

**The effect of stressors, disturbance regimes
and environmental gradients on riparian
arthropods: implications for management and
conservation**

By

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PREFACE

This thesis is submitted to the School of Agriculture and Science, College of Agriculture, Engineering and Science, University of KwaZulu-Natal (UKZN), Pietermaritzburg, South Africa, for the degree of Master's in Entomology, under the supervision of Prof. Caswell Munyai, Prof. Rob Slotow and Dr. Sindiso Nkuna. The research was financially supported by Durban Research Action Partnership (D'RAP), Oppenheimer Fellowship in Biodiversity and National Research Foundation (NRF).

This thesis has been prepared according to **Format 2** as outlined in the UKZN information for the guidance of examiners of Higher degrees, as a set of papers which are published, in press, submitted, or intended for submission.

As the candidate's supervisor, I have approved this thesis for submission.


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ABSTRACT

Riparian zones remain highly threatened by anthropogenic activities and climate change despite being ecologically valuable ecosystems. Understanding their complex and dynamic nature is crucial to effectively restore, manage, and conserve them and their biodiversity. Therefore, this study aimed to examine the influence of riparian environmental gradients, stressors, and disturbance regimes on the biodiversity of terrestrial arthropods and their implications for management and conservation policies. The first objective was to systematically review, using PRISMA guidelines, the response of riparian arthropods to flooding, alien plant invasion, and river engineering at a global scale and identify potential management strategies. The second objective was to determine, at a local scale, whether seasonal changes, location and increasing distance along the uMngeni riparian habitats, and from these habitats to the adjacent uplands, affect ant and spider diversity, community composition, and their foraging strategies, using pitfall traps. Findings from the systematic review highlighted that terrestrial arthropods' biodiversity was predominantly adversely affected by flooding, alien plant invasion, and river engineering due to changes in environmental conditions, although responses to alien plant invasion differed among taxa. At the local scale, ant and spider richness in the studied gradients were not affected by seasonality or distance from the river and along the river. However, during the wet season, ant abundance decreased with increasing distance from the riparian to the upland areas, while spider abundance increased. The representation of spider foraging strategies was affected by season and location (study sites: Umgenipoort vs Hilton), contrary to that of ants which was only influenced by distance. Distance from the riparian habitats to the uplands significantly influenced ant community composition, whereas seasonal variation was the primary driver of spider community composition. Species turnover mainly accounted for overall beta diversity, with some ant and spider species unique to specific distances within the studied gradients. To conserve riparian biodiversity and function from further threats, eligible studies from the systematic review suggested creating and protecting heterogeneous habitats within riparian zones, restoring native vegetation and natural water flow, while considering species-specific ecological needs. This study has highlighted the factors that compromise riparian biodiversity and ecological processes that explain the observed patterns, providing valuable insights for conservationists to predict ecological changes. It also highlights the need for collaboration and long-term monitoring to sustain biodiversity and ecosystem functions along riparian zones.

Keywords: arthropod, flooding, river engineering, alien plant invasion, upland, gradient

DECLARATIONS

DECLARATION 1: PLAGIARISM

I, Asande Hadebe declare that:

1. The research reported in this thesis is my original research, except where otherwise indicated.
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DECLARATION 2: PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis:

PUBLICATION 1 (in preparation)

The response of terrestrial arthropods to natural and anthropogenically altered disturbance and stress regimes in riparian zones: A systematic review

Target Journal = Freshwater Biology

A. Hadebe, R. Slotow, S. Nkuna and T.C. Munyai

Author contributions:

AH: conceptualization, methodology, original draft. **TCM, SN, RS:** conceptualization, supervision, review and editing

PUBLICATION 2 (in preparation)

Environmental factors affecting ant and spider biodiversity patterns in riparian habitats and the surrounding uplands of the uMngeni River, KwaZulu-Natal Midlands, South Africa
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DECLARATION 3: CONFERENCE PROCEEDINGS

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Date: November 2025

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Working in riparian zones was, at first, an act of courage for someone who had always feared deep and large water bodies. Therefore, this dissertation is more than an academic pursuit and a product of my effort; it reflects every person, moment, and encouragement that carried me here.

TABLE OF CONTENTS

PREFACE.....	ii
ABSTRACT.....	iii
DECLARATION 1: PLAGIARISM	iv
DECLARATION 2: PUBLICATIONS	v
DECLARATION 3: CONFERENCE PROCEEDINGS	vi
ACKNOWLEDGEMENTS.....	vii
TABLE OF CONTENTS.....	viii
LIST OF TABLES.....	x
LIST OF FIGURES	11
CHAPTER 1: Introduction	13
1.1 Background of the study	13
1.2 Problem statement.....	14
1.3 Hypothesis, aim and objectives.....	15
1.4 References.....	17
CHAPTER 2 : The response of terrestrial arthropods to natural and anthropogenically altered disturbance and stress regimes in riparian zones: A systematic review	22
Abstract.....	22
2.1 Introduction.....	23
2.2 Methods and materials	25
2.3 Results.....	28
2.4 Discussion	31
2.5 Conclusion	38
2.6 References.....	39
CHAPTER 3 : The effect of distance along the uMngeni riparian habitats and from these habitats to the uplands on ant and spider biodiversity patterns in the KwaZulu-Natal Midlands	
46	
Abstract.....	46
3.1 Introduction.....	47

3.2	Methods and materials	49
3.2.1	<i>Study sites</i>	49
3.2.2	<i>Arthropod sampling</i>	50
3.2.3	<i>Statistical analysis</i>	52
3.3	Results.....	53
3.4	Discussion.....	69
3.5	References.....	74
CHAPTER 4	: Conclusions and recommendations	81
4.1	Study summary	81
4.2	Contributions of the study.....	82
4.3	Future directions	83
4.4	References.....	84
Supplementary material		Error! Bookmark not defined.
Chapter 2 material		86
Chapter 3 material		97

LIST OF TABLES

Table 1: Inclusion and exclusion criteria for study selection.....26

Table 2: Categories used to classify the impact of disturbance or stressor on terrestrial arthropods.27

LIST OF FIGURES

Figure 2.1: Flow diagram summarizing the global study selection process for systematically reviewing the responses of terrestrial arthropods to natural and anthropogenically altered disturbance or stressors in riparian zones.	29
Figure 2.2: Synthesis of eligible study outcomes showing the response (negative, positive, no effect, changed, unchanged and unclear) of terrestrial arthropods to alien plant invasion, flooding and river engineering (a), ecological parameters measured (abundance, richness, diversity and assemblage composition; b) and across taxonomic groups (c).	30
Figure 2.3: Geographic location of eligible studies projected on the world map.	31
Figure 3.1: Map of the uMngeni River in the KwaZulu-Natal province, South Africa (Department of Water Affairs, 2002), showing the locations of the sampled study sites	51
Figure 3.2: The sampling design for collecting ground-dwelling ants and spiders along the longitudinal and lateral gradients of the uMngeni River.	52
Figure 3.3: Ant abundance (a) and richness (b) from the uMngeni riparian habitat (0 m), to the uplands (50 m, 100 m, 300 m), location (Hilton, Umgenipoort) and season (wet and dry), with bars filled with their foraging strategies.	55
Figure 3.4: Spider abundance (a) and richness (b) from the uMngeni riparian habitats (0 m) to the uplands (50 m, 100 m, 300 m), location (Hilton, Umgenipoort) and season (wet and dry), with bars filled by foraging strategies.....	57
Figure 3.5: Ant abundance (a) and richness (b) along the longitudinal gradient of the uMngeni riparian zones (0 m, 50 m, 100 m, 300 m, 700 m, 1000 m, 2200 m), location (Hilton, Umgenipoort) and season (wet and dry), with bars filled by their foraging strategies.....	58
Figure 3.6: Spider abundance (a) and richness (b) along the longitudinal gradient of the uMngeni riparian zones (0 m, 50 m, 100 m, 300 m, 700 m, 1000 m, 2200 m), location (Hilton, Umgenipoort) and season (wet and dry), with bars filled by foraging strategies.	60
Figure 3.7: Non-Metric Multidimensional Scaling (NMDS) ordination of ant (a) and spider (b) community composition from the riparian habitat (0 m) to the uplands (50 m, 100m, 300 m). The distances are shown by colour, seasons are represented by shape, locations are differentiated by the size of the shape and convex hulls surround seasons. Stress values more than 0.2 should be interpreted with caution (Clarke, 1993).....	61

Figure 3.8: Relationship between turnover and nestedness and spatial distance for ant (a) and spider (b) community composition from the riparian habitat (0 m) to the uplands (50 m, 100 m, 300 m) during the dry and wet seasons.....	64
Figure 3.9: Mean Jaccard dissimilarity index showing gradual changes in ant (a) and spider (b) communities from the riparian habitat to the uplands across Hilton and Umgenipoort. ...	65
Figure 3.10: Non-Metric Multidimensional Scaling (NMDS) ordination of ant (a) and spider (b) community composition along the riparian habitat. The distances are shown by colour, seasons are represented by shape, locations are differentiated by the size of shape and convex hulls surround seasons. Stress values more than 0.2 should be interpreted with caution (Clarke, 1993).	66
Figure 3.11: Relationship between turnover and nestedness and spatial distance for ant (a) and spider (b) community composition along the riparian habitat during the wet and dry season.	68
Figure 3.12: Mean Jaccard dissimilarity index showing gradual changes in ant (a) and spider (b) communities along the riparian habitats across Hilton and Umgenipoort.	69

CHAPTER 1: Introduction

1.1 Background of the study

Riparian zones are transitional areas between land and freshwater ecosystems, including riverbanks and floodplains (Wang et al., 2019a; Urbanič et al., 2022; Dahal and Chakraborty, 2024). They are dynamic ecosystems shaped by land uses, geomorphological and bioclimatic factors (Riis et al., 2020). Their interconnected nature allows them to regulate floods, filter pollutants (Singh et al., 2021), control erosion, contribute to climate change resilience (Dyakov and Zhelev, 2013; Riis et al., 2020), and sustain rich biodiversity (Sabo et al., 2005; Wang et al., 2019b), making them crucial for environmental resilience and human well-being (Jakubínský et al., 2021). Furthermore, recognizing their tourism potential could provide economic incentives for their preservation while balancing environmental protection with community benefits (Dahal and Chakraborty, 2024). Therefore, their ecological, cultural, and economic significance makes them essential for conservation and sustainable development (Singh et al., 2021; Dahal and Chakraborty, 2024).

Although over 50% of the world's river water is used for human use (Feld et al., 2018), there is still a high demand for hydro-electric power, water storage, and supply, leading to their morphological and hydrological modifications (Paetzold et al., 2008; Wang et al., 2019b; Xiao et al., 2022). These alterations alter the natural flow regimes (Paetzold et al., 2008; Wang et al., 2019b) in which the flood dynamics are the key drivers of riparian ecosystem structure and function (Naiman and Décamps, 1997; Frisch et al., 2004; Xiao et al., 2020). The ecological importance of predictable, moderate floods in maintaining the productivity and biodiversity of riparian zones can be explained by the Flood Pulse Concept (which describes how seasonal floods shape the productivity and biological interactions of riparian habitats) and Intermediate Disturbance Hypothesis (Connell, 1979; Junk et al., 1989). However, alterations to natural flood regimes may lead to elevated or reduced water levels, prolonged or shortened flood durations, and shifts in seasonal timing, potentially resulting in negative impacts on biodiversity (Wang et al., 2019b). By altering habitat conditions, nutrient distribution, and species composition, floods influence biodiversity, ecological services, resource availability, and ultimately, vulnerability to alien plant invasion (Yoshioka et al., 2010; Zelnik et al., 2015; Jakubínský et al., 2021; Anđelković and Radulović, 2022).

Rivers shape distinct environmental gradients both along their course (longitudinal) and across their surrounding landscapes (lateral) that influence species diversity (Wishart, 2000; Sabo et al., 2005), whereby the high spatial and temporal heterogeneity of riparian zones increase

resource availability and niche overlap, making them complex and distinct from adjacent ecosystems (Ward et al., 2002; Singh et al., 2021). This is mainly due to their strong association with water, resulting in different soil properties, microclimates, vegetational composition, and structure than the uplands (Zelnik et al., 2015; Ramey and Richardson, 2017). However, the seasonal fluctuations of environmental conditions can drive higher species turnover when species struggle to adapt to habitat changes (Ramey and Richardson, 2017). While some mobile species can benefit from riparian zones seasonally, they remain dependent on the uplands for most of their life cycle (Sabo et al., 2005).

The reciprocal exchange of energy and nutrients between rivers, riparian zones, and their uplands further highlights their close association (Baxter et al., 2005; Nyffeler and Pusey, 2014; Middendorf et al., 2025). Invertebrates exemplify this relationship, as some aquatic invertebrates serve as prey for terrestrial predators such as birds and spiders, while other terrestrial invertebrates serve as food for fish, connecting the two ecosystems (Kato et al., 2003; Baxter et al., 2005; Xiang et al., 2016; Wang et al., 2019b). This trophic link is pronounced in riparian spiders, whose diet contains 40% to 80% aquatic insects and drops sharply to less than 1% when 20 meters away from the river (Jackson et al., 2016; Xiang et al., 2016; Ramey and Richardson, 2017). On the other hand, the high diversity of invertebrates allows them to play multiple functional roles in an ecosystem, such as pollination (Calderone, 2012), soil aeration (Lavelle et al., 2006), nutrient recycling (McCary and Schmitz, 2021), seed dispersal (Lengyel et al., 2010) and population regulation (Carlson, 2025). Among them, ants are noteworthy and considered ecosystem engineers due to their ability to alter physical and chemical soil properties during nest construction, as well as their interactions with vegetation and other invertebrates, which they also prey upon, thereby promoting habitat heterogeneity and ecological niches (De Almeida et al., 2020). Similarly, ants and spiders have diverse foraging strategies (functional guilds) that are influenced by resource availability and environmental conditions (Nelson and Jackson, 2011; Lanan, 2014). However, species diversity and foraging strategies can exhibit varied responses to similar abiotic influences (Griotti et al., 2017). It is therefore essential to consider both taxonomic and functional diversity to gain a deeper understanding of community dynamics in any studied system.

1.2 Problem statement

Anthropogenic activities increasingly threaten tropical and subtropical riparian zones, yet much of their biodiversity remains poorly documented (Murgu and Rîșnoveanu, 2023). Invertebrates make ideal biological indicators for monitoring riparian zone health due to their

sensitivity to environmental changes (Xiao et al., 2020; Zina et al., 2021; Ye et al., 2024). However, the current state of knowledge primarily focuses on plants and aquatic species, for example, fish (Pusey and Arthington, 2003; Xiong et al., 2021), riparian vegetation (Dyakov and Zhelev, 2013; Riis et al., 2020; Singh et al., 2022), and aquatic insects (Siegloch et al., 2016; Twining et al., 2021), often overlooking terrestrial invertebrates such as ants and spiders.

While studies have begun to address the under-representation of terrestrial invertebrates and how they are impacted by riparian environmental gradients and disturbance regimes in developed countries, for example, in European countries (Adis and Junk, 2002; Paetzold et al., 2008; Maceda-Veiga et al., 2016) and China (Wang et al., 2019a, 2019b), the scarcity of studies remains pronounced in African countries (Pedraza et al., 2021; Middendorf et al., 2025). In South Africa, the uMngeni catchment is one of the most important rivers in KwaZulu-Natal, providing surrounding communities and four dams with water whilst being heavily impacted by anthropogenic factors (Agunbiade and Moodley, 2014; Singh and Lin, 2015; Mdluli et al., 2023). Its riparian zones serve as early indicators of environmental change and play a crucial role in mediating interactions between terrestrial and aquatic ecosystems (Dyakov and Zhelev, 2013). Given the ecological and socio-economic value of the uMngeni River, knowledge about its riparian zones in their less modified state is crucial for informing conservation and restoration efforts (Ward et al., 2002). Although aquatic invertebrates in the uMngeni River have been monitored using standard bioassessment tools (Mbanjwa, 2025), no study has explored the riparian arthropods of the uMngeni River.

Furthermore, studies have documented that the dynamic nature of river ecosystems makes them highly susceptible to climate change and anthropogenic activities, causing distorted biodiversity patterns; however, there is still a lack of sufficient data for applicable conservation and restoration measures (Ward et al., 2002; Feld et al., 2018; Jakubínský et al., 2020). This limitation creates a knowledge gap that hinders the development of effective conservation and management strategies along the riparian zone of the uMngeni catchment.

1.3 Hypotheses, aim and objectives

The systematic review hypothesized that globally, given the susceptibility of riparian zones to climate change and anthropogenic activities, flooding, river engineering, and alien plant invasion will negatively impact the biodiversity of terrestrial arthropods. Along the uMngeni catchment, it was hypothesized that the complexity of riparian zones would support highly

diverse arthropod foraging strategies and unique community composition compared to the adjacent uplands.

Aim:

To examine the influence of riparian environmental gradients, stressors, and disturbance regimes on the biodiversity of terrestrial arthropods at various scales and their implications on management and conservation policies.

Objectives:

1. To systematically review the response of riparian arthropods to flooding, alien plant invasion, and river engineering at a global scale and identify potential management strategies (Chapter 2).
2. To determine the global distribution of eligible studies examining the effects of disturbance and stressors on riparian arthropods (Chapter 2).
3. To determine whether seasonal changes, location and increasing distance along the uMngeni riparian habitats and from the riparian to the uplands affect the distribution of ant and spider diversity and their foraging strategies in the KwaZulu-Natal Midlands (Chapter 3).
4. To determine how ant and spider community composition differ between seasons, localities and distances (beta diversity) in both gradients and whether beta diversity increase with increasing distance along and from the riparian zones to the uplands (Chapter 3).

1.4 References

- Adis, J., Junk, W.J., 2002. Terrestrial invertebrates inhabiting lowland river floodplains of Central Amazonia and Central Europe: a review. *Freshwater Biology* 47(4), 711-731.
- Agunbiade, F.O., Moodley, B., 2014. Pharmaceuticals as emerging organic contaminants in Umgeni River water system, KwaZulu-Natal, South Africa. *Environmental Monitoring and Assessment* 186(11), 7273-7291.
- Anđelković, A., Radulović, S., 2022. The role of riparian areas in alien plant invasions. *Acta Herbologica* 31(2), 93-104.
- Baxter, C.V., Fausch, K.D., Carl Saunders, W., 2005. Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. *Freshwater Biology* 50(2), 201-220.
- Calderone, N.W., 2012. Insect pollinated crops, insect pollinators and US agriculture: trend analysis of aggregate data for the period 1992-2009. *PLoS One* 7(5), e37235.
- Carlson, P.E., 2025. The influence of land use, microhabitat and aquatic insect subsidies on predatory riparian arthropod distributions. *Aquatic Sciences* 87(1), 26.
- Connell, J.H., 1979. Response: intermediate-disturbance hypothesis. *Science* 204(4399), 1345-1345.
- Dahal, R., Chakraborty, S., 2024. The study of riparian areas in tourism: toward a conceptual framework of riparian tourism. *Proceedings of the International Association of Hydrological Sciences* 387, 47-51.
- De Almeida, T., Mesleard, F., Santonja, M., Gros, R., Dutoit, T., Blight, O., 2020. Above-and below-ground effects of an ecosystem engineer ant in Mediterranean dry grasslands. *Proceedings of the Royal Society B* 287(1935), 20201840.
- Dyakov, N., Zhelev, P., 2013. Alien species invasion and diversity of riparian forest according to environmental gradients and disturbance regime. *Applied Ecology and Environmental Research* 11(2), 249-272.
- Feld, C.K., Fernandes, M.R., Ferreira, M.T., Hering, D., Ormerod, S.J., Venohr, M., Gutiérrez-Cánovas, C., 2018. Evaluating riparian solutions to multiple stressor problems in river ecosystems—a conceptual study. *Water Research* 139, 381-394.
- Frisch, D., Libman, B.S., D'Surney, S.J., Threlkeld, S.T., 2004. Diversity of floodplain copepods (Crustacea) modified by flooding: species richness, diapause strategies and population genetics. *Archiv fur Hydrobiologie* 162(1), 1-18.

- Griotti, M., Muñoz-Escobar, C., Ferretti, N.E., 2017. Linking vegetation structure and spider diversity in riparian and adjacent habitats in two rivers of Central Argentina: An analysis at two conceptual levels. *Environmental Entomology* 46(4), 794-803.
- Jackson, M.C., Woodford, D.J., Bellingan, T.A., Weyl, O.L., Potgieter, M.J., Rivers-Moore, N.A., Ellender, B.R., Fourie, H.E., Chimimba, C.T., 2016. Trophic overlap between fish and riparian spiders: potential impacts of an invasive fish on terrestrial consumers. *Ecology and Evolution* 6(6), 1745-1752.
- Jakubínský, J., Pelíšek, I., Cudlín, P., 2020. Linking Hydromorphological Degradation with Environmental Status of Riparian Ecosystems: A Case Study in the Stropnice River Basin, Czech Republic. *Forests* 11(4), 460.
- Jakubínský, J., Prokopová, M., Raška, P., Salvati, L., Bezak, N., Cudlín, O., Cudlín, P., Purkyt, J., Vezza, P., Camporeale, C., Daník, J., 2021. Managing floodplains using nature-based solutions to support multiple ecosystem functions and services, *Wiley Interdisciplinary Reviews: Water* 8(5), e154.
- Junk, W.J., Bayley, P.B., Sparks, R.E., 1989. The flood pulse concept in river-floodplain systems. *Canadian Special Publication of Fisheries and Aquatic Sciences* 106(1), 110-127.
- Kato, C., Iwata, T., Nakano, S., Kishi, D., 2003. Dynamics of aquatic insect flux affects distribution of riparian web-building spiders. *Oikos* 103(1), 113-120.
- Lanan, M., 2014. Spatiotemporal resource distribution and foraging strategies of ants (Hymenoptera: Formicidae). *Myrmecological News/Osterreichische Gesellschaft für Entomofaunistik* 20, 53-70.
- Lavelle, P., Decaëns, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., Margerie, P., Mora, P., Rossi, J.P., 2006. Soil invertebrates and ecosystem services. *European Journal of Soil Biology* 42, S3-S15.
- Lengyel, S., Gove, A.D., Latimer, A.M., Majer, J.D., Dunn, R.R., 2010. Convergent evolution of seed dispersal by ants, and phylogeny and biogeography in flowering plants: a global survey. *Perspectives in Plant Ecology, Evolution and Systematics* 12(1), 43-55.
- Maceda-Veiga, A., Basas, H., Lanzaco, G., Sala, M., De Sostoa, A., Serra, A., 2016. Impacts of the invader giant reed (*Arundo donax*) on riparian habitats and ground arthropod communities. *Biological Invasions* 18(3), 731-749.
- Mbanjwa, S.T., 2025. A Cross-sectional bio-assessment of ecological integrity using SASS5 in the Umngeni, Thukela, Umvoti, Umdloti, and Umfolozi rivers, KwaZulu-Natal. *Student's Journal of Health Research Africa* 6(6), 9.

