysmenidae (ORB)	Mysmenidae sp.1		1			1
	Mysmenidae sp.2	1	4	2		7
	Mysmenidae sp.3		1			1
	Mysmenidae sp.4	2				2
Nemesiidae (HAS)	Nemesiidae sp.1	1				1
	Nemesiidae sp.2			1		1
Ochyroceratidae (SPW)	Ochyroceratidae sp.1		4			4
Oonopidae (HRU)	Oonopidae sp.1	1				1
Oxyopidae (HAS)	<i>Oxyopes salticus</i>			15	18	33
Philodromidae (HAS)	<i>Berlandiella magna</i>		1		1	2
	<i>Berlandiella meridionalis</i>				1	1
Pholcidae (SPW)	Pholcidae sp.1			1		1
	Pholcidae sp.2	1				1
Salticidae (HAS)	Salticidae sp.1				1	1
	Salticidae sp.2			2	15	17

	Salticidae sp.3			1	1
	Salticidae sp.4			1	1
	Salticidae sp.5		1		1
	Salticidae sp.6		1		1
	Salticidae sp.7		1		1
	Salticidae sp.8		1		1
	<i>Tullgrenella</i> sp.			1	1
Scytodidae (SPW)	<i>Scytodes</i> sp.1	1	1		1
	<i>Scytodes</i> sp.2	1			1
	<i>Scytodes</i> sp.3		1		1
Selenopidae (HAS)	Selenopidae sp.1		1		1
Tetragnathidae (ORB)	<i>Glenognatha lacteovittata</i>	4	5	30	43
Theridiidae (SPW)	Spintharinae sp.		1		1
	<i>Steatoda</i> sp.			1	1
	<i>Chrosiothes niteroi</i>		7	7	14
	<i>Chryso</i> sp.	26	17		43
	<i>Coleosoma acutiventer</i>		1	1	2
	<i>Cryptachaea dea</i>	1	1		2
	<i>Cryptachaea taim</i>	2			2
	<i>Dipoena pumicata</i>		1		1
	<i>Euryopsis</i> sp.			2	2
	<i>Theridion</i> aff. <i>bergi</i>			13	13
	<i>Thymoites</i> sp.			1	1
Theridiosomidae (ORB)	<i>Theridiosoma chiripa</i>	2			2
Thomisidae (HAS)	<i>Tmarus</i> sp.		1		1
Trachelidae (HRU)	Trachelidae sp.1		1		1
	Trachelidae sp.2			1	1

ORB = orb weavers, SPW = space-web sheet builders, HRU = hunting runners, HAS = hunting ambushers.

Taxonomic and guild composition

The taxonomic composition significantly varied among riparian vegetation widths (Pseudo- $F_{1,34} = 10.12$; $R^2 = 0.17$; $P < 0.001$). The effects of seasons (Pseudo- $F_{3,34} = 1.5$; $R^2 = 0.078$; $P = 0.06$) and of the interaction between riparian vegetation widths and seasons on spider composition (Pseudo- $F_{3,34} = 1.34$; $R^2 = 0.075$; $P = 0.11$) were not significant. Spider composition also significantly differed among tributaries (Pseudo- $F_{3,34} = 2.19$; $R^2 = 0.071$; $P < 0.0047$). The PCoA diagram segregated the two widest riparian vegetation widths (> 40 m and < 30 m) from the two narrowest ones (< 15 m and < 5 m) (Fig. 4a). The following spider taxa were associated with specific riparian vegetation widths: *Chryso* sp. (Theridiidae) and *Meioneta* sp.1 (Linyphiidae) were indicators of riparian vegetation widths > 40 m; *Meioneta* sp.2 (Linyphiidae) was indicator of riparian vegetation width < 15 m; Lycosidae indet.1, Lycosidae indet.2, *Mermessus* sp.2, *Mermessus* sp.3, (Linyphiidae) and Salticidae indet.2 were indicators of riparian vegetation widths < 5 m.

Spider guild composition (Table S1) varied significantly among riparian vegetation widths (PERMANOVA Pseudo- $F_{3,40} = 6.97$; $R^2 = 0.33$; $P < 0.001$). The first PCoA axis segregated the two widest widths from the two narrowest ones. The fitted values of the guild CWM matrix onto the PCoA ordination diagram evidenced significant relationships between some of the guilds and

riparian vegetation widths. Space-web sheet builders and hunting ambushers predominated in the two wider widths, while hunting runner guild predominated in the two narrower widths (Fig. 4b).