- McCary, M.A., Schmitz, O.J., 2021. Invertebrate functional traits and terrestrial nutrient cycling: Insights from a global meta-analysis. *Journal of Animal Ecology* 90(7), 1714-1726.
- Mdluli, S., Vosloo, D., Lebepe, J., 2023. Biochemical and Histopathologic Biomarkers of Pollution in the uMgeni River System in KwaZulu-Natal, South Africa. *Polish Journal of Environmental Studies* 32(5), 4739-4752.
- Middendorf, F., Bundschuh, M., Eitzinger, B., Entling, M.H., Schirmel, J., 2025. Review of the importance of aquatic prey for riparian arthropod predators. *Basic and Applied Ecology* 86, 1-10.
- Murgu, C.A., Rîșnoveanu, G., 2023. Bridging the gaps: exploring aquatic–terrestrial connectivity through the trait-based ecology of riparian predatory arthropods. *Water* 15(22), 3983.
- Naiman, R.J., Décamps, H., 1997. The ecology of interfaces: riparian zones. *Annual Review of Ecology and Systematics* 28(1), 621-658.
- Nelson XJ, Jackson RR. 2011. Flexibility in the foraging strategies of spiders. In: Herberstein ME, ed. *Spider Behaviour: Flexibility and Versatility*. Cambridge: Cambridge University Press, 13-56.
- Nyffeler, M., Pusey, B.J., 2014. Fish predation by semi-aquatic spiders: a global pattern. *PLoS One* 9(6), e99459.
- Paetzold, A., Yoshimura, C., Tockner, K., 2008. Riparian arthropod responses to flow regulation and river channelization. *Journal of Applied Ecology* 45, 894-903.
- Pedraza, S., Clerici, N., Zuluaga Gaviria, J.D., Sanchez, A., 2021. Global Research on Riparian Zones in the XXI Century: A Bibliometric Analysis. *Water* 13(13), 1836.
- Pusey, B.J., Arthington, A.H., 2003. Importance of the riparian zone to the conservation and management of freshwater fish: a review. *Marine and freshwater Research* 54(1), 1-16.
- Ramey, T.L., Richardson, J.S., 2017. Terrestrial invertebrates in the riparian zone: mechanisms underlying their unique diversity. *BioScience* 67(9), 808-819.
- Riis, T., Kelly-Quinn, M., Aguiar, F.C., Manolaki, P., Bruno, D., Bejarano, M.D., Clerici, N., Fernandes, M.R., Franco, J.C., Pettit, N., Portela, A.P., 2020. Global overview of ecosystem services provided by riparian vegetation. *BioScience* 70(6), 501-514.
- Sabo, J.L., Sponseller, R., Dixon, M., Gade, K., Harms, T., Heffernan, J., Jani, A., Katz, G., Soykan, C., Watts, J., Welter, J., 2005. Riparian zones increase regional species richness by harboring different, not more, species. *Ecology* 86(1), 56-62.

- Siegloch, A.E., Schmitt, R., Spies, M., Petrucio, M., Hernández, M.I.M., 2016. Effects of small changes in riparian forest complexity on aquatic insect bioindicators in Brazilian subtropical streams. *Marine and Freshwater Research* 68(3), 519-527.
- Singh, A., Lin, J., 2015. Microbiological, coliphages and physico-chemical assessments of the Umgeni River, South Africa. *International Journal of Environmental Health Research* 25(1), 33-51.
- Singh, R., Tiwari, A.K., Singh, G.S., 2021. Managing riparian zones for river health improvement: an integrated approach. *Landscape and Ecological Engineering* 17(2), 195-223.
- Singh, R., Tiwari, A.K., Singh, G.S., 2022. Perceptions of the impacts of invasive alien plants in the riparian zone of the Ganga River: Insights from Varanasi, India. *River Research and Applications* 38(8), 1495-1509.
- Twining, C.W., Razavi, N.R., Brenna, J.T., Dzielski, S.A., Gonzalez, S.T., Lawrence, P., Cleckner, L.B., Flecker, A.S., 2021. Emergent freshwater insects serve as subsidies of methylmercury and beneficial fatty acids for riparian predators across an agricultural gradient. *Environmental Science and Technology* 55(9), 5868-5877.
- Urbanič, G., Politti, E., Rodríguez-González, P.M., Payne, R., Schook, D., Alves, M.H., Anđelković, A., Bruno, D., Chilikova-Lubomirova, M., Di Lonardo, S., Egozi, R., 2022. Riparian zones-from policy neglected to policy integrated. *Frontiers in Environmental Science* 10, 868527.
- Wang, K., Yuan, X., Wu, S., Zhang, G., Liu, H., Zhou, L., Zhang, M., 2019b. Effects of river damming on ground-dwelling arthropods along riparian-upland habitats. *Ecohydrology* 12(3), e2073.
- Wang, K., Yuan, X., Zhang, G., Liu, S., Wang, F., Liu, H., Zhang, M., Zhou, L., 2019a. Diversity and Distribution of Riparian Arthropods in the Drawdown Zone of China's Three Gorges Reservoir. *Environmental Entomology* 48(6), 1340-1348.
- Ward, J.V., Tockner, K., Arscott, D.B., Claret, C., 2002. Riverine landscape diversity. *Freshwater Biology* 47(4), 517-539.
- Wishart, M.J., 2000. The terrestrial invertebrate fauna of a temporary stream in southern Africa. *African Zoology* 35(2), 193-200.
- Xiang, H., Zhang, Y., Richardson, J.S., 2017. Importance of riparian zone: effects of resource availability at land-water interface. *Riparian Ecology and Conservation* 3(1), 1-17

- Xiao, H., Du, C., Yuan, X., Li, B., 2020. Multiple floods affect composition and community structure of the ground-dwelling arthropods in the riparian zone of the Three Gorges Reservoir. *Ecological Indicators* 113, 106220.
- Xiao, H., Li, B., Willison, J.M., Wang, Y., 2022. Habitat change and interspecific associations mediate the response of riparian ground-dwelling arthropod assemblages to flooding in the Three Gorges Reservoir. *Ecological Engineering* 185, 106812.
- Xiong, F., Olden, J.D., Lu, Y., Liu, H., Qu, X., Xia, W., Guo, C., Wu, X., Infante, D.M., Wang, L., Chen, Y., 2021. Riparian land use and in-channel stressors drive fish community structure in the Yangtze River. *Landscape Ecology* 36(10), 3079-3095.
- Ye, M., Hu, H., Wu, P., Xie, Z., Hu, Y., Lu, X., 2024. Ecological responses to hydrological connectivity in grassland riparian zones: Insights from vegetation and ground-dwelling arthropods. *Science of The Total Environment* 922, 171196.
- Yoshioka, A., Kadoya, T., Suda, S.I., Washitani, I., 2010. Impacts of weeping lovegrass (*Eragrostis curvula*) invasion on native grasshoppers: responses of habitat generalist and specialist species. *Biological Invasions* 12(3), 531-539.
- Zelnik, I., Haler, M., Gabersčik, A., 2015. Vulnerability of a riparian zone towards invasion by alien plants depends on its structure. *Biologia* 70(7), 869-878
- Zina, V., Ordeix, M., Franco, J.C., Ferreira, M.T., Fernandes, M.R., 2021. Ants as bioindicators of riparian ecological health in catalonian rivers. *Forests* 12(5), 625.

CHAPTER 2 : The response of terrestrial arthropods to natural and anthropogenically altered disturbance and stress regimes in riparian zones: A systematic review

Abstract

Riparian zones are vital for biodiversity and are increasingly threatened by natural and human-induced factors that disrupt their structure and function. Arthropods, which are dominant terrestrial organisms in these habitats, are essential for ecosystem services, influencing connectivity between terrestrial and aquatic webs, and are sensitive indicators of environmental changes. Previous studies have documented varying responses of arthropod biodiversity to flooding, alien plant invasion, and river engineering. Therefore, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, this review synthesized knowledge on how riparian arthropods respond to flooding, alien plant invasion and river engineering and proposed management strategies to conserve ecosystem biodiversity and services. The literature search used specific terms such as “riparian,” “arthropod,” “flooding,” “alien plant,” “river engineering,” and their synonyms to identify relevant publications from January 1968 to May 2023 in the Web of Science database. Citations of eligible studies were also searched to extend the scope. Among the 61 eligible studies reporting on the response (changes in biodiversity) of terrestrial arthropods to floods, alien plant invasion, and river engineering in riparian zones globally, responses significantly differed among measured parameters. Negative responses were mainly reported for abundance and species richness, whereas assemblage composition was mainly changed after disturbances and stressors. Variations among taxa were more pronounced in response to alien plant invasion, in contrast to the more uniform response to flooding and river engineering.. Furthermore, eligible studies highlighted that strategies to conserve and manage riparian zones should involve creating and protecting heterogeneous habitats within these zones, restoring native vegetation and natural water flow while considering species-specific ecological needs. Regardless of the literature reviewed, knowledge gaps were identified, highlighting the need for long-term collaboration among policymakers, researchers, and communities, which is essential for effective, holistic conservation of biodiversity and riparian ecosystems in the face of anthropogenic activities and climate change.

Keywords: biodiversity; ; flooding; alien plant invasion; river engineering

2.1 Introduction

Terrestrial riparian zones (hereafter riparian zones) are unique and dynamic habitats that support biodiversity, yet are highly threatened ecosystems (Paetzold et al., 2008; Wang et al., 2019a). Natural and anthropogenic activities such as flooding, alien plant invasion, and river engineering have modified riparian zones (Zulka, 1994; Paetzold et al., 2008; Bush et al., 2020; Xiao et al., 2022). Globally, only a small proportion of all riparian zones are not extensively exploited for human benefit (Tockner and Stanford, 2002; Wang et al., 2019a). Riparian landscape changes affect neighbouring aquatic environments that support organisms directly or indirectly dependent on the terrestrial environment and the biodiversity within that landscape (Borges et al. 2020). Furthermore, the biological characteristics of riparian organisms render them susceptible to environmental change (Borges et al., 2020).

Arthropods are among the dominant animal groups in riparian zones (Wang et al., 2019a). They are highly diverse and play multiple roles in ecosystems as pollinators (Calderone, 2012), decomposers (Wardle et al., 2004), predators (Paetzold and Tockner, 2005), seed dispersers (Lengyel et al., 2010), and soil aerators (Lavelle et al., 2006), thereby influencing the structure and function of riparian ecosystems (Wang et al., 2019a; Xiao et al., 2022). More importantly, arthropods facilitate connectivity between riparian zones, river ecosystems, and neighboring uplands, for example, linking terrestrial and aquatic webs as food resources for fish and birds (Paetzold et al., 2008; Wang et al., 2019a; Xiao et al., 2020, 2022). Furthermore, some arthropods are semi-aquatic (with at least one life stage on land and water) and interact with different ecosystems, further strengthening ecological relationships (Xiao et al., 2022). Riparian arthropods are sensitive to river system modifications (Paetzold et al., 2008; Wang et al., 2019a), making them potential indicators for assessing, managing, and restoring river systems (Wang et al., 2019b).

Despite the tremendous richness of river ecosystems, including those in nearby terrestrial environments, floods (natural and anthropogenically altered hydrological events) can change the structure and stability of aquatic and terrestrial invertebrate populations (Akamatsu and Toda 2011). In particular, the assemblage structure of riparian terrestrial arthropods is influenced by floods (Wang et al., 2019a), and the level of flooding disturbance is a crucial determinant of this (Xiao et al., 2020). The length, severity, and frequency of flood cycles affect the ability of terrestrial arthropod species to survive flooding in floodplains (Aranda and Aoki, 2018). Mainly, the dispersal of ground arthropods within riparian zones is mediated by

fluctuations in water levels, whereby an increase in water levels displaces arthropods; in contrast, a decrease in water levels leads to plant regeneration, attracting arthropods to inhabit riparian zones (Xiao et al., 2022).

Natural environments worldwide have been significantly damaged and threatened by the invasion of non-native species into ecosystems (Durst et al., 2008; Yoshioka et al., 2010) and are considered the second-worst ecological threat after habitat destruction (Durst et al., 2008). Between 1997 and 2011, floodplain areas decreased by 106 million hectares worldwide (Costanza et al., 2014). In addition, a wide range of other disturbances, such as the introduction of exotic species, also have an impact (Bush et al., 2020). Riparian zones are inherently vulnerable to plant invasion owing to loss of plant biomass, lower levels of competition, and increased resource availability caused by flood disturbances (Yoshioka et al., 2010). Introduced plant species can alter ecological processes, plant and arthropod communities in riparian zones, which are highly susceptible to environmental change, thereby intensifying the impacts of plant invasions (Uhey et al., 2020).

The energy and water storage demand for human use has threatened natural rivers, as river engineering has become a norm, leaving only 40% of large rivers without dams (Wang et al., 2019b). In dammed river reservoirs, water levels are controlled to generate power and control floods (Xiao et al., 2022). Modifications of natural flow regimes due to river engineering have significantly altered riparian zones (Paetzold et al., 2008). In particular, river engineering that cuts off flooding areas has changed the ecological conditions of the riparian zones (Zulka, 1994). This prevalent human activity alters sunlight exposure, water flow, and temperature of water bodies, thereby influencing their biodiversity (Araujo et al., 2022). Ecosystems are significantly affected by the artificial regulation of floods (Xiao et al., 2022).

Generally, the disturbances and stressors mentioned above are expected to have a negative impact on the biodiversity of riparian zones. However, previous studies have reported mixed responses from arthropods, ranging from negative (Paetzold et al., 2008), uncategorized (Xiao et al., 2022), positive (Zulka, 1994), and no change in assemblage structure or abundance after disturbance (Truxa and Fiedler, 2012). Comprehensive knowledge of the composition and dynamics of arthropod assemblages and their response to disturbances is crucial to effectively protect ecosystem biodiversity and services. Therefore, this study aims to review the responses

of riparian arthropods to flooding, alien plant invasion, and river engineering, and identify potential management strategies. The main questions addressed in this review were:

- a) How does flooding (natural and human-induced), alien plant invasion, and river engineering influence arthropod biodiversity?
- b) How are the studies examining the effects of disturbance and stressors on riparian arthropods globally distributed?
- c) What are the potential management strategies to conserve riparian zones and their arthropods?

2.2 Materials and methods

Search strategy

The current review followed the Preferred Reporting Items for Systematic Reviews (PRISMA) approach (Moher et al., 2009) and checklists (Page et al., 2021) to explore the impact of natural and anthropogenic disturbance and stressors on terrestrial arthropod biodiversity in riparian zones globally. I searched for literature published between January 1968 and May 2023 using the Web of Science database (<https://www.webofscience.com>). Although studies on riparian zones date back to the 1950s and early 1960s, they primarily focused on water use. From the late 1960s onward, research on riparian zones as dynamic, disturbance-prone ecosystems gained momentum; hence, the literature search commenced in January 1968. The following search terms were used to find studies on the effects of natural and/or anthropogenic disturbances on riparian arthropods: ("riparian" OR "floodplain*") AND ("arthropod*" OR "insect*" OR "arachnid*" OR "myriapod*" OR "crustacea*" OR "hexapod*") AND ("flood*" OR "inundat*") AND ("invasive" OR "alien" OR "exotic") AND ("river dam*" OR "river engineer*" OR "river channelization" OR "river regulation"). Response variables, such as abundance, richness, composition, and diversity, were not included in the search string because they resulted in irrelevant publications. All the references cited within the selected articles were also inspected and included if they fulfilled the inclusion criteria.

Data collection

We screened and extracted data from the selected articles. Firstly, the title and abstract of the obtained papers were assessed for relevance according to the inclusion/exclusion criteria in

Table 2.1. A more detailed analysis of the selected articles' full text was conducted to confirm inclusion. Following a comprehensive reading of each article's full text, data such as title, author, year, study site, type of disturbance or stressor, motivation, purpose, key findings, impact on arthropods, study taxa, measured parameters, recommendations, and summary were extracted without determining whether the arthropods are alien or native. Eligible articles were grouped by disturbance and stressor type which were flooding, alien plant invasion and river engineering.

Inclusion and exclusion criteria

Table 1: Inclusion and exclusion criteria for study selection.

Inclusion	Exclusion
Population (target group): Terrestrial riparian arthropods (including semi-aquatic arthropods)	Articles solely reporting about aquatic arthropods
Concept: Changes in abundance, richness, assemblage composition and/or diversity (response to disturbance/stressor)	Articles reporting on arthropod communities in riparian zones excluding the influence of disturbance or stressor
Context: Flooding, alien plant invasion and river engineering in riparian zones	Articles reporting on functional traits of arthropods outside the context of disturbances and stress in riparian zones
Articles reporting original research or review articles	Articles reporting on arthropod communities after restoration
Published in English	Grey literature

Data extraction and synthesis

To appraise the quality of studies eligible for this systematic review, we evaluated their quality using the following criteria: (1) study duration indicated, (2) peer-reviewed, (3) sampling methods are well-established and replicable, and (4) data are statistically tested and reported in detail. For each eligible study, responses were categorised for each taxonomic ranking and measured parameter (abundance, richness, diversity and assemblage composition) due to expected varied reactions to the disturbances and stressors assessed. Each taxon-specific response was considered an independent incident and classified into one of the four impact categories. Results were synthesized according to response to disturbance or stressor, study taxon, measured ecological parameter and geographic location of the study site.

Table 2: Categories used to classify the impact of disturbance or stressor on terrestrial arthropods.

Response	Description
Negative	Decrease in diversity, richness and abundance.
Positive	Increase in diversity, richness and abundance.
No effect	No changes in diversity, richness and abundance.
Unclear	Ambiguous response in diversity, richness, abundance
Changed	Differences in assemblage composition

Unchanged

No differences in assemblage composition

Data analysis

The studies eligible for this systematic review used different data collection methods and reported on different arthropod taxonomic groups, making it difficult to conduct a statistical meta-analysis. Therefore, effect sizes were not calculated. Instead, a qualitative and narrative synthesis approach was used, where the findings from each study were summarized (see Table S1; supplementary materials). Data entries were calculated as frequencies and percentages of response within taxa, parameter and disturbance type. Row-standardised contingency tables were used to compare response distribution among groups. The Chi-square tests of independence were used to assess whether arthropods responded differently among ecological parameters (abundance, richness, diversity and assemblage composition), taxa and disturbance types (flooding, alien plant invasion and river engineering). When the expected cell counts were less than 5, Fisher's exact test were used instead, with Monte Carlo simulation (10 000 replicates) to confirm statistical significance (Fisher, 1922; Mehta and Patel, 1983). The contingency table construction and statistical analyses were conducted in R statistical software version 4.4.1 (R Core Team, 2024).

2.3 Results

The search yielded 615 articles, 596 of which were from the Web of Science database and 19 from citation searching in the eligible studies. After title and abstract screening, 505 studies were excluded as they did not meet the inclusion criteria, leaving 110 studies eligible for full-text screening. We resolved discrepancies, excluding further 48 articles as they focused on the wrong intervention (not flooding, alien plant invasion and river engineering disturbance or stressors in riparian zones, $n=45$), wrong outcome (did not document changes in abundance, richness and/ or diversity, $n=1$) and wrong community (not terrestrial arthropods, $n=2$). Ultimately, 61 articles were eligible for extraction and included in the systematic review (Figure 2.1).

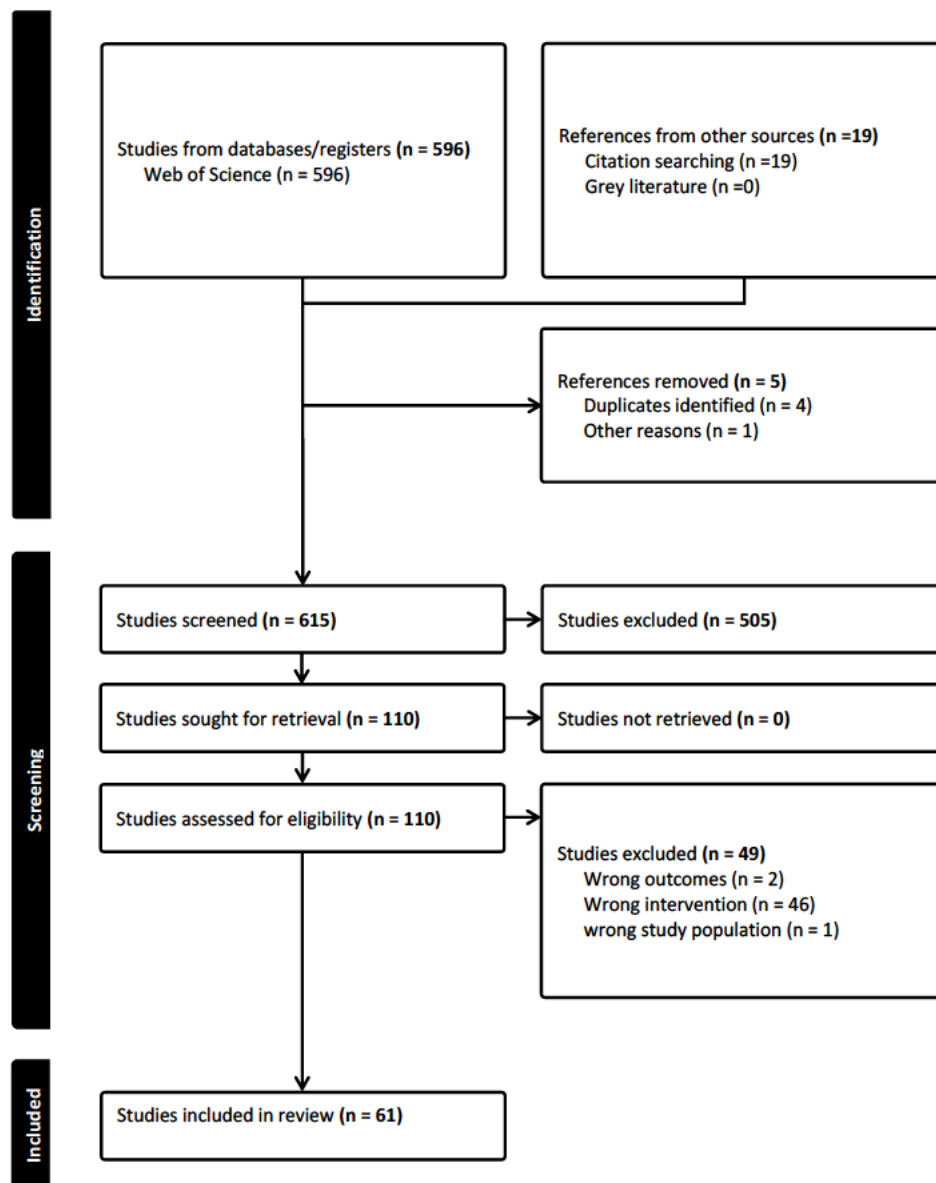


Figure 2.1: Flow diagram summarizing the global study selection process for systematically reviewing the responses of terrestrial arthropods to natural and anthropogenically altered disturbance or stressors in riparian zones.

Global response of arthropods to natural and anthropogenic disturbance and stress regimes along riparian zones

The general response pattern of arthropods across disturbances and stressors were similarly distributed ($p = 0.1173$; Figure 2.2a). The response of arthropods to disturbances significantly differed among ecological parameters ($p < 0.001$). Abundance was generally negatively (50 - 60%) affected across disturbance types, richness was variably affected, with negative responses

most common under river engineering and alien plant invasion while flooding had a mix of positive and negative effects. Diversity showed varied responses while assemblage composition was mostly changed (77.8 – 96.4%) under all disturbances and stressors (Figure 2.2b).

The responses of taxonomic groups to disturbances and stressors showed variations, however, the differences among taxa within each disturbance type were only significant for alien plant invasion ($p = 0.0119$) and not for river engineering ($p = 0.9675$) and flooding ($p = 0.0598$; Figure 2.2c).

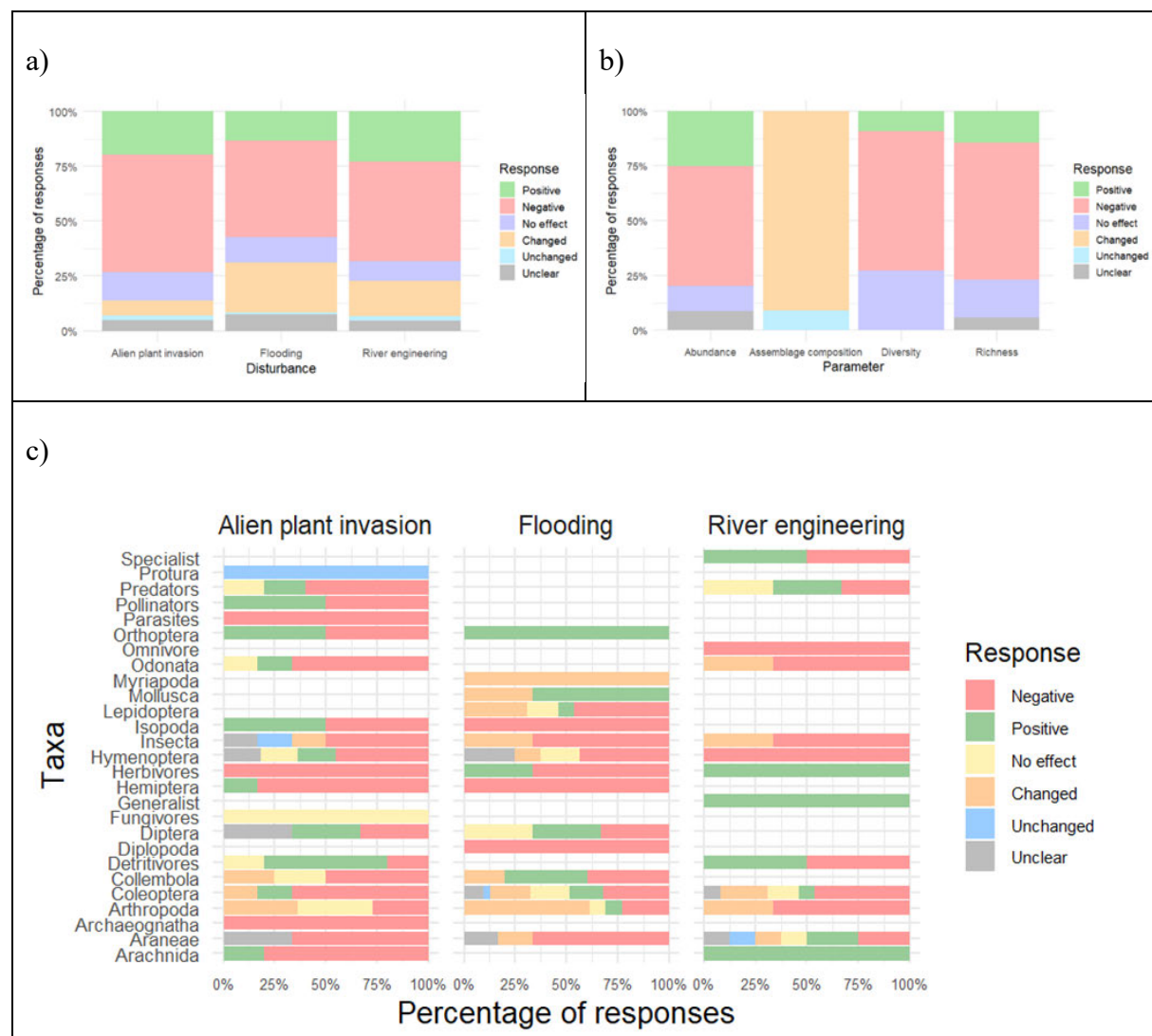


Figure 2.2: Synthesis of eligible study outcomes showing the response (negative, positive, no effect, changed, unchanged and unclear) of terrestrial arthropods to alien plant invasion, flooding and river engineering (a), ecological parameters measured (abundance, richness, diversity and assemblage composition; b) and across taxonomic groups (c).

Global trends observed among eligible studies

The majority (90.2%) of eligible studies were conducted in developed countries, with a noticeable gap in research conducted in developing countries (9.8%). Geographically, 29.5% (18 out of 61) of studies investigating the impact of disturbances or stressors on terrestrial arthropods in riparian zones were published in the United States of America. In contrast, only one eligible study was conducted and published in Africa, specifically in South Africa (Figure 2.3).

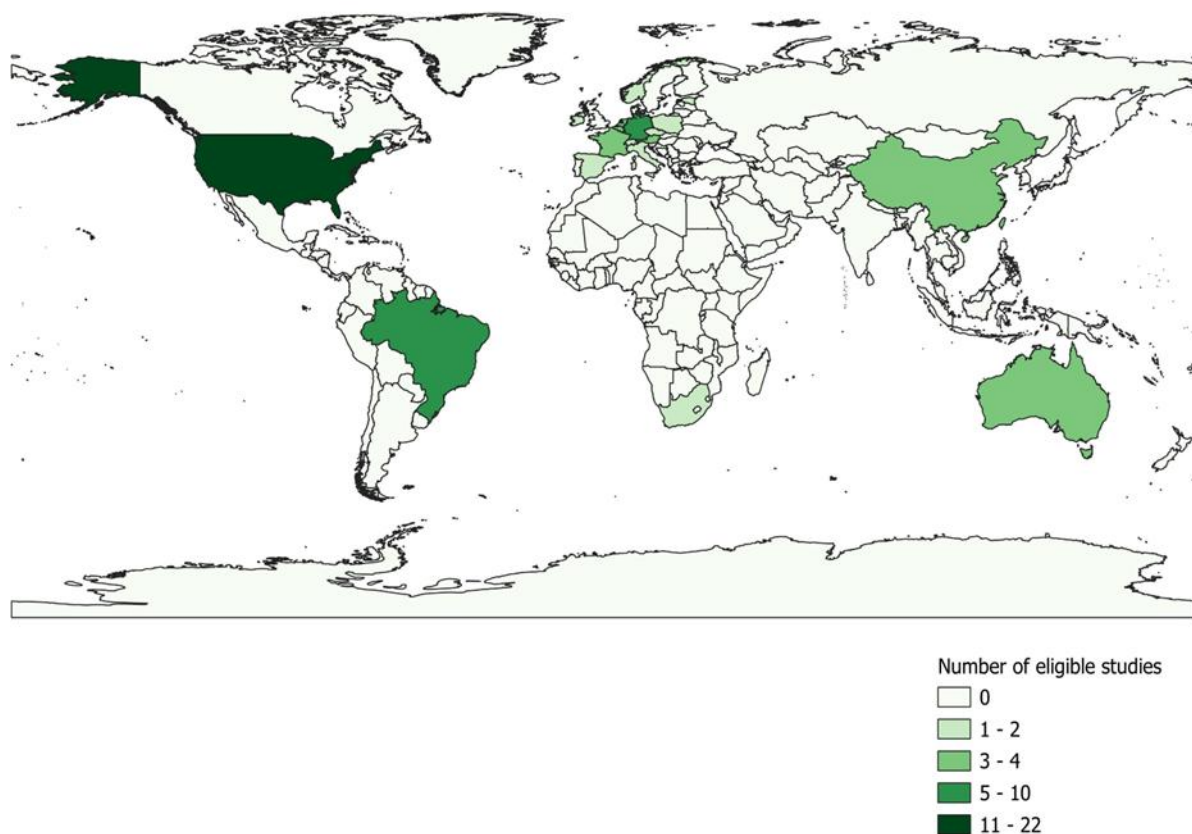


Figure 2.3: Geographic location of eligible studies projected on the world map.

2.4 Discussion

Response of arthropods to different anthropogenic and natural disturbances and stressors along riparian zones

a) Flooding

Floods primarily influence changes in ground-dwelling arthropod communities (Xiao et al., 2022). The consensus is that floods are expected to alter microhabitat conditions within the

riparian zone, influencing factors such as moisture content, temperature regime, light intensity, vegetation density, and substrate composition (Xiao et al., 2022). Due to the impact of water level fluctuations, diverse habitats emerge within floodplains (Xiao et al., 2020). The current review demonstrated that taxonomic groups do not exhibit significantly varied responses to flooding, their assemblage compositions were changed (96%) while their diversity (50 – 66%) were mainly negatively affected by flooding (Figure 2.2). This outcome can be explained by changes in microclimate, vegetation, and organic matter that are anticipated to occur over time following the recession of floodwaters. These changes are expected to result in temporal and spatial fluctuations in ground-dwelling arthropod populations (Xiao et al., 2020). The impact of floods on riparian arthropods is intricately tied to factors such as migratory capabilities and resource accessibility (Ilg et al., 2008; Lambeets et al., 2009; Xiao et al., 2020). Arthropods with robust dispersal abilities can successfully evade floods, whereas species with limited dispersal may perish or be carried downstream (Xiao et al., 2022). Furthermore, floods directly impact microhabitat conditions and trigger a ripple effect that influences various aspects of the environment and, consequently, the populations of ground-dwelling arthropods.

The lag phase after flooding allows an increase in the population of ground-dwelling arthropods (Xiao et al., 2020). It can potentially explain the positive (14- 22%) influence of flooding on arthropod diversity in the current review (Figure 2.2). Xiao et al. (2022) revealed similar trends where flooded sites were typically rapidly colonized by ground beetles, springtails, and crickets (Ellis et al., 2001; Smith et al., 2006). Xiao et al. (2022) further noted that after floods, vegetation swiftly re-emerges in the recently exposed riparian zone, originating from both surviving ramets (perennials) and seeds (annuals). The regenerating plants contribute to the formation of a distinct riparian vegetation pattern (Xiao et al., 2022) and subsequently offer plentiful food resources for various feeding guilds. This plant growth, in turn, triggers the arrival of arthropod predators such as carabid beetles and wolf spiders (Lambeets et al., 2009; Xiao et al., 2020). However, taxa like terrestrial isopods with lower mobility recolonize microhabitats over shorter distances and much longer time scales can be negatively impacted by floods (Xiao et al., 2022; Ellis et al., 2001; Smith et al., 2006). To avoid adverse impacts of flooding, taxa more sensitive to flooding are primarily distributed at higher elevations where flooding effects are constrained (Wang et al., 2019a). For example, ants occupied upland areas which were characterized by relatively dry environmental conditions (Xiao et al., 2022). While some species mitigate flood effects through intricate nest construction, they still face impacts due to soil saturation, which limit oxygen availability (Fellendorf et al. 2004). In contrast,

Carabids have traits that enhance survival during unfavourable phases of the flooding cycle, which include synchronizing life cycles with disturbance patterns, reproductive dormancy, and tolerance to submersion (Peterson et al., 2021).

b) Alien plant invasion

Variations in landscape-level factors such as the distance, size, composition, and arrangement of riparian patches, along with the influence of the surrounding vegetation, contribute to diverse conclusions in studies of arthropod communities in riparian habitats (Durst et al., 2008). In general, a decline in the variety of plant community types and a deterioration in essential habitat quality may lead to a decrease in the diversity of ground-dwelling arthropods in riparian zones, resulting in an ecosystem imbalance and diminished ecosystem health (Xiao et al., 2022). The current review supports these claims, documenting a decline in arthropod biodiversity (52 – 75%) due to alien plant invasion (Figure 2.2) despite taxonomic groups having varied responses. Previous studies have shown that when the diversity of plant communities diminishes and habitat quality degrades, it can negatively impact the availability of suitable resources and shelter for various arthropod species (Xiao et al., 2022). Furthermore, the effects of plant invasions are more noticeable on ground-dwelling arthropods than on aquatic arthropods (Riedl et al., 2018). This is evident in a study conducted by Yoshioka et al. (2009), whereby grasshopper species with a specialized habitat were more adversely impacted by the invasion of weeping lovegrass compared to those with a more generalist habitat preference due to limited or no adaptability in host plant species selection. The ecological impact of disturbance plays a crucial role in determining the composition of the arthropod community, overshadowing the influence of alien plant invasion, and favouring species with generalist traits (Kjar and Park, 2016).

In some cases of alien plant invasion, species can adapt to altered conditions (Kjar and Park, 2016). The distinct characteristics of alien invasive plants may contribute to ecological conditions favouring the establishment and proliferation of non-native arthropods. An example is the study by Uhey et al. (2020), which found that the invasive plant tamarisk supported a distinct arthropod community compared to native vegetation, potentially fostering non-native arthropods. The findings of this review indicated that alien plant invasion also changed the assemblage compositions (78%) and positively impacted the diversity of arthropods (20 – 24%; Figure 2.2); however, the origins of arthropods were not considered as they were not part of the scope for the current systematic review.

c) River engineering

The abundance and diversity of terrestrial arthropods will likely experience a significant decline in river segments influenced by river engineering (Lambeets et al., 2009). The decline is due to a physical barrier between the aquatic and terrestrial environments (Kennedy and Turner, 2011; Wang et al., 2019b), which then disrupts the natural flow of energy and organisms between these ecosystems. Additionally, the construction of a dam can lead to changes in the composition of species present and the dynamics of interactions within the food web (Wang et al., 2019b) due to biotic homogenization (Araujo et al., 2022). The present study found similar trends in the response of taxonomic groups to river engineering, where it was mainly negative to their abundance and richness (50 – 78%; Figure 2.2) and changed assemblage composition. In accordance with the present study, a previous study undertaken by Paetzold et al. (2008) in Switzerland and Italy documented that channelization results in a significant decrease in both the abundance and richness of spiders, while ground beetles exhibited no significant response. Rove beetles, on the other hand, experienced a negative impact from hydropeaking, and channelization had an adverse effect only in rivers where hydropeaking was present (Paetzold et al., 2008). In a similar case, the reduction in abundance and diversity was particularly significant among predatory arthropods, including species like wolf spiders and toad bugs, which coincided with a substantial 50% reduction in the density of aquatic macroinvertebrates, indicating a broader disturbance in the river ecosystem (Kennedy and Turner, 2011).

In contrast, Wang et al. (2019b) reported that river engineering created conditions in the regulated section that are more favourable or conducive to the abundance and richness of arthropods, especially those occupying ecological roles such as predators, detritivores, and herbivores in China. Moreover, twenty-four taxa disappeared from the riparian zone following damming, while 11 new taxa colonized the altered habitat, indicating the introduction or establishment of different arthropod species in response to the changes induced by the dam (Wang et al., 2019a). The study further demonstrated that the effects of river damming extend beyond the composition and abundance of arthropods; they also include shifts in spatial distribution along riparian–upland gradients and changes in the temporal dynamics of arthropod communities.

Potential reasons why other responses were uncategorised.

Variations in the distribution patterns of species are anticipated due to differences in their responses, which arise from the diversity in functional traits (Lambeets et al., 2009); however, the present review documented 6.06% unclear responses of arthropods to disturbances and stressors (Figure 2.2). Xiao et al. (2020) highlighted a challenge in ecological research, specifically regarding the difficulty in quantifying the impact of water fluctuation on ground-dwelling arthropods. The challenge is attributed to a lack of information available prior to the disturbance, indicating that the absence of baseline data hinders the accurate assessment of how water fluctuations affect these arthropods. In accordance with previous claims, Ralston et al. (2017) lacked arthropod data before the dam construction, making it difficult to determine whether the observed arthropod biodiversity differences in the current pre-dam riparian zone and post-dam riparian zones are due to river engineering or alien invasion in the post-dam riparian zone. Furthermore, research assessing the impacts of such catastrophic events is uncommon, primarily due to the lack of precise data describing the conditions before the flood in almost all cases (Ilg et al., 2008). As a result, quantifying the impact of a solitary extreme event on the long-term variability patterns of the observed communities and taxonomic groups can pose challenges (Ilg et al., 2008). This reinforces the importance of collecting comprehensive pre-disturbance data to enhance our ability to assess and predict ecological responses to disturbances, ultimately contributing to more effective conservation and management strategies.

Geographic distribution of eligible studies

The geographical distribution of studies focusing on the response of terrestrial arthropods to riparian disturbances and stressors revealed an imbalance, highlighting a need for more research in the developing world, which houses the majority of the world's biodiversity (Gaikwad and Chavan, 2006). Further research will help assess whether the findings from a set of observations can be generalized and applied to other regions or if the patterns are unique to the specific location in which they were observed. The current findings also align with the reports by Pedraza et al. (2021), which showed that limited research on riparian zones emerged from countries with low to middle-income levels.

Strategies to conserve and manage riparian zones and terrestrial arthropods

Ilg et al. (2008) argue that a crucial assessment of the impacts stemming from an increased frequency of extreme events on floodplain biodiversity demands a comprehensive and sustained approach. They emphasize the importance of long-term monitoring tailored to riparian ecosystems to achieve this. The necessity for employing standardized methods in this monitoring process is emphasized, ensuring consistency and comparability in data collection and analysis. This approach is fundamental for gaining insights into the long-term ecological consequences and adaptive responses of floodplain ecosystems in the face of frequent floods resulting from changing environmental conditions caused by climate change (Swain et al., 2020; Milan and Schwendel, 2021), and will contribute to more effective conservation and management strategies.

The study by Lambeets et al. (2009) proposes effective strategies for conserving uncommon arthropods along disturbed riparian zones. The key approach involves enhancing habitat heterogeneity through comprehensive river restoration and rehabilitation efforts directed explicitly at the riparian corridor (Paetzold et al., 2008; Lambeets et al., 2009). Critical considerations in this process include addressing factors such as sediment composition and vegetation structure along the riparian zones (Lambeets et al., 2009).

Ecological restoration efforts should concentrate on enlarging riparian habitat patches to enhance habitat heterogeneity and, therefore, maintain the occurrence of arthropods (Maher et al., 2014). Maintaining habitat diversity emerges as a pivotal factor for the well-being of riparian ecosystems, as intermediate disturbance rates play a crucial role in promoting the highest levels of habitat heterogeneity (Maher et al., 2014). It is noted that riparian species, particularly those with specific habitat preferences, face heightened vulnerability during periods of extreme disturbance (Maher et al., 2014; Ramey and Richardson, 2017). A multifaceted approach is recommended to optimize biodiversity and uphold the long-term ecological integrity of rivers. This entails the restoration of natural hydrogeomorphical processes (Fies et al., 2016; Borges et al., 2021), the minimization of anthropogenic impacts on water discharge patterns, and the incorporation of species-specific ecological needs into river management and restoration planning (Palmer and Rohi, 2019). Future river management should acknowledge the environmental constraints that influence the susceptibility of arthropod fauna in the riparian transition zone and not only evaluate the characteristics of the river channel concerning in-stream biota (Lambeets et al., 2009).

When planning and implementing measures to address the consequences of severe flooding, it is essential to consider how various species or taxonomic groups adapt to such events (Ilg et al., 2008; Aranda and Aoki, 2018). Understanding their specific modes of adaptation can inform more targeted and effective strategies for minimizing the adverse effects of extreme flood events on biodiversity and ecosystems.

In addressing alien plant invasion, management strategies should be tailored to the specific habitat needs of native species while accounting for the influence of invasive species in relation to the presence or absence of native vegetation (Yoshioka et al., 2009). Additionally, it is essential to consider limiting the growth of alien plants and rehabilitating native ecosystems (Herrera and Dudley, 2003; Samways and Grant, 2006; Gutiérrez-López et al., 2014; Ralston et al., 2017).

Paetzold et al. (2008) emphasized the importance of directing conservation efforts more precisely, considering the distinct reactions of various taxa to human activities in riparian ecosystems. Restoration and management strategies for regulated rivers should encompass the restoration of natural flow variability (Paetzold et al., 2008). Additionally, measures should be taken to limit bank stabilization, thereby preventing channelization and preserving connectivity and a healthy transition zone (Kennedy and Turner, 2011; Skalski et al., 2016). Employing bioindication ratio tools, which consider the richness or abundance of high-level taxonomic categories with contrasting responses, will offer a practical approach to assess and reflect the overall impact of river engineering (Araujo et al., 2022). Effective, holistic conservation strategies for biodiversity and riparian ecosystems can be developed through collaboration between policymakers, researchers, and communities.

Limitations and recommendations

We acknowledge the review's limitations as we only screened articles and extracted data from a single database using specific terms and eligible studies limited to English publications. Moreover, the heterogeneity of study species and sampling methods made assessing the risk of bias challenging. However, we remain assured that these limitations will not alter the conclusions drawn from this review.

The variations in responses among arthropod taxa in this review suggests that the multi-taxon studies are likely to provide more comprehensive insight into the complexity of interspecific associations among different taxa of ground-dwelling arthropods (Santos-Silva et al., 2018;

Xiao et al., 2022). This focused approach allows a more detailed understanding of how these key species interact within the ecosystem, shedding light on the complex web of relationships. Moreover, there is room for further progress in determining whether ground-dwelling arthropods' presence, abundance, or diversity can serve as reliable indicators of the effectiveness of habitat restoration initiatives (Cartron et al., 2003).

Future studies should adopt a more comprehensive approach to sampling arthropods (Truxa and Fiedler, 2012; Peterson et al., 2021). In addition to pitfall trapping, a standard method for capturing ground-dwelling arthropods, the proposal is to incorporate supplementary sampling methods (Xiao et al., 2022). This integrated approach aims to improve the capture rates of diverse taxa, providing a more thorough and accurate dataset of ground-dwelling arthropods.

2.5 Conclusion

Arthropods play a significant role in riparian habitats, and their diversity and abundance are crucial for the sustainability of ecosystem health (Uhey et al., 2020). Therefore, this systematic review's primary objective was to evaluate riparian arthropods' response to flooding, alien plant invasion, and river engineering globally and identify potential management strategies. One of the more significant findings from this systematic review is that terrestrial arthropods are predominantly adversely affected by flooding, alien plant invasion, and river engineering, although responses differed among taxa under alien plant invasion. The second key finding was the uneven geographic distribution of studies and the lack of long-term and multi-taxa studies, limiting the ability to manage and conserve riparian zones and their biodiversity effectively. In conclusion, this systematic review provides valuable insights into the factors that need to be considered to enhance our understanding of riparian threats and their impact on biodiversity, ultimately enabling better conservation of riparian ecosystems in the face of anthropogenic change.

2.6 References

- Andersen, J.O.H.A.N., 1968. The effect of inundation and choice of hibernation sites of Coleoptera living on river banks. *Norsk Entomologisk Tidsskrift* 15, 115-133.
- Aranda, R., Aoki, C., 2018. Diversity and effect of historical inundation on bee and wasp (Hymenoptera: Apoidea, Vespoidea) communities in the Brazilian Pantanal. *Journal of Insect Conservation* 22(3), 581-591.
- Araujo, B.R., Pinto, A.P., Padial, A.A., 2022. Influence of landscape homogenization due to river damming on dragonfly (Odonata) community structuring in a subtropical forest in the southern Atlantic Forest. *Ecohydrology* 15(3), e2419.
- Ballinger, A., Lake, P.S., Nally, R.M., 2007. Do terrestrial invertebrates experience floodplains as landscape mosaics? Immediate and longer-term effects of flooding on ant assemblages in a floodplain forest. *Oecologia* 152(2), 227-238.
- Bonn, A., Hagen, K., Reiche, D.W.V., 2002. The significance of flood regimes for carabid beetle and spider communities in riparian habitats-a comparison of three major rivers in Germany. *River Research and Applications* 18(1), 43-64.
- Borges, L.R., Barbosa, M.S., Carneiro, M.A.A., Santos, J.C., 2021. Habitat integrity drives Odonata diversity in *Eucalyptus*-dominated landscape. *Environmental Monitoring and Assessment* 193(1), 1-14.
- Bush, B.M., Ulyshen, M.D., Batzer, D.P., 2020. Effects of Chinese privet (*Ligustrum sinense*) invasion on decomposition and litter-dwelling invertebrates in Southeastern US floodplain forests. *Biological Invasions* 22(6), 1957-1965.
- Calderone, N.W., 2012. Insect pollinated crops, insect pollinators and US agriculture: trend analysis of aggregate data for the period 1992–2009. *PLoS One* 7(5), e37235.
- Cartron, J.L.E., Molles, M.C., Schuetz, J.F., Crawford, C.S., Dahm, C.N., 2003. Ground arthropods as potential indicators of flooding regime in the riparian forest of the middle Rio Grande, New Mexico. *Environmental Entomology* 32(5), 1075-1084.
- Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., Turner, R.K., 2014. Changes in the global value of ecosystem services. *Global Environmental Change* 26, 152-158.
- Durst, S.L., Theimer, T.C., Paxton, E.H., Sogge, M.K., 2008. Temporal variation in the arthropod community of desert riparian habitats with varying amounts of saltcedar (*Tamarix ramosissima*). *Journal of Arid Environments* 72(9), 1644-1653.