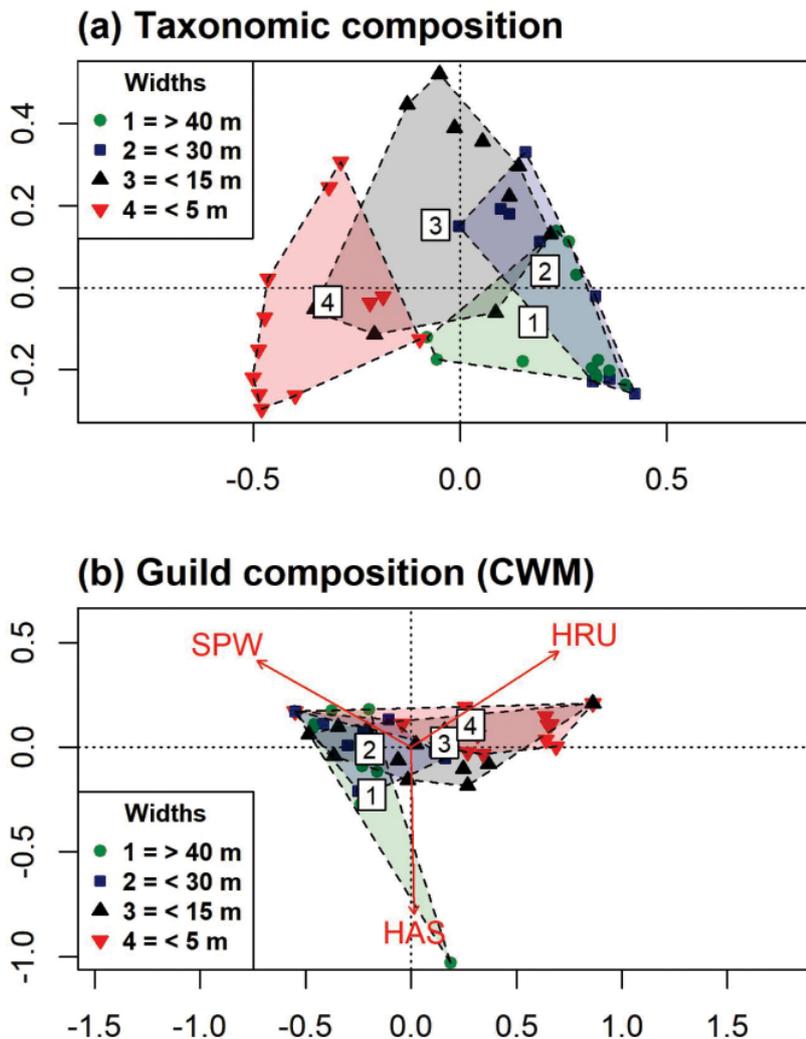


Fig. 4. PCoA ordination diagrams of the (a) taxonomic and (b) guild composition of ground-dwelling spider communities among riparian vegetation widths. Abbreviations in (b): HRU = hunting-runner spiders; HAS = hunting-ambusher spiders; SPW = space-web sheet builder spiders. (two-column width figure).

Influence of environmental variables on spider communities

Spider composition was significantly associated with leaf litter height and canopy openness across the classes of riparian vegetation widths ($F = 1.65$; $R^2 = 0.073$; $P < 0.001$). In general, leaf litter height was directly associated with the composition of spider communities in the two widest riparian vegetation width (> 40 and < 30 m), while spider composition in the narrowest width (< 15 m) was associated with canopy openness (Fig. 5).