- Ellis, L.M., Crawford, C.S., Molles Jr, M.C., 2001. Influence of annual flooding on terrestrial arthropod assemblages of a Rio Grande riparian forest. *Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management* 17(1), 1-20.
- Fellendorf, M., Mohra, C., Paxton, R.J., 2004. Devasting effects of river flooding to the ground-nesting bee, *Andrena vaga* (Hymenoptera: Andrenidae), and its associated fauna. *Journal of Insect Conservation* 8(4), 311-312.
- Fies, R., Rabl, D., Schulze, C.H., Fiedler, K., 2016. Summer floods shape meadow butterfly communities in a floodplain nature reserve in Central Europe. *Journal of Insect Conservation* 20(3), 433-445.
- Gaikwad, J., Chavan, V., 2006. Open access and biodiversity conservation: challenges and potentials for the developing world. *Data Science Journal* 5, 1-17.
- Gerber, E., Krebs, C., Murrell, C., Moretti, M., Rocklin, R., Schaffner, U., 2008. Exotic invasive knotweeds (*Fallopia* spp.) negatively affect native plant and invertebrate assemblages in European riparian habitats. *Biological Conservation* 141(3), 646-654.
- Gerisch, M., Dziock, F., Schanowski, A., Ilg, C., Henle, K., 2012. Community resilience following extreme disturbances: The response of ground beetles to a severe summer flood in a Central European lowland stream. *River Research and Applications* 28(1), 81-92.
- Gratzer, M., Rabitsch, W., Schulze, C.H., 2013. Impact of flooding on true bug communities (Heteroptera) on meadows of the Morava River floodplains, Eastern Austria. In *Proceedings of 5th Symposium for Research in Protected Areas*, 245-250.
- Greenwood, H., O'Dowd, D.J., Lake, P.S., 2004. Willow (*Salix* × *rubens*) invasion of the riparian zone in south-eastern Australia: reduced abundance and altered composition of terrestrial arthropods. *Diversity and Distributions* 10(5-6), 485-492.
- Gutiérrez-López, M., Ranera, E., Novo, M., Fernández, R., Trigo, D., 2014. Does the invasion of the exotic tree *Ailanthus altissima* affect the soil arthropod community? The case of a riparian forest of the Henares River (Madrid). *European Journal of Soil Biology* 62, 39-48.
- Herrera, A.M., Dudley, T.L., 2003. Reduction of riparian arthropod abundance and diversity as a consequence of giant reed (*Arundo donax*) invasion. *Biological Invasions* 5(3), 167-177.
- Ilg, C., Dziock, F., Foeckler, F., Follner, K., Gerisch, M., Glaeser, J., Rink, A., Schanowski, A., Scholz, M., Deichner, O., Henle, K., 2008. Long-term reactions of plants and

- macroinvertebrates to extreme floods in floodplain grasslands. *Ecology* 89(9), 2392-2398.
- Juen, L., Cunha, E.J., Carvalho, F.G., Ferreira, M.C., Begot, T.O., Andrade, A.L., Shimano, Y., Leão, H., Pompeu, P.S., Montag, L.F.A., 2016. Effects of oil palm plantations on the habitat structure and biota of streams in Eastern Amazon. *River Research and Applications* 32(10), 2081-2094.
- Kennedy, T.L., Turner, T.F., 2011. River channelization reduces nutrient flow and macroinvertebrate diversity at the aquatic terrestrial transition zone. *Ecosphere* 2(3), 1-13.
- Kjar, D., Park, Z., 2016. Increased ant (Hymenoptera: Formicidae) incidence and richness are associated with alien plant cover in a small mid-Atlantic riparian forest. *Myrmecological News* 22, 109-117.
- Lafage, D., Sibelle, C., Secondi, J., Canard, A., Pétilion, J., 2015. Short-term resilience of arthropod assemblages after spring flood, with focus on spiders (Arachnida: Araneae) and carabids (Coleoptera: Carabidae). *Ecohydrology* 8(8), 1584-1599.
- Lambeets, K., Hendrickx, F., Vanacker, S., Van Looy, K., Maelfait, J.P., Bonte, D., 2008a. Assemblage structure and conservation value of spiders and carabid beetles from restored lowland river banks. *Biodiversity and Conservation* 17(13), 3133-3148.
- Lambeets, K., Vandegehuchte, M.L., Maelfait, J.P., Bonte, D., 2008b. Understanding the impact of flooding on trait-displacements and shifts in assemblage structure of predatory arthropods on river banks. *Journal of Animal Ecology* 77(6), 1162-1174.
- Lambeets, K., Vandegehuchte, M.L., Maelfait, J.P., Bonte, D., 2009. Integrating environmental conditions and functional life-history traits for riparian arthropod conservation planning. *Biological Conservation* 142(3), 625-637.
- Lavelle, P., Decaëns, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., Margerie, P., Mora, P., Rossi, J.P., 2006. Soil invertebrates and ecosystem services. *European Journal of Soil Biology* 42, S3-S15.
- Lengyel, S., Gove, A.D., Latimer, A.M., Majer, J.D., Dunn, R.R., 2010. Convergent evolution of seed dispersal by ants, and phylogeny and biogeography in flowering plants: a global survey. *Perspectives in Plant Ecology, Evolution and Systematics* 12(1), 43-55.
- Lessel, T., Marx, M.T., Eisenbeis, G., 2011. Effects of ecological flooding on the temporal and spatial dynamics of carabid beetles (Coleoptera, Carabidae) and springtails (Collembola) in a polder habitat. *ZooKeys*, 100: 421-446

- Looy, K.V., Jochems, H., Vanacker, S., Lommelen, E., 2007. Hydropeaking impact on a riparian ground beetle community. *River Research and Applications* 23(2), 223-233.
- Maceda-Veiga, A., Basas, H., Lanzaco, G., Sala, M., De Sostoa, A., Serra, A., 2016. Impacts of the invader giant reed (*Arundo donax*) on riparian habitats and ground arthropod communities. *Biological Invasions* 18(3), 731-749.
- Maher, C., Gormally, M., Williams, C., Skeffington, M.S., 2014. Atlantic floodplain meadows: influence of hydrological gradients and management on sciomyzid (Diptera) assemblages. *Journal of Insect Conservation* 18(2), 267-282.
- Meriste, M., Helm, A., Ivask, M., 2016. Ground-dwelling spider fauna of flooded meadows in Matsalu, Estonia. *Wetlands* 36(3), 525-537.
- Milan, D.J., Schwendel, A.C., 2021. Climate-change driven increased flood magnitudes and frequency in the British uplands: geomorphologically informed scientific underpinning for upland flood-risk management. *Earth Surface Processes and Landforms* 46(15), 3026-3044.
- Milford, E.R., 1999. Ant communities in flooded and unflooded riparian forest of the middle Rio Grande. *The Southwestern Naturalist*, 278-286.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., PRISMA Group, T., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine* 151, 264-269.
- Nienhuis, C.M., Dietzsch, A.C., Stout, J.C., 2009. The impacts of an invasive alien plant and its removal on native bees. *Apidologie* 40(4), 450-463.
- Oliveira, I.F., Baccaro, F.B., Werneck, F.P., Haugaasen, T., 2023. Seasonal flooding decreases fruit-feeding butterfly species dominance and increases spatial turnover in floodplain forests of central Amazonia. *Ecology and Evolution* 13(1), e9718.
- Paetzold, A., Tockner, K., 2005. Effects of riparian arthropod predation on the biomass and abundance of aquatic insect emergence. *Journal of the North American Benthological Society* 24(2), 395-402.
- Paetzold, A., Yoshimura, C., Tockner, K., 2008. Riparian arthropod responses to flow regulation and river channelization. *Journal of Applied Ecology* 45, 894-903.
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *British Medical Journal*, 372.

- Palmer, M., Ruhi, A., 2019. Linkages between flow regime, biota, and ecosystem processes: Implications for river restoration. *Science* 365(6459), eaaw2087.
- Pedraza, S., Clerici, N., Zuluaga Gaviria, J.D., Sanchez, A., 2021. Global Research on Riparian Zones in the XXI Century: A Bibliometric Analysis. *Water* 13(13), 1836.
- Peterson, K.N.R., Browne, R.A., Erwin, T.L., 2021. Carabid beetle (Coleoptera, Carabidae) richness, diversity, and community structure in the understory of temporarily flooded and non-flooded Amazonian forests of Ecuador. *ZooKeys* 1044, 831-876.
- R Core Team, 2024. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Rabelo, R.M., Pereira, G.C., Valsecchi, J., Magnusson, W.E., 2021. The role of river flooding as an environmental filter for Amazonian butterfly assemblages. *Frontiers in Ecology and Evolution* 9, 693178.
- Ralston, B.E., Cobb, N.S., Brantley, S.L., Higgins, J., Yackulic, C.B., 2017. Taxonomic and compositional differences of ground-dwelling arthropods in riparian habitats in Glen Canyon, Arizona, USA. *Western North American Naturalist* 77(3), 369-384.
- Ramey, T.L., Richardson, J.S., 2017. Terrestrial invertebrates in the riparian zone: mechanisms underlying their unique diversity. *BioScience* 67(9), 808-819.
- Remsburg, A.J., Olson, A.C., Samways, M.J., 2008. Shade alone reduces adult dragonfly (Odonata: Libellulidae) abundance. *Journal of Insect Behavior* 21(6), 460-468.
- Riedl, H.L., Clements, W.H., Pejchar, L., 2019. An introduced plant is associated with declines in terrestrial arthropods, but no change in stream invertebrates. *Canadian Journal of Fisheries and Aquatic Sciences* 76(8), 1314-1325.
- Roeder, K.A., Roeder, D.V., Kaspari, M., 2018. Disturbance mediates homogenization of above and belowground invertebrate communities. *Environmental Entomology* 47(3), 545-550.
- Samways, M.J., Grant, P.B.C., 2006. Regional response of Odonata to river systems impacted by and cleared of invasive alien trees. *Odonatologica* 35(3), 297-303.
- Santos-Silva, L., Pinheiro, T.G., Chagas-Jr, A., Marques, M.I., Battirola, L.D., 2018. Temporal and spatial variation of Myriapoda (Diplopoda and Chilopoda) assemblages in a Neotropical floodplain. *Biota Neotropica* 18, e20180514.
- Sienkiewicz, P., Zmihorski, M., 2012. The effect of disturbance caused by rivers flooding on ground beetles (Coleoptera: Carabidae). *European Journal of Entomology* 109(4), 535.

- Skalski, T., Kędzior, R., Wyżga, B., Radecki-Pawlik, A., Plesiński, K., Zawiejska, J., 2016. Impact of Incision of Gravel-bed Rivers on Ground Beetle Assemblages. *River Research and Applications* 32(9), 1968-1977.
- Slupik, O., McCune, F., Watson, C., Proulx, R., Fournier, V., 2022. Response of bee and hoverfly populations to a land-use gradient in a Quebec floodplain. *Journal of Insect Conservation* 26(6), 919-932.
- Smith, D.M., Kelly, J.F., Finch, D.M., 2006. Influences of disturbance and vegetation on abundance of native and exotic detritivores in a southwestern riparian forest. *Environmental Entomology* 35(6), 1525-1531.
- Sterzyńska, M., Shrubovych, J., Nicia, P., 2017. Impact of plant invasion (*Solidago gigantea* L.) on soil mesofauna in a riparian wet meadows. *Pedobiologia* 64, 1-7.
- Swain, D.L., Wing, O.E.J., Bates, P.D., Done, J.M., Johnson, K.A., Cameron, D.R., 2020. Increased flood exposure due to climate change and population growth in the United States. *Earth's Future* 8(11), e2020EF001778.
- Tajovsky, K., 1999. Impact of inundations on terrestrial arthropod assemblages in Southern Moravian floodplain forests, the Czech Republic. *Ekologia(Bratislava)/Ecology(Bratislava)* 18, 177-184.
- Talley, T.S., Nguyen, K.C., Nguyen, A., 2012. Testing the effects of an introduced palm on a riparian invertebrate community in Southern California. *PLoS One* 7, e42460.
- Tockner, K., Stanford, J.A., 2002. Riverine flood plains: present state and future trends. *Environmental Conservation* 29(3), 308-330.
- Topp, W., Kappes, H., Rogers, F., 2008. Response of ground-dwelling beetle (Coleoptera) assemblages to giant knotweed (*Reynoutria* spp.) invasion. *Biological Invasions* 10(4), 381-390.
- Truxa, C., Fiedler, K., 2012. Down in the flood? How moth communities are shaped in temperate floodplain forests. *Insect Conservation and Diversity* 5(5), 389-397.
- Uetz, G.W., Van Der Laan, K.L., Summers, G.F., Gibson, P.A., Getz, L.L., 1979. The effects of flooding on floodplain arthropod distribution, abundance and community structure. *American Midland Naturalist* 101, 286-299.
- Uhey, D.A., Rowe, A.K., Kendall, D., 2020. Tamarisk alters arthropod composition, but has little negative effect on richness and abundance in Southwestern Colorado. *Southwestern Entomologist* 45(3), 585-600.

- Wang, K., Yuan, X., Zhang, G., Liu, S., Wang, F., Liu, H., Zhang, M., Zhou, L., 2019a. Diversity and Distribution of Riparian Arthropods in the Drawdown Zone of China's Three Gorges Reservoir. *Environmental Entomology* 48(6), 1340-1348.
- Wang, K., Yuan, X., Wu, S., Zhang, G., Liu, H., Zhou, L., Zhang, M., 2019b. Effects of river damming on ground-dwelling arthropods along riparian-upland habitats. *Ecohydrology* 12(3), e2073.
- Wardle, D.A., Bardgett, R.D., Klironomos, J.N., Setälä, H., Van Der Putten, W.H., Wall, D.H., 2004. Ecological linkages between aboveground and belowground biota. *Science* 304(5677), 1629-1633.
- Wenninger, E.J., Fagan, W.F., 2000. Effect of river flow manipulation on wolf spider assemblages at three desert riparian sites. *The Journal of Arachnology* 28(1), 115-122.
- Whiles, M.R., Goldowitz, B.S., 2005. Macroinvertebrate communities in central Platte River wetlands: patterns across a hydrologic gradient. *Wetlands* 25(2), 462-472.
- Xiao, H., Du, C., Yuan, X., Li, B., 2020. Multiple floods affect composition and community structure of the ground-dwelling arthropods in the riparian zone of the Three Gorges Reservoir. *Ecological Indicators* 113, 106220.
- Xiao, H., Li, B., Willison, J.M., Wang, Y., 2022. Habitat change and interspecific associations mediate the response of riparian ground-dwelling arthropod assemblages to flooding in the Three Gorges Reservoir. *Ecological Engineering* 185, 106812.
- Yoshioka, A., Kadoya, T., Suda, S.I., Washitani, I., 2010. Impacts of weeping lovegrass (*Eragrostis curvula*) invasion on native grasshoppers: responses of habitat generalist and specialist species. *Biological Invasions* 12(3), 531-539.
- Zulka, K.P., 1994. Carabids in a Central European floodplain: species distribution and survival during inundations. In: Desender K., Dufrêne M., Loreau M., Luff ML, Maelfait JP. (Eds.), *Carabid Beetles. Ecology and Evolution* Kluwer Academic Publishers, Dordrecht, Boston, London, 399-406.

CHAPTER 3 : Environmental factors affecting ant and spider biodiversity patterns in riparian habitats and the surrounding uplands of the uMngeni River, KwaZulu-Natal Midlands, South Africa

Abstract

Given the conservation value of riparian zones worldwide, it is essential to investigate biodiversity patterns in these zones. The environmental gradients between riparian habitats and the surrounding uplands promote habitat heterogeneity. At the same time, the physical boundary of riparian zones may vary across taxonomic groups, depending on their specific needs. This study, therefore, assessed the influence of spatiotemporal changes on ant and spider biodiversity in riparian habitats and from these habitats to the uplands of the KwaZulu-Natal Midlands in South Africa. Sampling plots were placed along a transect from 0 to 2200 m within the riparian habitats and on a transect from 0 (i.e. within the riparian habitats) to 300 m from the riparian habitats to the uplands, sampled using pitfall traps during the wet and dry seasons. A total of 6 906 ant and 1 453 spider individuals were collected. In the gradient from the riparian habitats to the uplands, ant and spider abundance decreased with increasing distance from the riparian zones, while abundance for both taxa increased during the wet season. Ant species richness was higher at distances further from the riparian zones contrasting to species richness along the riparian zone. In contrast, spider species richness was not significantly influenced by distance, season and location in both gradients. The distribution of foraging strategies for both ants and spiders was influenced by distance, seasonality and location. Spider community composition was not significantly influenced by distance, however, nestedness increased with distance from the riparian zones to the uplands at Hilton., suggesting that upland spider communities represented subsets of riparian spider communities. Contrasting to ant community composition along the riparian zones where turnover increased with distance at Hilton, indicating species replacement along the gradient. The observed findings indicated that ant species turnover may have been influenced by temporal changes and habitat heterogeneity along riparian habitats. The observed patterns highlight how changes in resource availability and habitat conditions between riparian habitats and adjacent uplands may differentially influence arthropod diversity and may increase their vulnerability to habitat structure and vegetational difference. Therefore, this study offers valuable insights for predicting how arthropods may respond to ecological changes, especially in the face of climate

change and highlights the need to extend conservation and restoration efforts to adjacent uplands to sustain biodiversity and ecosystem functions along riparian zones.

Keywords: riparian zone, upland, gradient, biodiversity, ant, spider

3.1 Introduction

Despite riparian zones covering a small area, they are among the fifteen universally recognised terrestrial biomes due to their ecological significance (Singh et al., 2021). They support significantly higher biodiversity than the surrounding areas (Faria et al., 2019; Singh et al., 2021). Their soil and vegetation are uniquely structured (Griotti et al., 2017) and have distinct topography and microclimate (Singh et al., 2021). The moisture and disturbance regimes (Pettit and Naiman, 2007), such as flooding, also differ from surrounding uplands, leading to high productivity (Sabo et al., 2005). These factors contribute to the complexity and variability of riparian zones over time and space, resulting in highly diverse biophysical characteristics (Wang et al., 2019; Singh et al., 2021). In contrast, the surrounding uplands, such as grasslands and wooded grasslands, are among the most widespread terrestrial biomes in many regions worldwide (Zhao et al., 2020). The various features of grassland landscapes, such as plant species composition, soil types, and topographical variations, play a crucial role in shaping the structure and functioning of these ecosystems (Zhao et al., 2020). The vegetation structure found in both habitats is among the key factors influencing riparian fauna, with the more complex vegetation supporting greater faunal diversity (Naiman and Décamps, 1997; Brose, 2003; Griotti et al., 2017).

Ecological research often centres on understanding temporal and spatial variations in biodiversity within ecosystems, providing crucial insights into ecological health and dynamics (Griotti et al., 2017; Hsieh and Linsenmair, 2017). Strategies such as partitioning beta diversity into turnover (species replacement) and nestedness (species overlap due to species gain or loss without replacement) serve as essential tools for understanding the processes responsible for variations in species composition (Baselga, 2010; Legendre, 2014). It is essential to evaluate the health and integrity of riparian zones for their restoration and conservation purposes, particularly in the face of heightened anthropogenic activities and climate change (Park and Kim, 2020; Zina et al., 2021).

Studies (Soykan et al., 2012; Hamilton et al., 2015) have suggested that riparian zones house more species than the uplands; however, Sabo et al. (2005) inferred that they are not a home for more species but house unique species. To clearly understand these dynamics, ants (Hymenoptera: Formicidae) are used as effective bioindicators due to their widespread presence, diversity, ease of collection and identification, and year-round activity (Zina et al., 2021). Ant diversity often covaries with that of other taxa, making them useful indicators for monitoring broader biodiversity, although their effectiveness is context and scale dependent (Andersen, 1997; Underwood and Fisher, 2006; Peters et al., 2016). They have been extensively used in environmental monitoring for assessing ecological changes (Tiede et al., 2017) and for evaluating conservation status in various ecosystems (Zina et al., 2021). Similarly, spiders are diverse and widespread predators that serve as an excellent model for studying community ecology within terrestrial ecosystems and are vital for maintaining ecological balance, highlighting their functional importance in these ecosystems (Marc et al., 1999; Gomez et al., 2016). Species and guild diversity of ants and spiders respond to environmental changes resulting from seasonality and anthropogenic activities while contributing significantly to ecosystem functions (Cardoso et al., 2011; Hsieh and Linsenmair, 2017; Wang et al., 2019; Zina et al., 2021; Xiao et al., 2022; Cardoso et al., 2025). More importantly, they facilitate connectivity between riparian zones, river ecosystems, and neighbouring uplands as they link terrestrial and aquatic food webs through predator-prey relationships (Paetzold et al., 2008; Wang et al., 2019; Xiao et al., 2020, 2022). Their foraging strategies respond to resource availability (Wardhaugh, 2014) and habitat conditions, with higher guild diversity found in complex habitats (Cardoso et al., 2011).

Additionally, Drucker et al. (2008) argued that riparian zones boost the overall diversity observed across different ecosystems, however organisms differ in spatial responses to riparian environmental gradients based on their habitat needs. For example, amphibians (Perkins and Hunter, 2006), invertebrates (Rykken et al., 2007; Cawood et al., 2024) and birds (Chan et al., 2008) show different preferences. Similarly, Soykan et al. (2012) hypothesized that competition, habitat complexity, and predation decrease from the riparian zones to the uplands. The shift in ecological dynamics may regulate biodiversity patterns. However, differences in results observed from previous studies (Soykan et al., 2012) have led to the recommendation of using multiple taxa, such as spiders and ants, as focal study species to clarify whether the discrepancies are due to taxonomy or geography (Soykan et al., 2012; Santos-Silva et al., 2018; Xiao et al., 2022). Furthermore, given the conservation value of riparian zones, it is essential

to assess biodiversity at different temporal and spatial scales to guide conservation efforts (Hsieh and Linsenmair, 2017; Wang et al., 2019). Additionally, terrestrial invertebrates have been largely overlooked in riparian research (Ramey and Richardson, 2017; Wang et al., 2019).

Therefore, this study aimed to determine how the biodiversity of ants and spiders varied along the riparian habitat and from the riparian habitat to the adjacent uplands in the upper catchment of the uMngeni River, South Africa. We, therefore, tested whether seasonal changes, study location and the increasing distance along the river and from the river margins to the uplands affect the distribution of ant and spider diversity and their foraging strategies? Secondly, how does ant and spider community composition differ between sampling locations at different distances per season, and did beta diversity increase with increasing distance along and from the riparian zones to the uplands, respectively?

3.2 Materials and methods

3.2.1 Study sites

The study was conducted in the riparian zones and uplands of the upper uMngeni River at two sites (Figure 3.1). The first site, Umgeniport Research Facility (29°28'24" S; 29°53'52.7" E), is situated in the Drakensberg Foothill Moist Grassland region of the Sub-escarpment Grassland Bioregion, with elevations ranging from 1,370 to 1,780 m a.s.l. (Howard et al., 2022). It is characterized by open grasslands dominated by *Panicum ecklonii* and *Aristida junciformis*. The common grass species in the riparian habitat is *Eragrostis curvula* (Simelane et al., 2018). The site is characterized by a summer rainfall pattern, with annual rainfall averaging 800 mm and an average temperature of 24.8°C (Mthimunya and Munyai, 2022). Sampling plots were established on the bank with grassland uplands (Figure S1, Supplementary material).

The second site, Doreen Clark Nature Reserve (29°34'41" S; 30°17'19" E, also referred to as Hilton Nature Reserve), located in the suburb of Winterskloof, northwest of the city of Pietermaritzburg, features five hectares of the Southern Mistbelt Forest and Midlands Mistbelt Grassland vegetation (Brijlal et al., 2021). The climate is notably temperate, with frequent misty and overcast days (Brown, 2016). It is characterized by a summer rainfall pattern, with annual rainfall averaging 1069 mm and an average temperature of 17°C. The forest covers the majority of the reserve, with the genus *Podocarpus* and other angiosperms meeting the grassland at the narrow forest-grassland ecotone (Brijlal et al., 2021). In this site, the sampled

upper altitude plots were dominated by trees and understory vegetation, while the lower altitude plots featured a mix of trees and grasses (Figure S1, Supplementary material). Both study sites are not exposed to adjacent communities and do not experience intensive land-use activities.

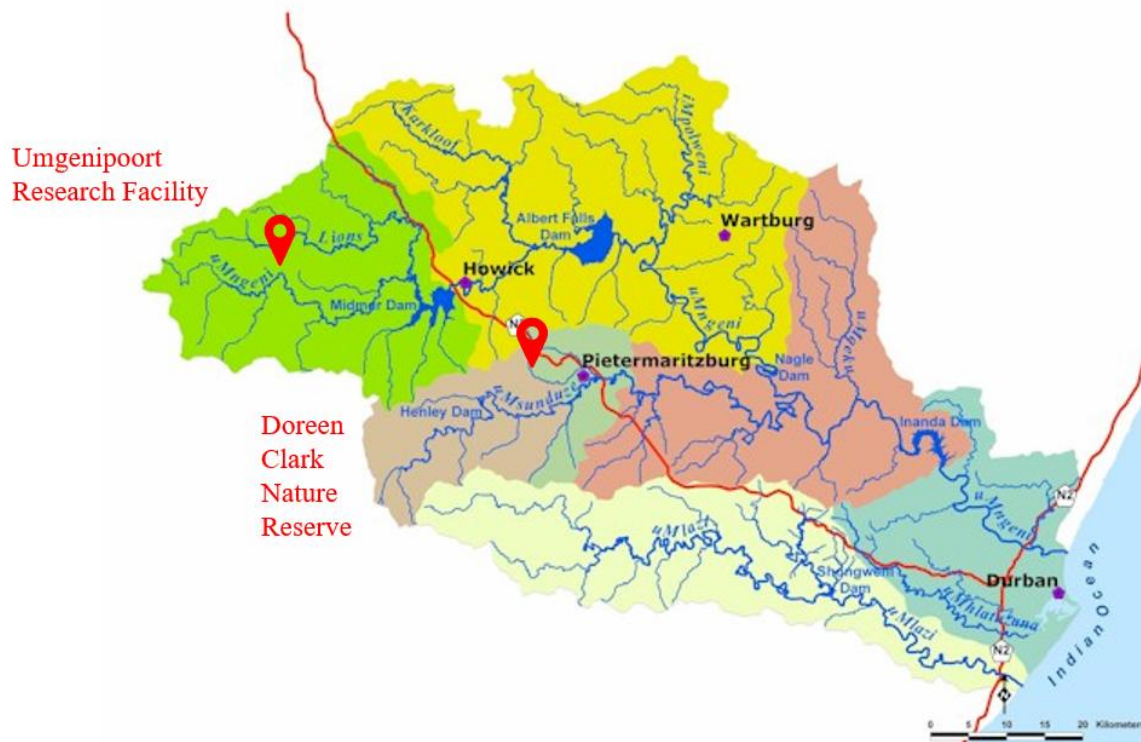
3.2.2 *Arthropod sampling*

Ground-dwelling arthropods were sampled using the standardized pitfall trapping method, as described in Munyai and Foord (2012), during the wet season (March 2023) and dry season (October 2023) to account for seasonal variations. The pitfall trapping technique efficiently captures a substantial number of ground-dwelling arthropods in a short time with minimal labour (Leather, 2005; Xiao et al., 2022). A single transect of seven sampling plots separated by different distances was established along the riparian habitat, from 0 to 2200 meters (0m, 50m, 100m, 300m, 700m, 1000m, 2200m; from the edge of the first plot) along the river (Figure 3.2), resulting in a single riparian replicate at each site. Four parallel transects of sampling plots extending from the riparian habitat to the uplands, from 0 to 300 meters (0m, 50m, 100m, 300m), were established at each site, resulting in four replicates of each distance at each site. Each sampling plot consisted of a two lines of four pitfall traps spaced 10 m apart (Figure 3.2). Pitfall traps (62 mm in diameter) were half-filled with a 50% propylene glycol solution serving both as a preservative and killing agent. The pitfall traps were left open for seven days.

Arthropod identification

Ants were identified to species level where possible by the first author with assistance from the last author. Those not identified to species level were identified to genus level using Fisher and Bolton (2016), and were assigned to morphospecies. Spider specimens were mainly (88%) identified to species level and 12% were identified to family and genus level by Professor A.S. Dippenaar-Schoeman. Voucher specimens are lodged in the Agricultural Research Council (ARC) collection in Pretoria. Ant vouchers were pinned and deposited at the School of Agriculture and Science, University of KwaZulu-Natal, in the Pietermaritzburg campus and will later be deposited at the Iziko Museums in Cape Town. Spider species were assigned to foraging strategies based on how they hunt for prey and use microhabitat following a classification system proposed by Foord et al., 2011. Foraging strategies recognised in this study included wanderers (actively hunting for prey on the ground/ plants), web builders (use web to capture prey, which were further subdivided into orb-web, funnel-web, gumfoot web,

retreat-web, sheet-web and space-web builders) and burrow dwellers (ambush prey rather than



actively searching). Ant species were assigned to foraging strategies based on their feeding behaviour, which included granivores, honeydew feeders, nectivores, omnivores, predators and scavengers (Tshiguvho et al., 1999).

Figure 3.1: Map of the uMngeni River in the KwaZulu-Natal province, South Africa (Department of Water Affairs, 2002), showing the locations of the sampled study sites

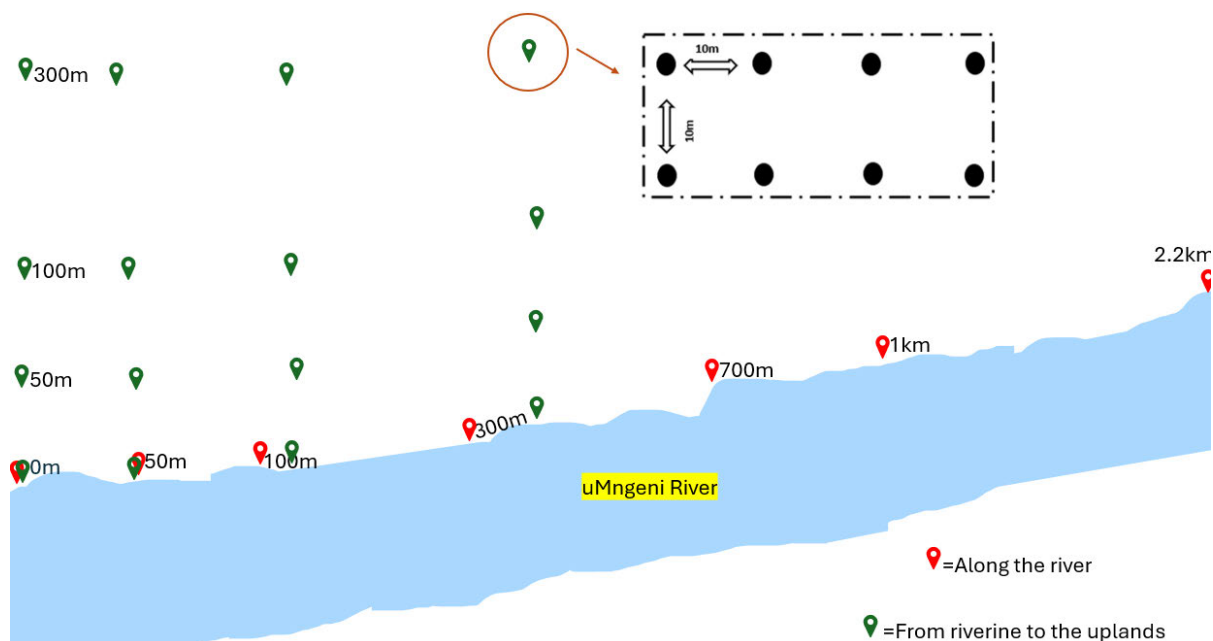


Figure 3.2: The sampling design for collecting ground-dwelling ants and spiders along the longitudinal and lateral gradients of the uMngeni River.

3.2.3 Statistical analysis

A Generalized Linear Mixed Model (GLMM) analysis was performed to investigate how distance from the river margins to the uplands, location (study sites where arthropods were sampled) and seasonality affect ant and spider diversity. Poisson regression models were used to analyse species abundance and richness. Each taxa had a separate model with distance (0, 50, 100, 300m), location (Hilton, Umgenipoort) and seasonality (dry and wet) set as fixed effects (Bolker et al., 2009). Distance replicates were included as a random effect to account for variability. The significance of each predictor (distance, location and seasonality in each model) was evaluated using the z-test, and the model fit was assessed using the Akaike Information Criterion (AIC) and residual deviance (Bolker et al., 2009). A post-hoc pairwise comparison was performed to determine where species abundance and richness differed significantly in each transect.

A Generalised Linear Model (GLM) analysis was performed to investigate how distance along the river, location and seasonality affect ant and spider diversity. Abundance and richness were analysed using GLM with negative binomial distribution to account for overdispersed data. Distance (0, 50, 100, 300, 700, 1000, 2200m), location (Hilton, Umgenipoort) and seasonality (dry, wet) were set as fixed effects. Model significance was tested using Type II likelihood

ratio χ^2 tests. Post-hoc pairwise comparisons were performed to determine where species abundance and richness differed significantly.

A multinomial logistic regression was used to investigate the influence of distance along the riparian and from the riparian to the uplands, respectively, season, and location on the distribution of ant and spider foraging strategies. The 'nnet' R package was used to fit a multinomial logistic regression model (Ripley et al., 2016). Foraging strategies were treated as a categorical response variable, and species abundance was incorporated as model weights to account for the number of individuals recorded per foraging strategy. The analysis modeled probabilities for each foraging strategy as a function of season, distance, and their interaction, while including location as a fixed effect to account for site differences.

A Permutational Multivariate Analysis of Variance (PERMANOVA) (Anderson, 2001) was conducted to evaluate the significant differences in community compositions across distances and location per season. The Non-Metric Multidimensional Scaling (NMDS) was run with a square root transformation and Wisconsin double standardization to visually represent community similarities and dissimilarities across distances, with similar communities plotted close to each other (Oksanen et al., 2013). Stress values were interpreted following Clarke (1993), where stress values more than 0.1 indicate a good representation, less than 0.2 indicate an acceptable representation, and more than 0.2 require cautious interpretation. Beta diversity was partitioned into turnover (species replacement between distances) and nestedness (species overlap due to species gain/loss without replacement) to determine whether distance affected community dissimilarity using the 'betapart' R package (Baselga and Orme, 2012). The mean Jaccard dissimilarity index was calculated for each distance and replicate to visualise gradual community changes that may have been statistically insignificant (Jaccard, 1912; Legendre and De Cáceres, 2013). All statistical analyses were conducted using RStudio (Posit Team, 2025) with R version 4.4.1 (R Core Team, 2024).

3.3 Results

The ant and spider fauna

A total of 6 906 ants and 1 453 spiders were collected across the riparian gradients of the uMngeni River. In the riparian habitat and adjacent uplands, subfamily Myrmicinae was the most species rich and abundant. The second most species rich ant subfamily was Formicinae,

while subfamilies Dorylinae, Dolichoderinae, and Ponerinae were the least species rich and abundant in both gradients (Table S2; Table S3, Supplementary material).

The most species rich family for spiders was Lycosidae, dominated by *Foveosa foveolata* in the riparian habitat and adjacent uplands. In both gradients, the second most species rich family was Salticidae along the riparian habitats and Gnaphosidae from the riparian habitats to the adjacent uplands (Table S4; Table S5, Supplementary material).

Ant and spider diversity in the gradient from the riparian habitat to the uplands

In the gradient from the riparian to the uplands, the GLMM analysis indicated that ant abundance was significantly affected by distance, location and seasonality. Ant abundance significantly decreased at 50m ($\beta = -0.901$, $p < 0.001$), at 100m ($\beta = -1.060$, $p < 0.001$) and at 300m ($\beta = -0.214$, $p < 0.001$). Ant abundance significantly increased during the wet season ($\beta = 0.272$, $p < 0.001$) and was significantly higher at Umgenipoort ($\beta = 0.337$, $p < 0.001$). The random effect of distance replicates contributed 19.4% to variation in ant abundance (Figure 3.3a; Table S6, Supplementary material).

Ant species richness significantly increased at 300m compare to 0m ($\beta = 0.228$, $p = 0.0498$) and at Umgenipoort compared to Hilton ($\beta = 0.173$, $p = 0.0422$). Ant richness did not significantly change during both seasons and at other distances ($p > 0.05$). Distance replicates accounted for 1.6% variation in ant richness (Figure 3.3b; Table S7, Supplementary material).

The multinomial logistic regression analysis indicated that seasonality ($X^2 = 80.01$, $p < 0.001$), distance from the riparian to the uplands ($X^2 = 491.50$, $p < 0.001$) and location ($X^2 = 970.27$, $p < 0.001$) had a significant effect on the distribution of ant foraging strategies. Predators and scavengers were significantly less likely to occur as the distance increased from 0m ($p < 0.001$), whereas omnivores and nectarivores were less likely to occur at 300 m ($p < 0.001$). Nectarivores ($p < 0.001$) and predators ($p = 0.004$) were more likely to be observed in the wet season, contrasting to omnivores ($p = 0.007$). In Umgenipoort, predatory and omnivorous ants were more common ($p < 0.001$) and scavengers were more common in Hilton ($p < 0.001$) (Figure 3.3a; Table S8, Supplementary material).

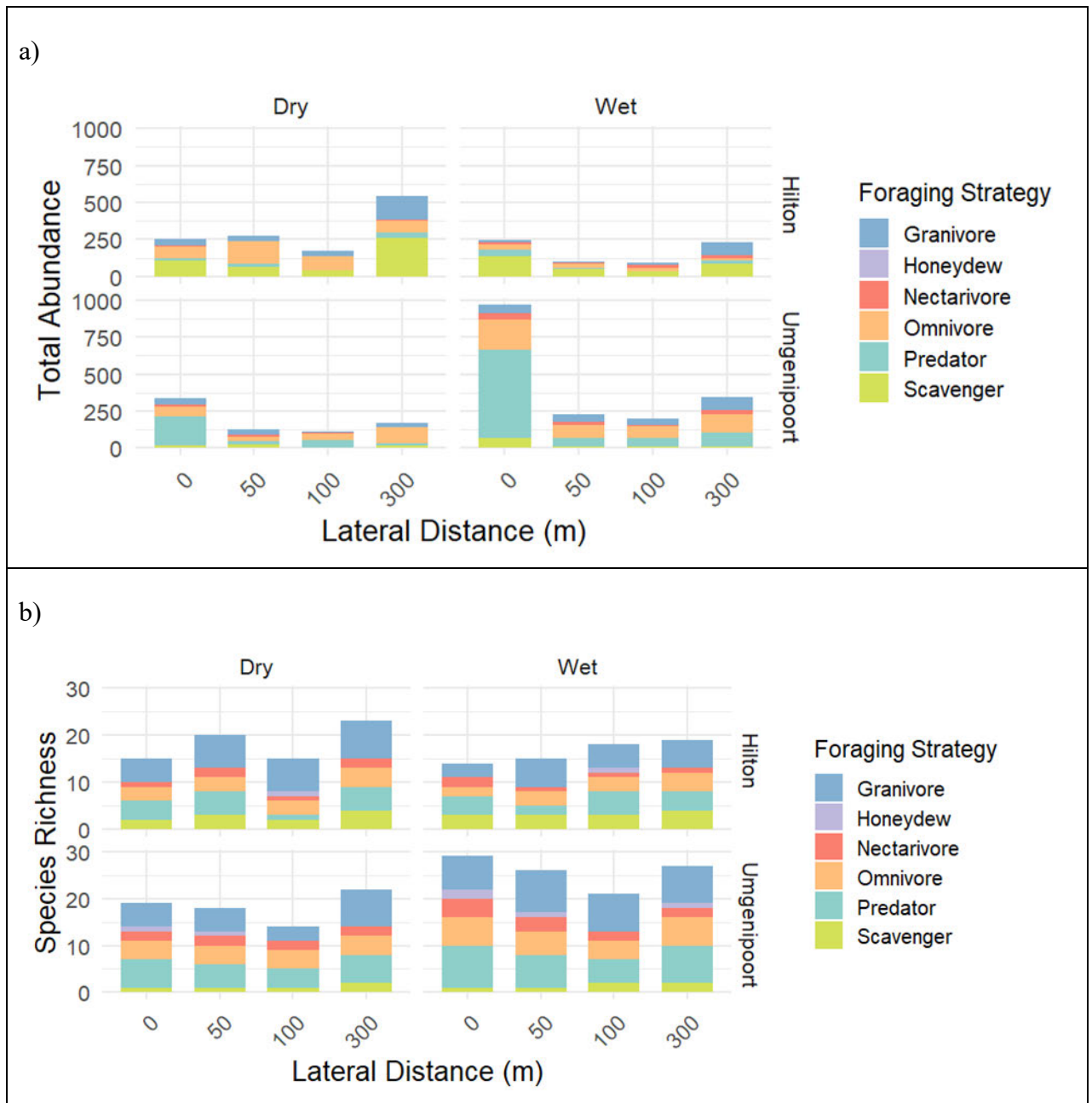
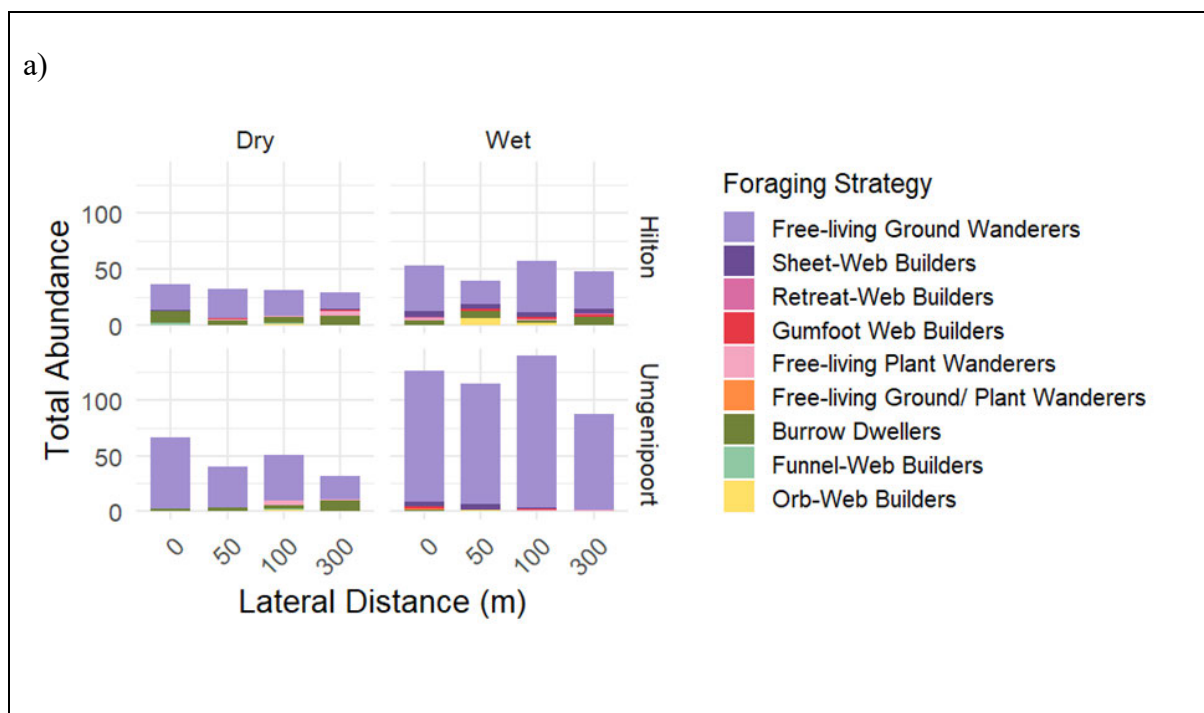


Figure 3.3: Ant abundance (a) and richness (b) from the uMngeni riparian habitat (0 m), to the uplands (50 m, 100 m, 300 m), location (Hilton, Umgenipoort) and season (wet and dry), with bars filled with their foraging strategies.

Across the gradient from the riparian to the uplands, seasonality, location and distance ($\beta = 2.021$, $p < 0.001$) had a significant effect on the spider abundance. Overall spider abundance decreased at 50m ($\beta = -0.188$, $p = 0.038$) and 300m ($\beta = -0.364$, $p < 0.001$) compared to 0m, while there was no significant effect at 100m ($p = 0.739$). Spider abundance was significantly higher during the wet season ($\beta = 0.676$, $p < 0.001$) and at Umgenipoort compared to Hilton ($\beta = 0.724$, $p < 0.001$). Replicates contributed 5.3% variation to spider abundance (Figure 3.4a; Table S9, Supplementary material)

Seasonality, location and distance from the riparian to the uplands had no significant effect on spider richness ($p > 0.05$). Replicates contributed to less than 0.01% variance in spider richness (Figure 3.4b).

Seasonality ($X^2 = 72.534$, $p < 0.001$), distance from the riparian to the uplands ($X^2 = 50.998$, $p = 0.001$) and location ($X^2 = 86.687$, $p < 0.001$) had a significant effect on the distribution of spider foraging strategies. Free-living ground wanderers were more common in the wet season ($p < 0.001$) and at Umgenipoort ($p < 0.001$). Gumfoot web builders ($p = 0.002$) and sheet-web builders ($p < 0.001$) were more common in the wet season (Figure 3.4a; Table S10, Supplementary material).



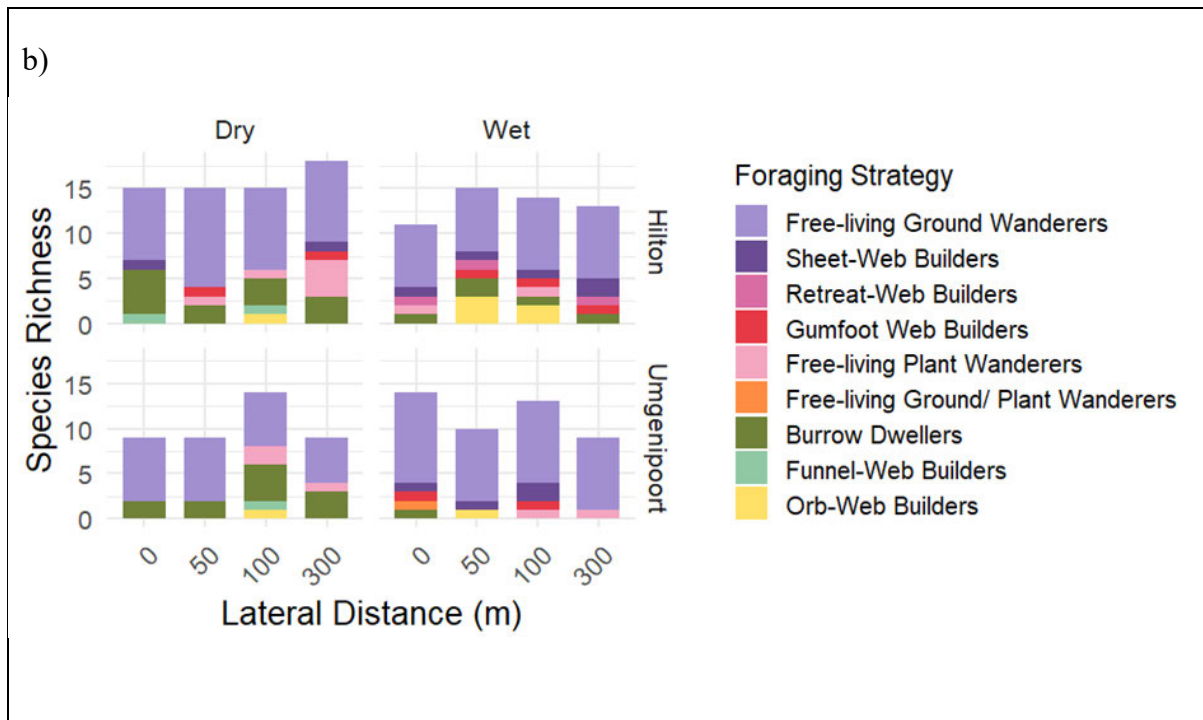


Figure 3.4: Spider abundance (a) and richness (b) from the uMngeni riparian habitats (0 m) to the uplands (50 m, 100 m, 300 m), location (Hilton, Umgenipoort) and season (wet and dry), with bars filled by foraging strategies.

Ant and spider diversity along the riparian habitat

For the gradient along the riparian habitat, ant abundance was not significantly affected by seasonality and location ($p > 0.05$). Distance had a significant effect ($X^2 = 30.17$, $p < 0.001$), with total ant abundance significantly lower at 50 m ($p < 0.001$), 100 m ($p = 0.001$), 300 m ($p = 0.008$), 700 m ($p < 0.001$), and 2200 m ($p < 0.001$) compared to 0 m. No significant difference were noted between 0 m and 1000 m ($p = 0.319$). (Figure 3.5a; Table S11, Supplementary material).

Ant species richness was significantly affected by distance ($X^2 = 17.93$, $p = 0.006$), but not by location or season ($p > 0.05$). Ant richness was significantly lower at 300 m ($\beta = -1.20$, $p < 0.001$), 1000 m ($\beta = -0.51$, $p = 0.048$), and 2200 m ($\beta = -0.49$, $p = 0.031$) compared to 0 m. There were no significant differences in ant richness between 0 m and 50 m, 100 m, or 700 m ($p > 0.05$) (Figure 3.5b; Table S12, Supplementary material).

Seasonality ($X^2 = 158.40$, $p < 0.001$), distance along the riparian ($X^2 = 117.21$, $p < 0.001$) and location ($X^2 = 624.26$, $p < 0.001$) significantly effected the distribution of ant foraging strategies. Predators, scavengers, nectarivores and honeydew feeding ants were more common

during the wet season and at Umgenipoort than Hilton ($p < 0.001$). Omnivores and scavengers were less common with increasing distance ($p < 0.05$), contrasting to predatory ants (Figure 3.5a; Table S13, Supplementary material).