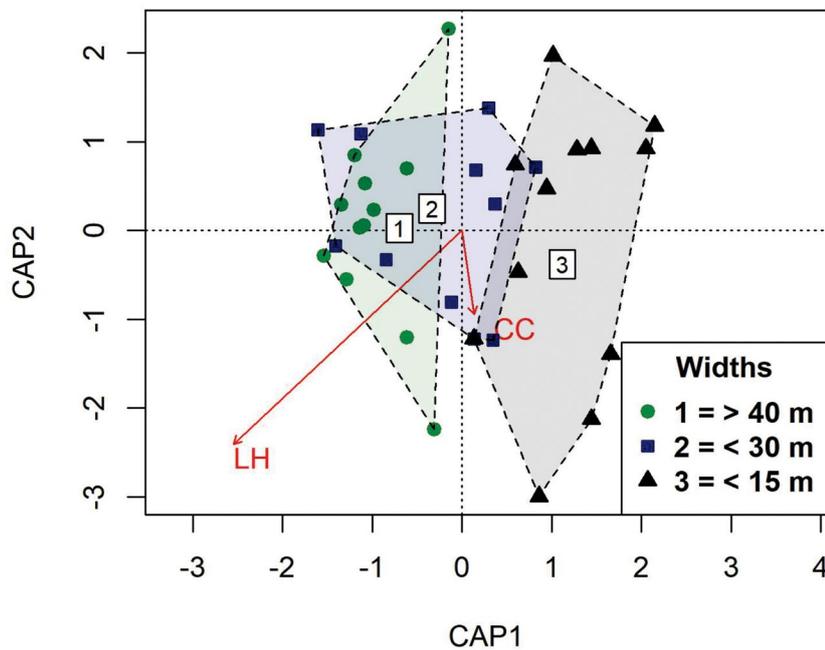


Fig. 5. Biplot of the distance-based redundancy analysis (dbRDA) for the relationship between the composition of ground-dwelling spiders and environmental variables across the classes of riparian vegetation width in the study region. CC = canopy cover; LH = leaf litter height. (one-column width figure).

DISCUSSION

The community structure of ground-dwelling spiders significantly varied among riparian vegetation fragments with different widths in Southern Brazil. Several studies showed that the composition of spider communities is affected by the changes in the integrity of the riparian vegetation (Bell et al. 1999; Buddle et al. 2004; Bonn et al. 2002; Laeser et al. 2005; Rodrigues et al. 2014; Hunt et al. 2020; Ramberg et al. 2020). However, the relationships between ground-dwelling spiders and riparian vegetation habitats have been largely overlooked in the Neotropical region, especially in non-tropical areas (Rodrigues 2011). In addition, most studies in this region focused the effects of conversion of riparian forest to other land uses or compared vegetation types (Lo-Man-Hung et al. 2011; Bizuet-Flores et al. 2015; da Rosa et al. 2019) rather than a gradient of forest widths. Here, spider taxonomic and guild composition differed among the two widest (> 40 m and < 30 m) and the two narrowest riparian vegetation widths (< 15 m and < 5 m). Our results are in line with the findings describing that the composition of soil spiders is affected by forest loss (Laeser et al. 2005), and they support our hypothesis that spider communities would respond to reduction in riparian vegetation widths.

Role of pitfall trapping

We highlight that the patterns here detected should take into account the limitations rendered by the pitfall-trapping methodology used for spider sampling. Pitfall traps are biased towards large-sized and high-mobility taxa (*e.g.*, ground-hunting, running, stalking spiders) (Turnbull 1973; Uetz and Unzicker 1976; Topping and Sunderland 1992; Weeks and Holtzer 2000; Bali et al. 2019). Given that, many authors highlighted that this method is not the most effective one for capturing the overall diversity of spiders (Turnbull 1973; Azevedo et al. 2014; Privet et al. 2020). Nevertheless, recent studies demonstrated that pitfall-trapping procedures are as useful as the most recommended methods (*e.g.*, nocturnal hunting) in the assessment of the taxonomic and guild composition of ground spiders along gradients of habitat structure in Neotropical forests (Privet et al. 2020), such as the covered in this study. Despite the limitations of the pitfall traps with respect to the estimation of local abundance of spiders, they can be reliable surrogates of the activity-density patterns of ground-dwelling spiders (Turnbull 1973; Topping and Sunderland 1992; Lafage et al. 2019). Therefore, we consider that our procedures provide an adequate estimate of the community structure of ground spiders across the classes of riparian vegetation.

Spider species composition and influence of environmental variables

As for the expectation on spider distribution among the classes of riparian vegetation width, the analysis of guild composition showed that space-web weaving taxa predominated in the two wider widths (> 40 m and < 30 m), while hunting runner guilds predominated in the two narrower widths (< 15 m and < 5 m). This result was further reinforced by the indicator species analysis, which showed that space-web sheet builders taxa (*Chryss* sp.; Theridiidae) were indicators of the widest riparian width, while hunting spiders (taxa from Linyphidae and Lycosidae families) were indicators of the narrowest riparian vegetation widths. Our results are consistent with earlier findings showing that web-building taxa were more sensitive to the loss of riparian vegetation (Miyashita et al. 1998; Laeser et al. 2005; Rodrigues and Mendonça 2012). The distribution of the spider fauna is related to several aspects of the vegetation structure in riparian habitats. Changes in the structure of the riparian vegetation alter environmental conditions that influence the establishment of spiders with various foraging strategies and mobility (Bell et al. 1999; Bonn et al. 2002; Laeser et al. 2005; Rodrigues et al. 2014; Hunt et al. 2020; Ramberg et al. 2020). For instance, reductions in riparian vegetation width could have represented an increasing edge effect to the web-building taxa in the study area, as found by many authors (Miyashita et al. 1998; Baldissera et al. 2004; Laeser et al. 2005; Rodrigues and Mendonça 2012; Ramberg et al. 2020). In specific, the edge effect could have acted through changes in microclimate such as reduced wind speeds, conditions that could have favored the web construction.