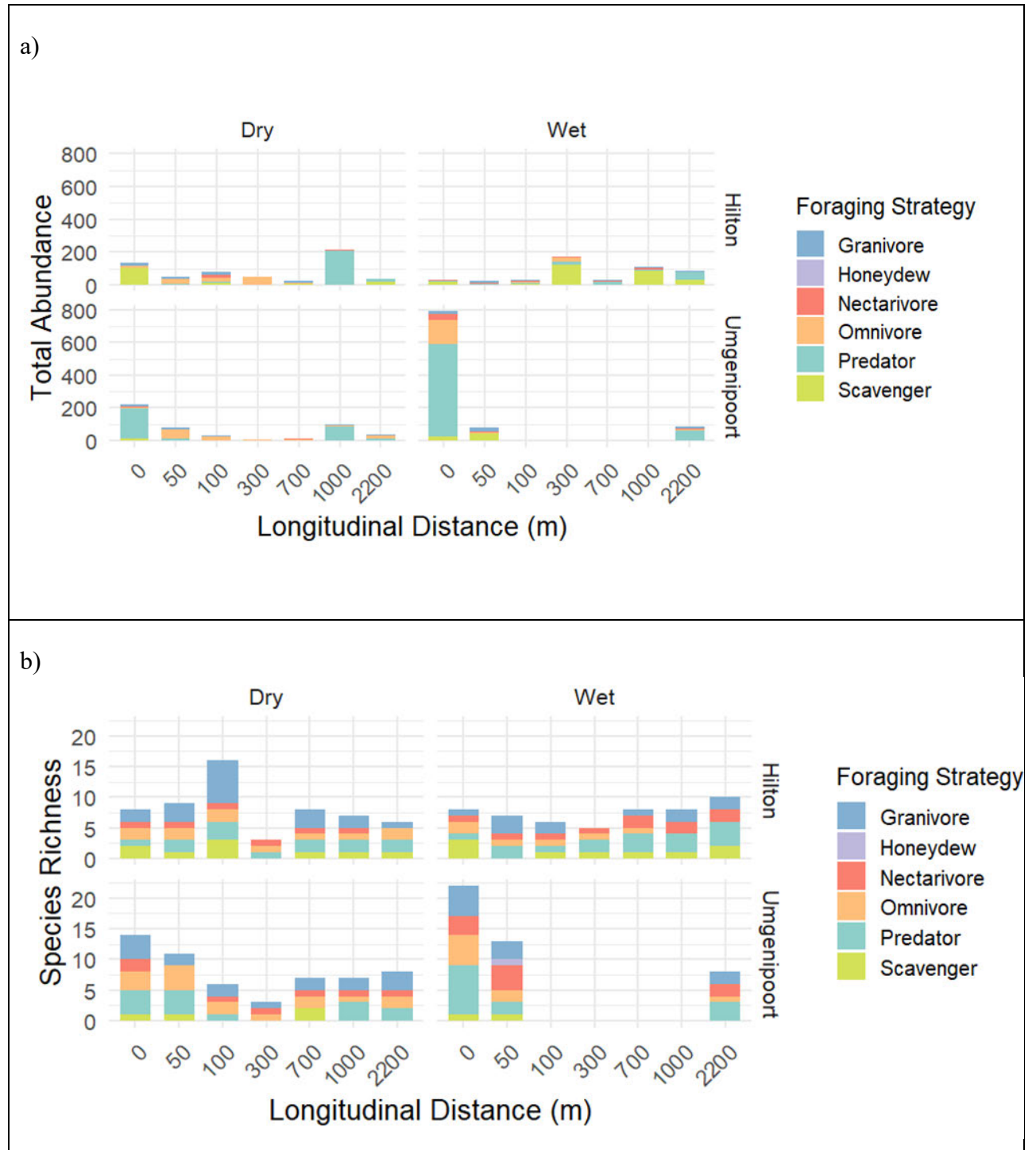
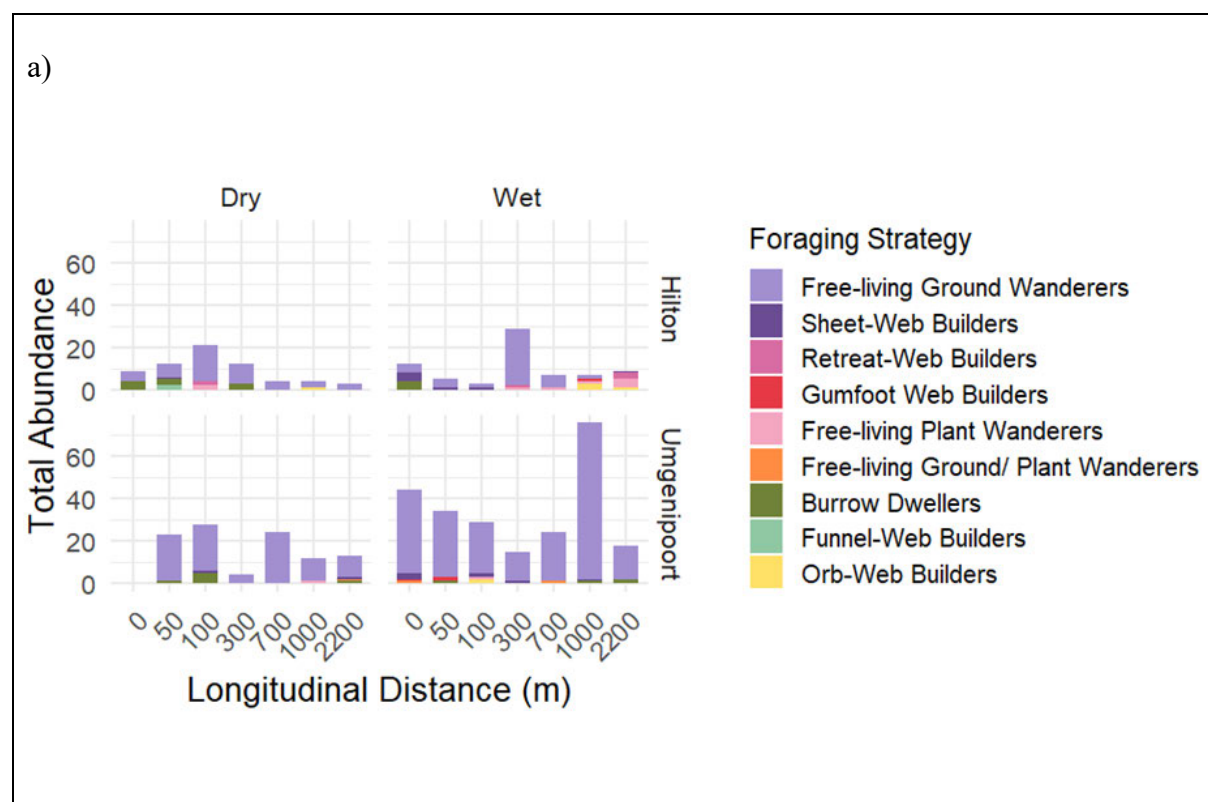


Figure 3.5: Ant abundance (a) and richness (b) along the longitudinal gradient of the uMngeni riparian zones (0 m, 50 m, 100 m, 300 m, 700 m, 1000 m, 2200 m), location (Hilton, Umgenipoort) and season (wet and dry), with bars filled by their foraging strategies.

In the gradient along the riparian habitat, the negative binomial GLM indicated that seasonality ($X^2 = 2.92$, $p = 0.087$) and distance ($X^2 = 4.69$, $p = 0.584$) had no significant effect on the overall spider abundance. Location, however, significantly influenced spider abundance ($X^2 = 17.38$, $p < 0.001$) with significantly higher spider abundance at Umgenipoort compared to Hilton ($\beta = 0.972$, $p < 0.001$) (Figure 3.6a; Table S14, Supplementary material).

Seasonality ($X^2 = 1.36$, $p = 0.244$, distance ($X^2 = 3.72$, $p = 0.715$) and location ($X^2 = 1.32$, $p = 0.250$) had no statistically significant effect on spider richness (Figure 3.6b).

Seasonality ($X^2 = 20.28$, $p = 0.009$), distance ($X^2 = 23.24$, $p = 0.003$), and location ($X^2 = 60.37$, $p < 0.001$) had a significant effect on the distribution of spider foraging strategies. Free-living plant wanderers ($p = 0.001$) and retreat-web builders ($p = 0.008$) were more common with increasing distance. At Hilton, funnel-web builders and retreat-web builders were common, whereas all the wanderers were more common at Umgenipoort ($p < 0.05$). Funnel-web builders were the only foraging strategy that was less likely to occur in the wet season ($p < 0.001$) (Figure 3.6a; Table S15, Supplementary material).



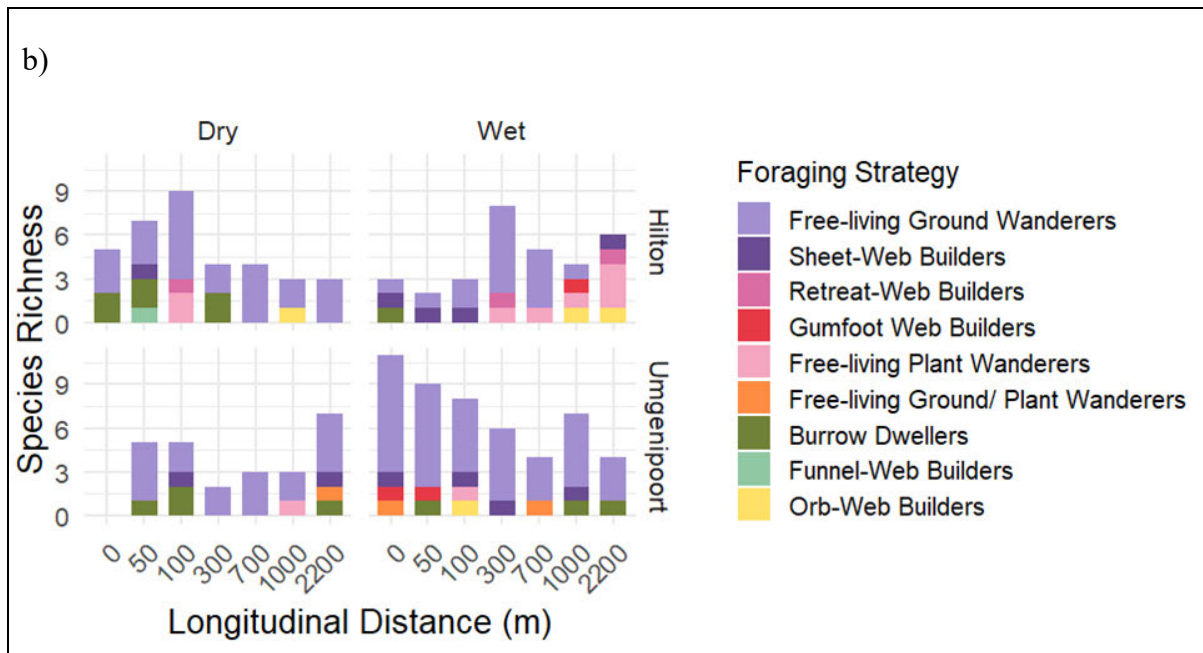


Figure 3.6: Spider abundance (a) and richness (b) along the longitudinal gradient of the uMngeni riparian zones (0 m, 50 m, 100 m, 300 m, 700 m, 1000 m, 2200 m), location (Hilton, Umgenipoot) and season (wet and dry), with bars filled by foraging strategies.

Ant and spider community composition from the riparian habitat to the uplands

The PERMANOVA test to determine significant differences in community composition indicated that the ant community composition differed significantly with location ($R^2 = 0.27316$, $F = 5.5518$, $p = 0.001$), whereas the distance from the riparian to the uplands ($R^2 = 0.06906$, $F = 1.4035$, $p = 0.181$) and seasonality ($R^2 = 0.06736$, $F = 1.3690$, $p = 0.200$) had no statistically significant effect, which was reflected by NMDS plot (Figure 3.7a).

In contrast, the spider community composition differed significantly with seasonality ($R^2 = 0.20136$, $F = 4.9693$, $p = 0.001$) and location ($R^2 = 0.26258$, $F = 6.4801$, $p = 0.001$) while distance had no significant effect ($R^2 = 0.04981$, $F = 1.2293$, $p = 0.261$) (Figure 3.7b).

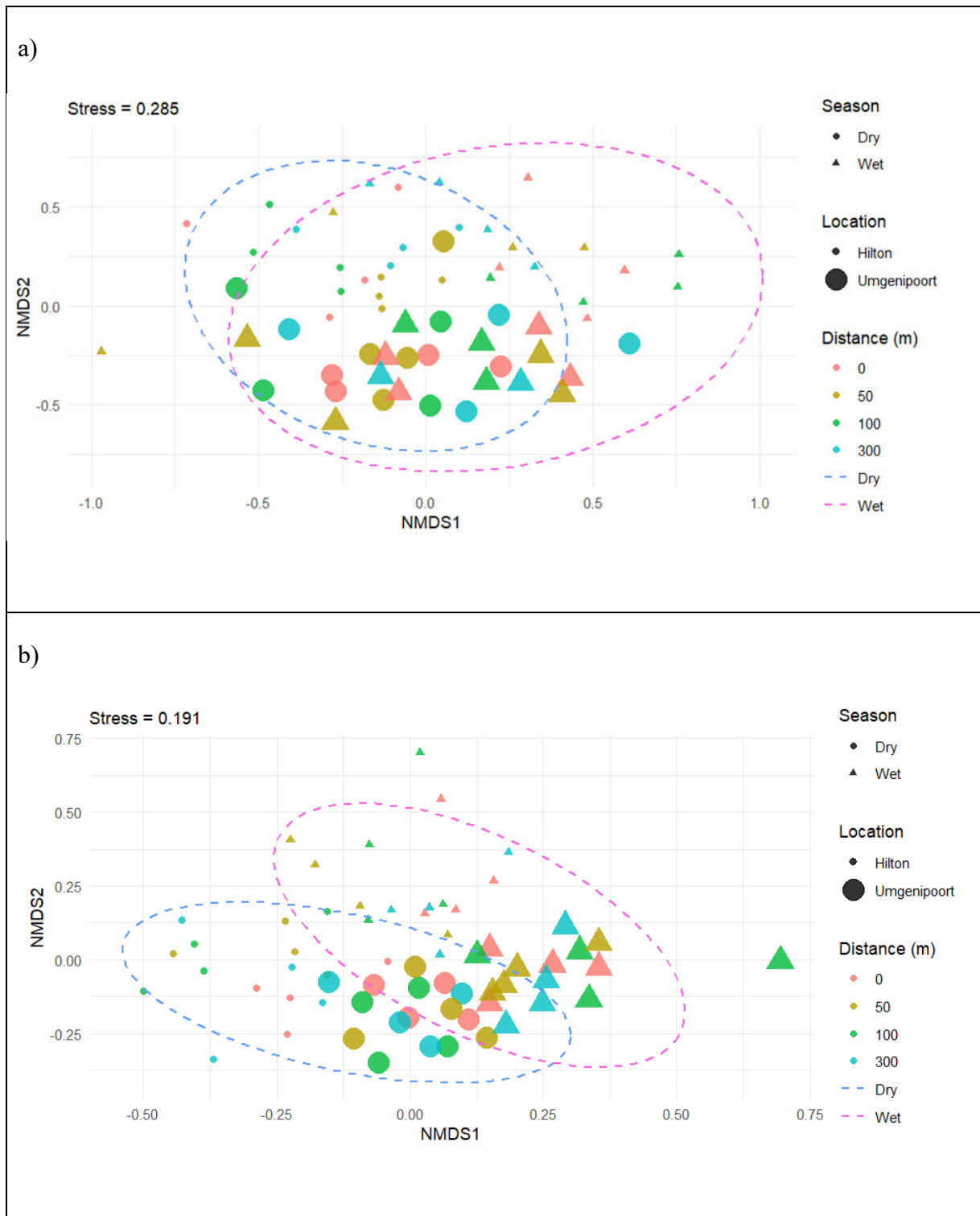
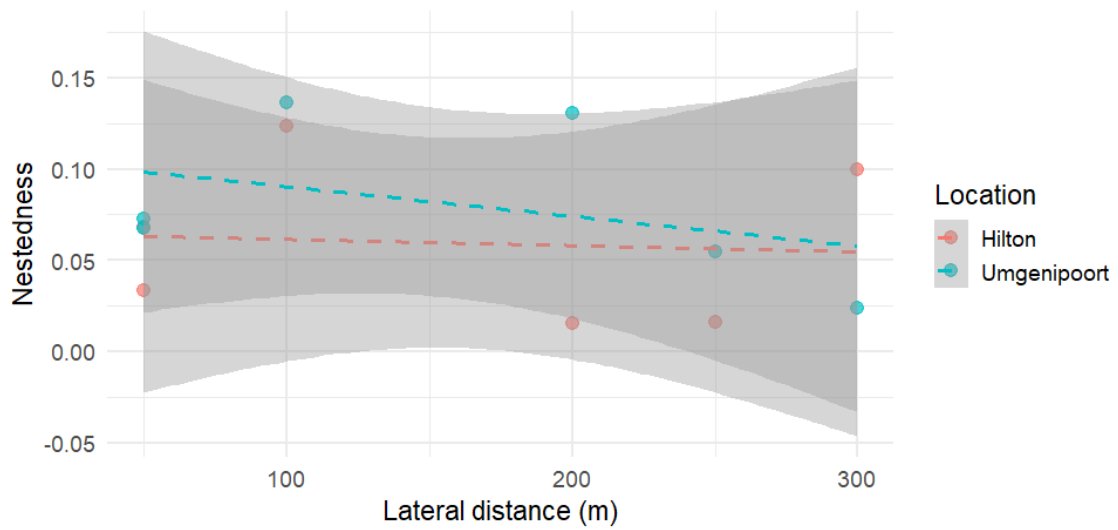
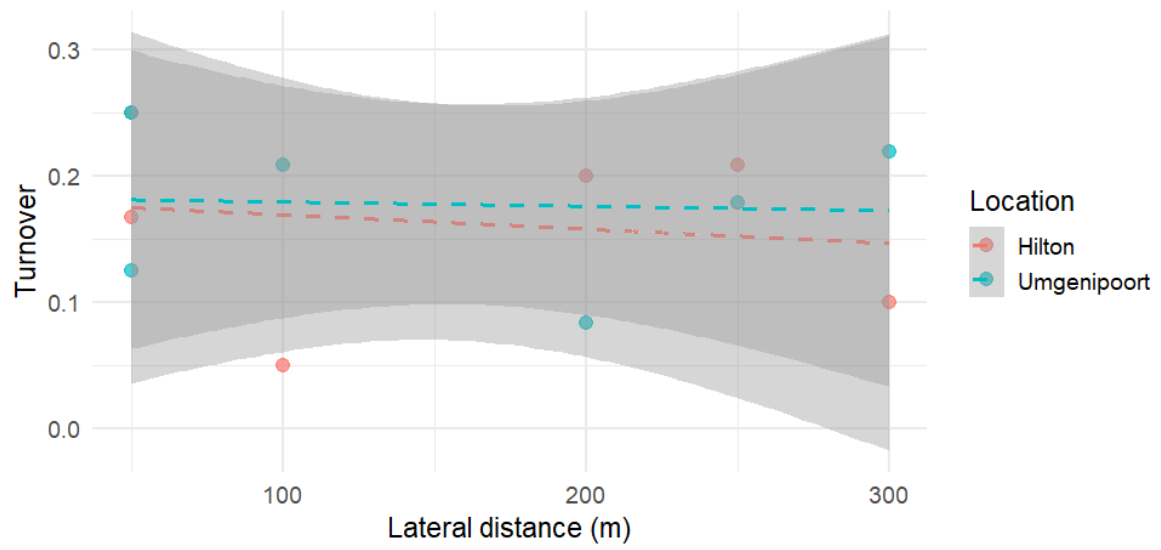


Figure 3.7: Non-Metric Multidimensional Scaling (NMDS) ordination of ant (a) and spider (b) community composition from the riparian habitat (0 m) to the uplands (50 m, 100m, 300 m). The distances are shown by colour, seasons are represented by shape, locations are differentiated by the size of the shape and convex hulls surround seasons. Stress values more than 0.2 should be interpreted with caution (Clarke, 1993).

Beta diversity was partitioned into turnover (species replacement) and nestedness (species overlap) to determine whether it increased with increasing distance from the riparian zones to the uplands. Turnover ($p = 0.759$) and nestedness ($p = 0.881$) did not show a significant relationship with distance from the riparian zones for ant communities at Hilton. Similarly, at Umgenipoort, neither turnover ($p = 0.913$) or nestedness ($p = 0.442$) significantly increased with distance (Figure 3.8a).

For spider communities, nestedness ($p = 0.001$) significantly increased with distance from the riparian zones to the uplands at Hilton, whereas turnover ($p = 0.273$) did not show significant relationship with distance. At Umgenipoort, neither turnover ($p = 0.487$) or nestedness ($p = 0.748$) showed significant relationship with distance (Figure 3.8b).

a)



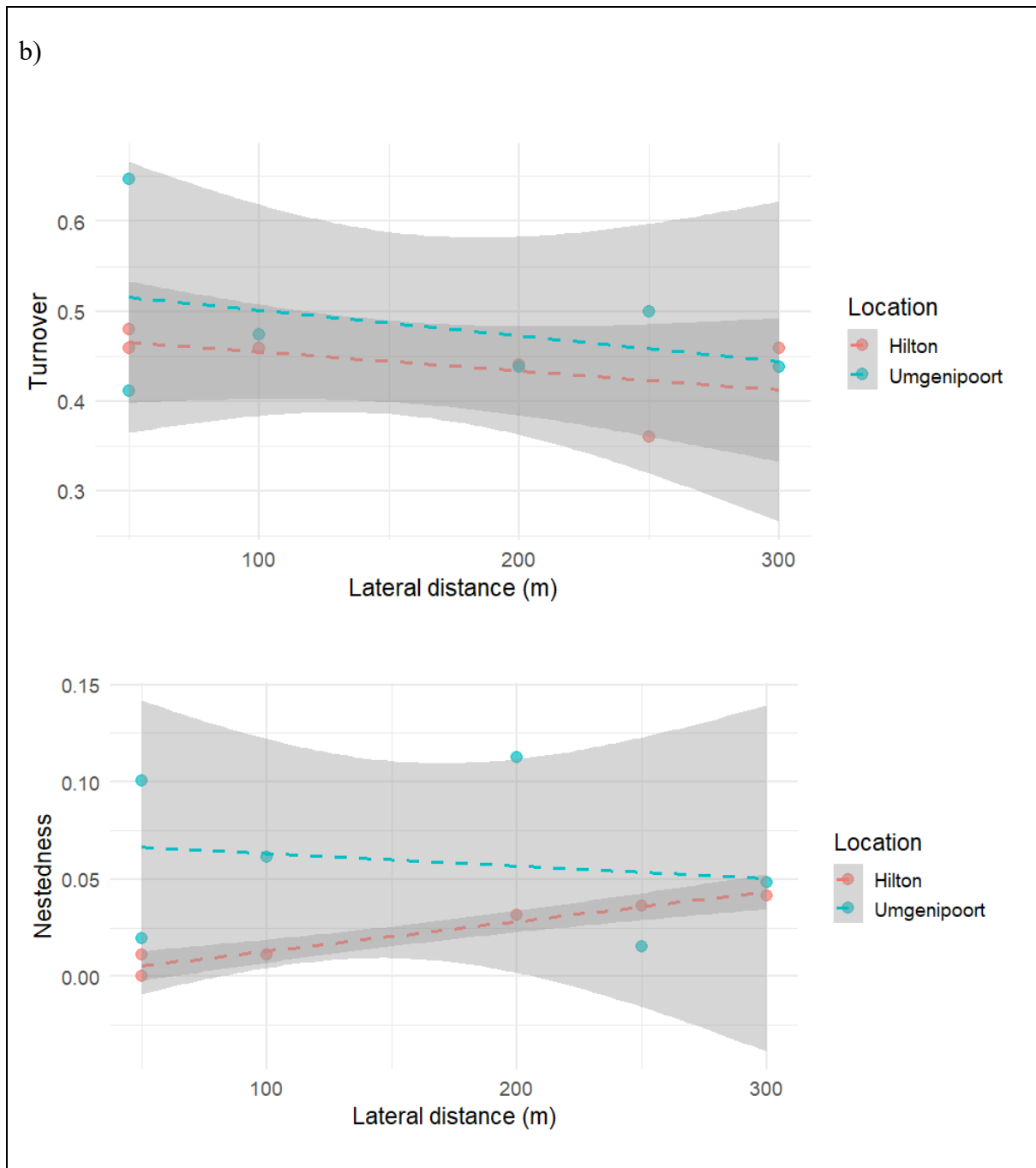


Figure 3.8: Relationship between turnover and nestedness and spatial distance for ant (a) and spider (b) community composition from the riparian habitat (0 m) to the uplands (50 m, 100 m, 300 m) during the dry and wet seasons.

The mean Jaccard dissimilarity to show gradual changes decreased with increasing distance from the riparian habitat to the uplands for ant communities in Hilton, whereas the ant communities in Umgenipoort exhibited opposite patterns (Figure 3.9a). In contrast, the mean Jaccard dissimilarity index varied within replicates for spider communities in both locations, showing no clear pattern of change (Figure 3.9b).

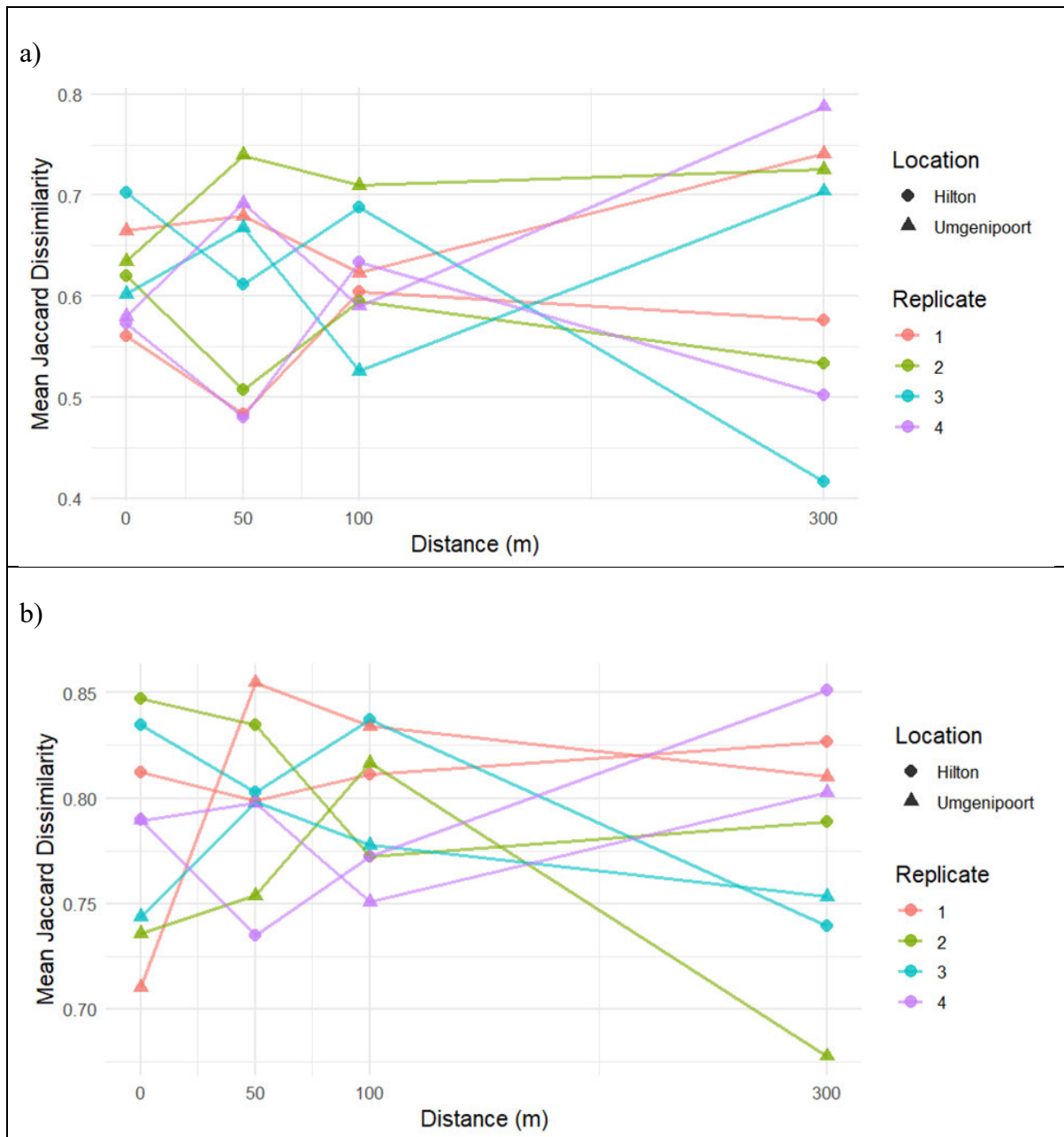


Figure 3.9: Mean Jaccard dissimilarity index showing gradual changes in ant (a) and spider (b) communities from the riparian habitat to the uplands across Hilton and Umgenipoort.

Ant and spider community composition along the riparian habitat

Ant community composition significantly differed with distance along the riparian habitat ($R^2 = 0.007$, $F = 2.98$, $p = 0.001$), location ($R^2 = 0.017$, $F = 7.16$, $p = 0.001$) and seasonality ($R^2 = 0.004$, $F = 1.73$, $p = 0.023$) (Figure 3.10a). Whereas, the spider community composition differed significantly with season ($R^2 = 0.102$, $F = 3.37$, $p = 0.002$) and location ($R^2 = 0.156$, $F = 5.13$, $p = 0.001$) while distance along the riparian habitat ($R^2 = 0.043$, $F = 1.076$, $p = 0.132$) had no significant effect (Figure 3.10b).

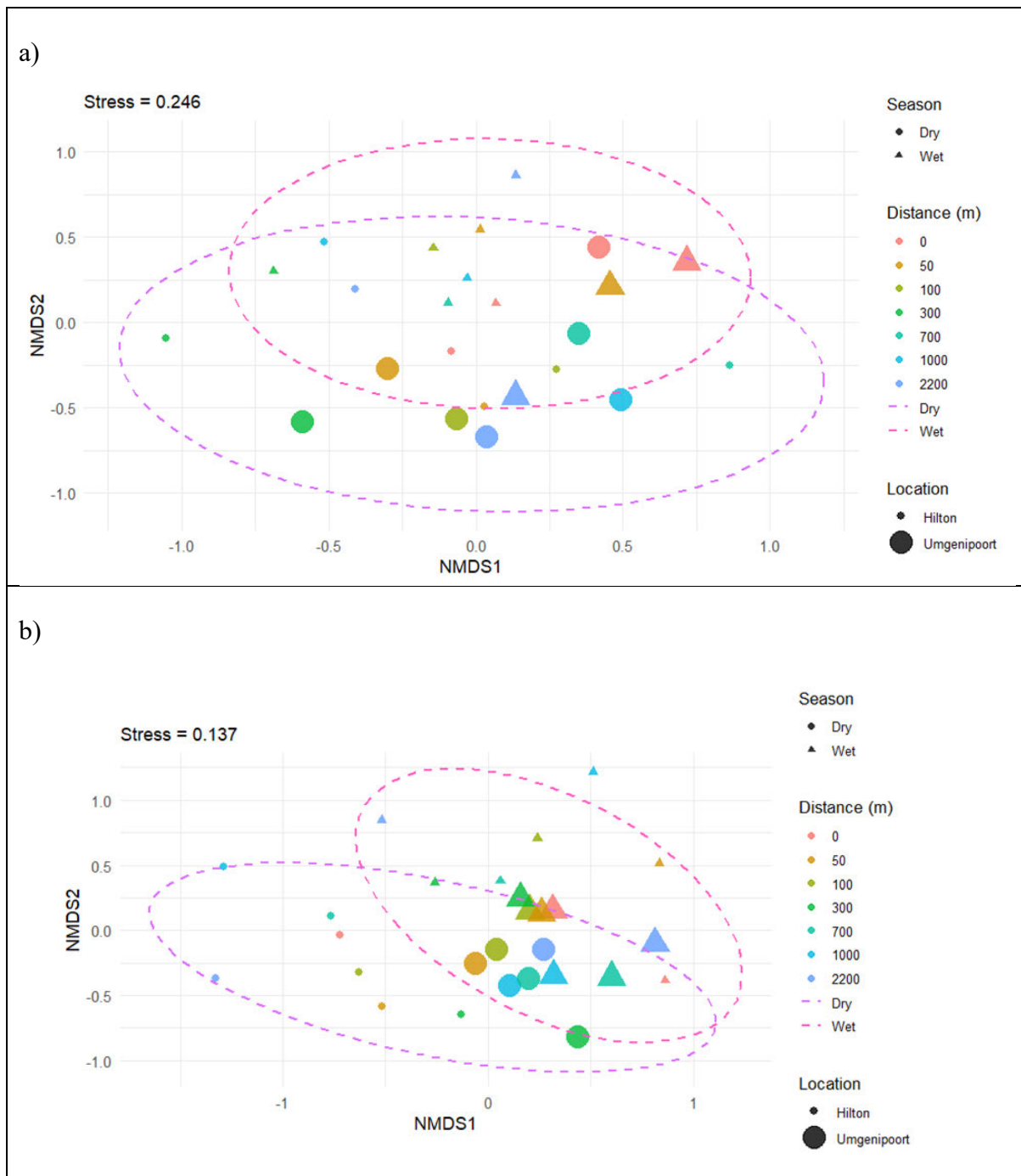
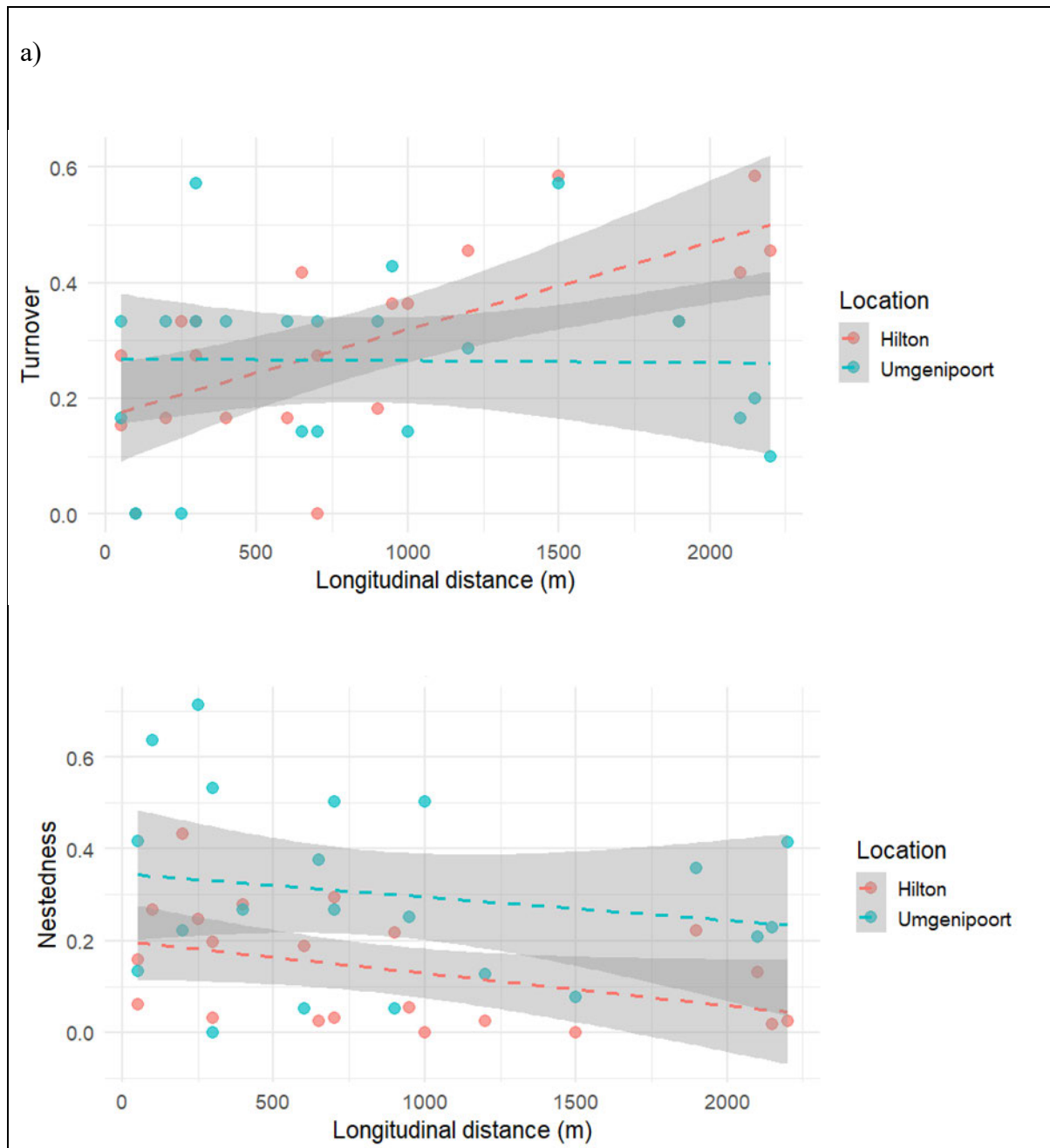


Figure 3.10: Non-Metric Multidimensional Scaling (NMDS) ordination of ant (a) and spider (b) community composition along the riparian habitat. The distances are shown by colour, seasons are represented by shape, locations are differentiated by the size of shape and convex hulls surround seasons. Stress values more than 0.2 should be interpreted with caution (Clarke, 1993).

For ant communities at Hilton, turnover ($p = 0.000867$) significantly increased with distance along the riparian zones whereas nestedness ($p = 0.066$) had no significant relationship with

distance. At Umgenipoort, neither turnover or nestedness showed a significant relationship with distance ($p > 0.05$) (Figure 3.11a). For spider communities, turnover and nestedness did not show a significant relationship with distance along riparian zones for both Hilton and Umgenipoort ($p > 0.05$) (Figure 3.11b).



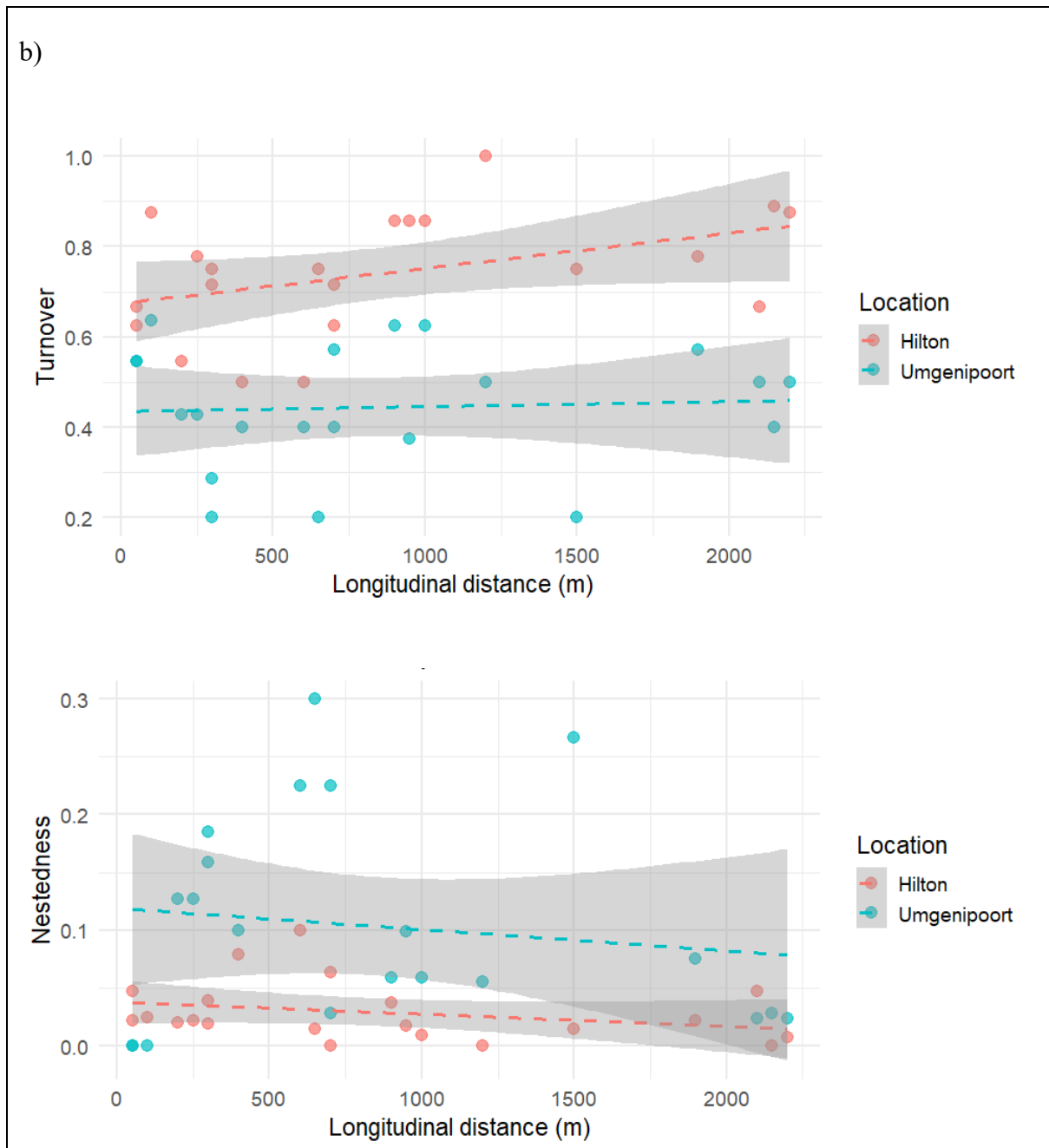


Figure 3.11: Relationship between turnover and nestedness and spatial distance for ant (a) and spider (b) community composition along the riparian habitat during the wet and dry season.

The mean Jaccard dissimilarity, which shows gradual changes, increased with distance along the riparian habitat for ant communities. Ant communities from Umgenipoort exhibited higher dissimilarities compared to those in Hilton (Figure 3.12a). Spider communities exhibited fluctuating dissimilarities with distance; however, spider communities from Hilton had higher dissimilarities with increasing distance (Figure 3.12b).

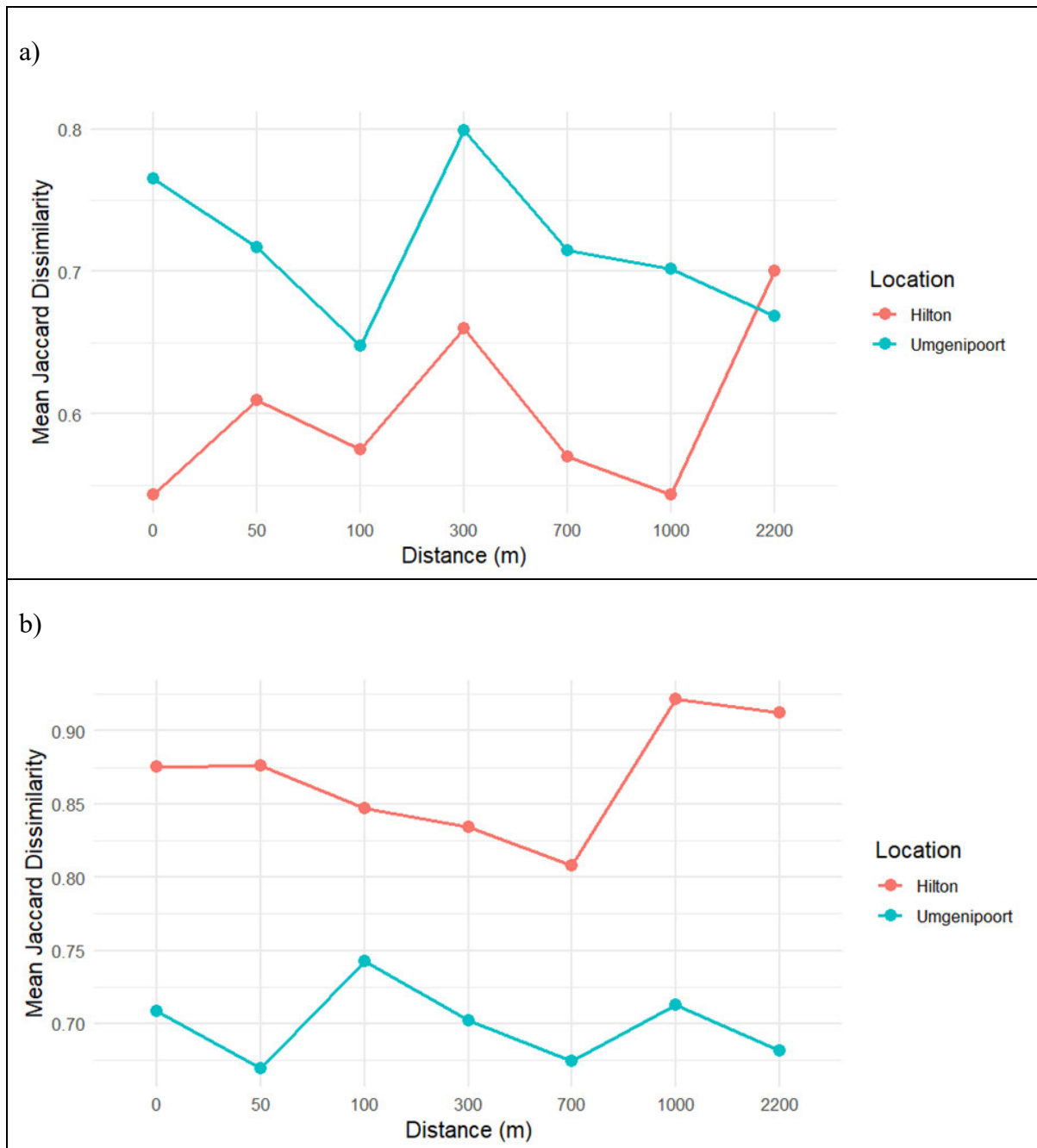


Figure 3.12: Mean Jaccard dissimilarity index showing gradual changes in ant (a) and spider (b) communities along the riparian habitats across Hilton and Umgenipoort.

3.4 Discussion

Arthropod diversity and abundance

The fascination of ecologists with the factors shaping biodiversity distribution inspired the creation of frameworks that include lateral and longitudinal gradients (Surmacz et al., 2024). Environmental gradients reflect different habitat conditions (Surmacz et al., 2024) in which the species' ecological needs must be met to occupy the habitat, thereby shaping their distribution

patterns (Beaugrand et al., 2024). The current study provides insight into how the gradient from the riparian habitats to the uplands and along the riparian habitats shapes ant and spider biodiversity patterns along the upper catchment of the uMngeni River. This was to clarify whether their riparian zones and the adjacent uplands house similar arthropod species and are resilient to temporal and spatial changes.

Arthropods are ectothermic, relying on biotic and abiotic factors to optimise their reproduction, fitness, and survival (Malamel, 2021; Harvey and Dong, 2023). In this study, ant abundance decreased with increasing distance along the riparian habitats and from the riparian to the uplands, while ant abundance increased from the riparian zones to the uplands during the wet season, highlighting the sensitivity of their ecological needs to seasonal changes. A similar trend was noted by Dalerum et al. (2019), who investigated how distance to a perennial water source from a semi-arid savanna in Botswana affected the diversity of ants. The wet season, characterised by warmer temperatures and moist soil, provides optimal vegetation growth and resource availability conditions, fostering greater terrestrial arthropod diversity than the dry season (Mavasa et al., 2022; Queiroz et al., 2022). The resilience of ants along the riparian zones to seasonal changes may be due to their ability to occupy diverse habitats, opportunistically adjust to changes in environmental conditions (Andersen, 2019)

Results from the current study suggest that spider spatial patterns differ between the lateral and longitudinal gradients. Spider abundance was higher at 0m and decreased at 50 m and 300 m in the lateral gradient, supporting that riparian predators, including spiders benefit from aquatic insects near river edges (Jackson et al., 2016). In contrast, spider abundance was not significantly affected by distance in the longitudinal gradient and was instead higher at Umgenipoort. The lack of seasonal and spatial influence on spider richness in both gradients in the current study suggests stability across the studied landscapes. Environmental simplification and habitat structure changes may have reduced the impact of seasonal changes (Montine et al., 2014). However, our findings differ from those observed in Australia by Framenau et al. (2002), where spiders were more abundant upstream than downstream along the longitudinal gradient.