Leaf litter height and canopy openness accounted for the distribution patterns of ground-dwelling spiders across the three wider classes of riparian vegetation width in the study area. In specific, spider composition was significantly associated with leaf litter height in the two widest riparian vegetation width (> 40 and < 30 m), while spider composition was associated with canopy openness in the narrowest width (< 15 m). This result roughly corroborates the views on the effects of litter height on the spider community (Hore & Uniyal 2008). In general, the higher amount of litter in the wider riparian vegetation could have allowed the establishment of the web-building taxa and decreased the dominance of cursorial spiders (Uetz 1976, 1979; Bultman and Uetz 1982; Hore and Uniyal 2008). The association between web-building and higher amounts of litter could have been facilitated through increased prey availability. In specific, leaf litter were associated with increasing abundance of potential prey (*e.g.*, beetles) in the study area (Viegas et al. 2014).

The increased canopy openness in the narrower widths was associated with cursorial taxa (*e.g.*, hunting spiders). Many ground-dwelling spiders are large-sized specimens with cursorial habits and high mobility (Uetz and Unzicker 1976; Weeks and Holtzer 2000). Such traits could have favored these taxa in open habitats like the narrower widths (Peres et al. 2007; Pitilin et al. 2019). This assumed high mobility of a subset of the ground-dwelling species can also be the potential mechanism underlying the similar community composition within tributaries. Tonkin et al. (2016) provided evidenced that spider communities in riparian habitats can be little limited by dispersal within networks. In turn, the increasing forest loss can limit the exchange of among watersheds (Raizer et al. 2005b; Lambeets et al. 2010) and account for the significant difference in spider composition among tributaries.

Finally, another potential mechanism explaining the differential distribution could be associated with trophic dynamic across vegetation widths. In specific, recent studies in the region found significant differences in the composition of aquatic macroinvertebrates among the studied riparian vegetation widths (Moraes et al. 2014; Braun et al. 2018; Pires et al. 2020). Given that aquatic insects are important components of the diet of riparian spiders, especially web-building spiders (Kato et al. 2003; Sanzone et al. 2003; Krell et al. 2015; Tagwireyi and Sullivan 2016; Hunt et al. 2020), the differential availability of prey items could have potentially affected the spider fauna in the riparian fragments in the study area.

CONCLUSIONS

Our study evidenced that the taxonomic and guild composition of ground-dwelling spiders varied among the widest (> 40 and < 30 m) and narrower riparian widths (< 15 m and < 5 m) in

Southern Brazilian riparian forests. In specific, web-building taxa specialized in fragments with wider riparian vegetation, whereas high-mobility taxa (*e.g.*, cursorial spiders) predominated in the narrower fragments, thus in accordance with our expectation on the differential responses of spiders to reduction in riparian vegetation widths. In addition, spider composition was significantly associated with leaf litter height in the two widest riparian vegetation width (> 40 and < 30 m) and with canopy openness in the narrowest width (< 15 m). Our results showed that reductions in riparian vegetation width were associated with significant changes in the community structure of ground-dwelling spiders, likely through top-down mechanisms associated with the higher input of litter by the riparian vegetation in wider fragments. In summary, the strong degradation and fragmentation of the riparian forests of the Sinos River basin probably influenced the results, with human disturbance gradients negatively associated with the occurrence of web-building spider taxa. Based on our results, we suggest that forest managers should avoid the substitution of native riparian vegetation in the Atlantic Forest at the region. Finally, our results also suggest that buffer strips narrower than 15 m can be impact thresholds on the activity and distribution of the ground-dwelling spiders in Southern Brazilian riparian forests.

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Supplementary Materials

Table S1. Composition of spiders (adults) species and morphospecies, and guilds in the fragments with different riparian vegetation widths over the seasons (A = Fall, W = Winter; Sp = Spring, Su = Summer; ORB = orb weavers, SPW = space-web sheet builders, HRU = hunting runners, HAS = hunting ambushers. (download)