Arthropod foraging strategy distribution

Environmental factors directly and indirectly influence ant foraging patterns, with food availability, quality, and foraging patterns varying seasonally (Montine et al., 2014; Queiroz et

al., 2022). The distribution of ant foraging strategies in both gradients were influenced by distance, location and seasonality. This pattern may be driven by the increase in plant foliage during the wet season, resulting in a rise in herbivorous insect populations that supply more prey for spiders, and some ants nesting and foraging on plants in search of extrafloral nectar (Menéndez-Acuña et al., 2023; Sampaio et al., 2023). These dynamics reflect that ant foraging strategies are adjusted based on the distribution and availability of resources, competitive pressures, and environmental risks while responding to colony demands and interactions with other foragers to ensure efficient food collection (Csata and Dussutour, 2019).

Previous studies have shown that complex vegetation supports spider diversity and foraging strategies by providing physical structure for web building, camouflage, and access to food resources (Cardoso et al., 2011; Griotti et al., 2017). Along both studied gradients in the current study, the distribution of spider foraging strategies was influenced by distance, seasonality and location. This could be explained by the need for complex riparian vegetation and stable microhabitats to anchor webs (Griotti et al., 2017; Geng et al., 2024) to capture flying and jumping insects (Menéndez-Acuña et al., 2023). The body size of some spiders allows them to quickly occupy communities through ballooning in the warm seasons (Hsieh and Linsenmair, 2012). Additionally, aquatic insects, an essential high-energy food source for web-building spiders, emerge in the warmer seasons (Griotti et al., 2017).

These observed patterns of arthropod diversity can be interpreted through the lens of the Flood Pulse Concept (Junk et al., 1989), which emphasizes the ecological significance of periodic flooding in river-floodplain systems and may reflect the dynamic habitat conditions created by seasonal inundation.

Arthropod community composition

To reduce competition, species use different resources or occupy different habitats. However, when resources are limited, species with low requirements persist while high-demanding species decline (Tilman, 1985). This dynamic then shapes community composition along environmental gradients. The distance-decay relationship describes how species composition becomes less similar as the spatial gap increases, primarily due to environmental differences, which influence species distribution based on their specific ecological needs (Antoniazzi et al., 2020). This pattern was evident in the gradient along the riparian zones, where the ant community composition differed with distance. Species turnover increased with greater

distance at Hilton along the riparian zones. This suggests a significant shift in habitat conditions at greater distance differences, resulting in species replacement rather than overlapping.

Meanwhile, spider communities in both gradients from the riparian habitats to the uplands and along the riparian habitats showed variation due to seasonality and locality. In the current study, nestedness increased with distance at Hilton in spider community composition from the riparian to the uplands. The observed pattern may be interpreted within the frameworks of metacommunity theory, which states that environmental filtering and dispersal capabilities can shape community composition (Chase et al., 2020). These findings contrast those of Soykan et al. (2012), who documented that community similarities between uplands and riparian zones are usually low due to high turnover, suggesting that environmental filtering may have influenced community composition through loss of species less that are less tolerant of changing environmental conditions, leading to nested community rather than species being replaced.

Spiders exhibit different dispersal strategies that may have contributed to the lack of significant variations in their community composition across distance in both gradients. Spider species use ballooning, a wind-driven long-distance dispersal method, in unstable habitats, and ground-based movement to colonise adjacent habitats (Müller et al., 2022). This dual dispersal strategy may enhance their ability to maintain relatively stable communities at different spatial scales. For example, a study by Botham et al. (2020) showed that spider species in Golden Gate Highlands National Park, South Africa displayed contrasting genetic diversity linked to their dispersal capabilities and topography. Such variation in dispersal capabilities may reduce spatial differentiation across moderate distances, potentially contributing to the absence of significant distance effects observed in the current study.

In conclusion, our findings demonstrate that even within a single study, different taxonomic groups and their foraging strategies respond uniquely to seasonality, locality and environmental gradients. The riparian zones of the uMngeni River support ant communities that are similar those in the adjacent uplands. However, within Hilton, ant community composition along riparian zones varied with increasing distance due to species replacement, suggesting environmental heterogeneity. In contrast, spider community composition from the riparian habitats to the uplands in Hilton showed nested pattern, where spider communities from further distances (uplands) represented subsets of communities closer to the riparian zones.

Given that riparian zones are highly threatened by anthropogenic activities (Wang et al., 2019) and possibly climate change, our results highlight how ants and spiders respond to spatial scales and seasonality. These patterns provide insight for conservationists to predict ecological changes as they indicate which arthropod species and foraging strategies are more sensitive to changes and develop strategies to sustain biodiversity, protect unique species, and ecosystem functions. Conservation and restoration efforts should consider adjacent uplands to maintain connectivity and ecosystem function. Future studies should consider the influence of microclimatic factors, soil properties, and vegetation structure on arthropod biodiversity along environmental gradients to enhance understanding of these dynamics.

3.5 References

- Andersen, A.N., 1997. Using ants as bioindicators: Multiscale issues in ant community ecology. *Conservation Ecology* 1(1).
- Andersen, A.N., 2019. Responses of ant communities to disturbance: Five principles for understanding the disturbance dynamics of a globally dominant faunal group. *Journal of Animal Ecology* 88(3), 350-362.
- Anderson, M.J., 2001. Permutation tests for univariate or multivariate analysis of variance and regression. *Canadian Journal of Fisheries and Aquatic Sciences* 58(3), 626-639.
- Antoniuzzi, R., Viana-Junior, A.B., Pelayo-Martínez, J., Ortiz-Lozada, L., Neves, F.S., Leponce, M., Dáttilo, W., 2020. Distance-decay patterns differ between canopy and ground ant assemblages in a tropical rainforest. *Journal of Tropical Ecology* 36(5), 234-242.
- Baselga, A. 2010. Partitioning the turnover and nestedness components of beta diversity. *Global Ecology and Biogeography* 19, 134-143.
- Beaugrand, G., Kléparski, L., Luczak, C., Goberville, E., Kirby, R.R., 2024. A niche-based theory of island biogeography. *Ecology and Evolution* 14(6), e11540.
- Bolker, B.M., Brooks, M.E., Clark, C.J., Geange, S.W., Poulsen, J.R., Stevens, M.H.H., White, J.S.S., 2009. Generalized linear mixed models: a practical guide for ecology and evolution. *Trends in Ecology and Evolution* 24(3), 127-135.
- Botham, J.L., Haddad, C.R., Gryzenhout, M., Swart, V.R., Bredenhand, E., 2020. High genetic diversity of spider species in a mosaic montane grassland landscape. *PLoS One* 15(6), e0234437.
- Brijlal, R., Rajak, A., Armstrong, A.J., 2021. Aspects of the life history and ecology of two wingless grasshoppers, *Eremidium armstrongi* and *Eremidium browni* (Lentulidae), at the Doreen Clark Nature Reserve, KwaZulu-Natal, South Africa. *Journal of Orthoptera Research* 30(1), 73-80.
- Brose U. 2003. Bottom-up control of carabid beetle communities in early successional wetlands: Mediated by vegetation structure or plant diversity? *Oecologia* 135: 407–413.
- Brown, H.D., 2016. A new genus and species of grasshopper from the Grassland Biome of northeast KwaZulu-Natal, South Africa (Orthoptera: Acridoidea: Caelifera, Lentulidae). *Annals of the Ditsong National Museum of Natural History* 6(7), 77-85.
- Cardoso, P., Pekár, S., Jocqué, R., Coddington, J.A., 2011. Global patterns of guild composition and functional diversity of spiders. *PLoS One* 6(6), e21710.

- Cardoso, P., Pekár, S., Birkhofer, K., Chuang, A., Fukushima, C.S., Hebets, E.A., Henaut, Y., Hesselberg, T., Malumbres-Olarte, J., Michálek, O., Michalko, R., 2025. Ecosystem services provided by spiders. *Biological Reviews* 100(6), 2217-2236.
- Cawood, R.A., Samways, M.J., Pryke, J.S., 2024. Umbrella index as a conservation tool across ponds: A case study using frogs, aquatic insects, and plants in South Africa. *Environmental and Sustainability Indicators* 24, 100478.
- Chan, E.K., Yu, Y.T., Zhang, Y., Dudgeon, D., 2008. Distribution patterns of birds and insect prey in a tropical riparian forest. *Biotropica* 40(5), 623-629.
- Chase, J.M., Jeliaskov, A., Ladouceur, E., Viana, D.S., 2020. Biodiversity conservation through the lens of metacommunity ecology. *Annals of the New York Academy of Sciences* 1469(1), 86-104.
- Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18(1), 117-143.
- Csata, E., Dussutour, A., 2019. Nutrient regulation in ants (Hymenoptera: Formicidae): a review. *Myrmecological News* 29, 111-124.
- Dalerum, F., Retief, T.A., Havemann, C.P., Chimimba, C.T., Janse van Rensburg, B., 2019. The influence of distance to perennial surface water on ant communities in Mopane woodlands, northern Botswana. *Ecology and Evolution* 9(1), 154-165.
- Department of Water Affairs, 2002. State of Rivers Report: uMngeni River and Neighbouring Catchments.
- Drucker, D.P., Costa, F.R.C., Magnusson, W.E., 2008. How wide is the riparian zone of small streams in tropical forests? A test with terrestrial herbs. *Journal of Tropical Ecology* 24(1), 65-74.
- Faria, A.S., Menin, M., Kaefer, I.L., 2019. Riparian zone as a main determinant of the structure of lizard assemblages in upland Amazonian forests. *Austral Ecology* 44, 850-858.
- Fisher, B. L., Bolton, B. 2016. *Ants of Africa and Madagascar: a guide to the genera*. University of California Press.
- Foord, S.H., Dippenaar-Schoeman, A.S., Haddad, C.R., Lotz, L.N., Lyle, R., 2011. The faunistic diversity of spiders (Arachnida: Araneae) of the Savanna Biome in South Africa. *Transactions of the Royal Society of South Africa* 66(3), 170-201.
- Framenau, V.W., Manderbach, R., Baehr, M., 2002. Riparian gravel banks of upland and lowland rivers in Victoria (south-east Australia): arthropod community structure and life-history patterns along a longitudinal gradient. *Australian Journal of Zoology* 50(1), 103-123.

- Geng, X., Lin, Y., He, Y., Liao, J., Ran, J., Zhang, P., 2024. Semi-natural habitats benefit maintaining the spider diversity in subtropical agroecosystems. *Land Degradation and Development* 35(4), 1580-1598.
- Gómez, J.E., Lohmiller, J., Joern, A., 2016. Importance of vegetation structure to the assembly of an aerial web-building spider community in North American open grassland. *The Journal of Arachnology* 44(1), 28-35.
- Grey-Ross, R., Downs, C.T., Kirkman, K., 2009. Reintroduction failure of captive-bred oribi (*Ourebia ourebi*). *South African Journal of Wildlife Research* 39(1), 34-38.
- Griotti, M., Muñoz-Escobar, C., Ferretti, N.E., 2017. Linking vegetation structure and spider diversity in riparian and adjacent habitats in two rivers of Central Argentina: An analysis at two conceptual levels. *Environmental Entomology* 46(4), 794-803.
- Hamilton, B.T., Roeder, B.L., Hatch, K.A., Eggett, D.L., Tingey, D., 2015. Why is small mammal diversity higher in riparian areas than in uplands? *Journal of Arid Environments* 119, 41-50.
- Harvey, J.A., Dong, Y., 2023. Climate change, extreme temperatures and sex-related responses in spiders. *Biology* 12(4), 615.
- Howard, A., Monadjem, A., MacFadyen, D., Chimimba, C.T., 2022. Testing the efficacy of bat monitoring methods for identification and species surveys in KwaZulu-Natal province, South Africa. *African Zoology* 57(4), 180-194.
- Hsieh, Y.L., Linsenmair, K.E., 2012. Seasonal dynamics of arboreal spider diversity in a temperate forest. *Ecology and Evolution* 2(4), 768-777.
- Jaccard, P., 1912. The distribution of the flora in the alpine zone. *New Phytologist* 11(2), 37-50.
- Jackson, M.C., Woodford, D.J., Bellingan, T.A., Weyl, O.L., Potgieter, M.J., Rivers-Moore, N.A., Ellender, B.R., Fourie, H.E., Chimimba, C.T., 2016. Trophic overlap between fish and riparian spiders: potential impacts of an invasive fish on terrestrial consumers. *Ecology and Evolution* 6(6), 1745-1752.
- Junk, W.J., Bayley, P.B., Sparks, R.E., 1989. The flood pulse concept in river-floodplain systems. *Canadian Special Publication of Fisheries and Aquatic Sciences* 106(1), 110-127.
- Leather, S.R., Watt, A.D., 2005. Sampling theory and practice. *Insect Sampling in Forest Ecosystems*, 1-15.
- Legendre, P., 2014. Interpreting the replacement and richness difference components of beta diversity. *Global Ecology and Biogeography* 23(11), 1324-1334.

- Legendre, P., De Cáceres, M., 2013. Beta diversity as the variance of community data: dissimilarity coefficients and partitioning. *Ecology Letters* 16(8), 951-963.
- Mamel, J., 2021. Seasonal dynamics on spider population in Pathiramanal island, Kerala, India: A case study. *Arthropods: Are They Beneficial for Mankind*, 55.
- Marc, P., Canard, A., Ysnel, F., 1999. Spiders (Araneae) useful for pest limitation and bioindication. *Agriculture, Ecosystems & Environment* 74(1-3), 229-273.
- Mavasa, R., Yekwayo, I., Mwabvu, T., Tsvuura, Z., 2022. Preliminary patterns of seasonal changes in species composition of surface-active arthropods in a South African savannah. *Austral Ecology* 47(6), 1222-1231.
- Menéndez-Acuña, M., Salas-Rodríguez, M., Montiel-Parra, G., Sotuyo, S., Rosas-Echeverría, M.V., 2023. Seasonality and Long-Term Effect of Environmental Variables on the Orb Weaver Spider Community of a Tropical Dry Forest in the Balsas Basin, Mexico. *Diversity* 15(3), 466.
- Montine, P.S.M., Viana, N.F., Almeida, F.S., da Cruz Dáttilo, W.F., Santanna, A.S., Martins, L., Vargas, A.B., 2014. Seasonality of epigaeic ant communities in a Brazilian Atlantic rainforest. *Sociobiology* 61(2), 178-183.
- Mthimunya, T.A., Munyai, T.C., 2022. Can Monoculture Timber Plantations Conserve More Ant Communities Than Adjacent Natural Forests? *Diversity* 14(6), 430.
- Müller, J., Brandl, R., Cadotte, M.W., Heibl, C., Bässler, C., Weiß, I., Birkhofer, K., Thorn, S., Seibold, S., 2022. A replicated study on the response of spider assemblages to regional and local processes. *Ecological Monographs* 92(3), e1511.
- Munyai, T.C., Foord, S.H., 2012. Ants on a mountain: spatial, environmental and habitat associations along an altitudinal transect in a centre of endemism. *Journal of Insect Conservation* 16(5), 677-695.
- Naiman, R.J., Décamps, H., 1997. The ecology of interfaces: riparian zones. *Annual Review of Ecology and Systematics* 28(1), 621-658.
- Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O'hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Wagner, H., 2013. Community ecology package. *R Package Version 2*, 321-326.
- Paetzold, A., Yoshimura, C., Tockner, K., 2008. Riparian arthropod responses to flow regulation and river channelization. *Journal of Applied Ecology* 45, 894-903.
- Park, S.R., Kim, S., Lee, S.W., 2021. Evaluating the relationships between riparian land cover characteristics and biological integrity of streams using random forest algorithms. *International Journal of Environmental Research and Public Health* 18(6), 3182.

- Perkins, D.W., Hunter, Jr, M.L., 2006. Use of amphibians to define riparian zones of headwater streams. *Canadian Journal of Forest Research* 36(9), 2124-2130.
- Peters, V.E., Campbell, K.U., Dienno, G., García, M., Leak, E., Loyke, C., Ogle, M., Steinly, B., Crist, T.O., 2016. Ants and plants as indicators of biodiversity, ecosystem services, and conservation value in constructed grasslands. *Biodiversity and Conservation* 25(8), 1481-1501.
- Pettit, N.E., Naiman, R.J., 2007. Fire in the riparian zone: characteristics and ecological consequences. *Ecosystems* 10(5), 673-687.
- Posit Team, 2025. RStudio: Integrated Development Environment for R. Posit Software, PBC, Boston, MA.
- Queiroz, A.C., Marques, T.G., Ribas, C.R., Cornelissen, T.G., Nogueira, A., Schmidt, F.A., Feitosa, R.M., Sobrinho, T.G., Quinet, Y., Baccaro, F.B., Ulysea, M.A., 2023. Ant diversity decreases during the dry season: A meta-analysis of the effects of seasonality on ant richness and abundance. *Biotropica* 55(1), 29-39.
- R Core Team, 2024. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Ramey, T.L., Richardson, J.S., 2017. Terrestrial invertebrates in the riparian zone: mechanisms underlying their unique diversity. *BioScience* 67(9), 808-819.
- Ripley, B., Venables, W., Ripley, M.B., 2016. Package ‘nnet’. R package version 7(3-12), 700.
- Rykken, J.J., Moldenke, A.R., Olson, D.H., 2007. Headwater riparian forest-floor invertebrate communities associated with alternative forest management practices. *Ecological Applications* 17(4), 1168-1183.
- Sabo, J.L., Sponseller, R., Dixon, M., Gade, K., Harms, T., Heffernan, J., Jani, A., Katz, G., Soykan, C., Watts, J., Welter, J., 2005. Riparian zones increase regional species richness by harboring different, not more, species. *Ecology* 86(1), 56-62.
- Sampaio, R.C., da Silva Laviski, B.F., de Souza Coelho, R.C., de Queiroz, J.M., 2023. Effects of vegetation structure on ant diversity in different seasonal periods in impacted fragments of Atlantic Forest. *Sociobiology* 70(2), e7949.
- Santos-Silva, L., Pinheiro, T.G., Chagas-Jr, A., Marques, M.I., Battistola, L.D., 2018. Temporal and spatial variation of Myriapoda (Diplopoda and Chilopoda) assemblages in a Neotropical floodplain. *Biota Neotropica* 18, e20180514.
- Simelane, F.N., Mahlaba, T.A.A., Shapiro, J.T., MacFadyen, D., Monadjem, A., 2018. Habitat associations of small mammals in the foothills of the Drakensberg Mountains, South Africa. *Mammalia* 82(2), 144-152.

- Singh, A., Lin, J., 2015. Microbiological, coliphages and physico-chemical assessments of the Umgeni River, South Africa. *International Journal of Environmental Health Research* 25(1), 33-51.
- Singh, R., Tiwari, A.K., Singh, G.S., 2021. Managing riparian zones for river health improvement: an integrated approach. *Landscape and Ecological Engineering* 17(2), 195-223.
- Soykan, C.U., Brand, L.A., Ries, L., Stromberg, J.C., Hass, C., Simmons Jr, D.A., Patterson, W.J., Sabo, J.L., 2012. Multitaxonomic diversity patterns along a desert riparian–upland gradient. *PLoS One* 7(1), e28235.
- Surmacz, B., Foremnik, K., Pielech, R., 2024. Along the river: Longitudinal patterns of functional and taxonomic diversity of plants in riparian forests. *Journal of Vegetation Science* 35(1), e13225.
- Tiede, Y., Schlautmann, J., Donoso, D.A., Wallis, C.I., Bendix, J., Brandl, R., Farwig, N., 2017. Ants as indicators of environmental change and ecosystem processes. *Ecological Indicators* 83, 527-537.
- Tilman, D., 1985. The resource-ratio hypothesis of plant succession. *The American Naturalist* 125(6), 827-852.
- Tshiguvho, T.E., Dean, W.R.J., Robertson, H.G., 1999. Conservation value of road verges in the semi-arid Karoo, South Africa: ants (Hymenoptera: Formicidae) as bio-indicators. *Biodiversity & Conservation* 8(12), 1683-1695.
- Underwood, E. C., Fisher, B. L. (2006). The role of ants in conservation monitoring: If, when, and how. *Biological Conservation* 132(2), 166–182.
- Wang, K., Yuan, X., Zhang, G., Liu, S., Wang, F., Liu, H., Zhang, M., Zhou, L., 2019. Diversity and Distribution of Riparian Arthropods in the Drawdown Zone of China's Three Gorges Reservoir. *Environmental Entomology* 48(6), 1340-1348.
- Wardhaugh, C.W., 2014. The spatial and temporal distributions of arthropods in forest canopies: uniting disparate patterns with hypotheses for specialisation. *Biological Reviews* 89(4), 1021-1041.
- Xiao, H., Du, C., Yuan, X., Li, B., 2020. Multiple floods affect composition and community structure of the ground-dwelling arthropods in the riparian zone of the Three Gorges Reservoir. *Ecological Indicators* 113, 106220.
- Xiao, H., Li, B., Willison, J.M., Wang, Y., 2022. Habitat change and interspecific associations mediate the response of riparian ground-dwelling arthropod assemblages to flooding in the Three Gorges Reservoir. *Ecological Engineering* 185, 106812.

Zina, V., Ordeix, M., Franco, J.C., Ferreira, M.T., Fernandes, M.R., 2021. Ants as Bioindicators of Riparian Ecological Health in Catalanian Rivers. *Forests* 12(5), 625.

CHAPTER 4 : Conclusions and recommendations

4.1 Study summary

This study aimed to investigate the impact of riparian environmental gradients, stressors, and disturbance regimes on the biodiversity of terrestrial arthropods at both global and local scales, and their implications for management and conservation policies. The objectives of Chapter Two were to systematically ascertain the response of riparian arthropods to flooding, alien plant invasion, and river engineering at a global scale, to determine the geographical distribution of eligible studies, and to identify potential management strategies. The findings suggested that terrestrial arthropods are predominantly adversely affected by flooding, alien plant invasion, and river engineering, although responses differ among taxa. This could be explained by changes in habitat quality and structure, with a potential risk of habitat homogenization due to river engineering and alien plant invasions. Interestingly, a noticeable gap exists in eligible studies conducted in developing countries may be due to financial constraints (Achieng et al., 2023), a lack of awareness, limited database coverage and challenges to accessing riparian areas/ large rivers. Eligible studies suggested creating and protecting heterogeneous habitats within riparian zones, restoring native vegetation and natural water flow while considering species-specific ecological needs to sustain riparian biodiversity and function.

Riparian zones are essential, dynamic, and complex components of riparian systems that are threatened by anthropogenic activities, yet support a diverse array of plants and animals. Their physical boundaries differ for each taxon based on their ecological needs; however, other taxa are overlooked in existing research. Therefore, the subsequent chapter (Chapter three) determined whether seasonal changes and increasing distance along the uMngeni riparian habitats and from the riparian habitats to the uplands affect the distribution of ant and spider diversity and their foraging strategies in the KwaZulu-Natal Midlands. The chapter also determined if ants and spiders are unique to specific distances in studied gradients, how their community composition differed between distances in sampled sites, and whether nestedness or turnover accounted for the observed patterns. The results indicated that ant abundance decreased as one moved away from riparian habitats to the uplands during the wet season.

In contrast, spider abundance generally increased during the wet season due to increased favourable conditions. However, ant and spider richness remained stable across distances in the studied gradients during the wet and dry seasons. The distribution of spider foraging

strategies was affected by the changes in seasonality and differences in the sampled locations. In contrast, distance mainly influenced the distribution of ant foraging strategies.

The chapter also found that most unique ant and spider species occurred at 0 m compared to other distances from the river gradient and may have contributed to the observed differences in ant and spider community composition. However, distance mainly accounted for variation in ant community composition, while differences in spider community composition were due to seasonality. Species turnover primarily accounted for observed total beta diversity patterns, suggesting a shift in environmental conditions when seasons change and after 100 m from the riparian habitat to the uplands.

The observed results from both chapters highlight that disturbance and stress regimes filter species (Yoshioka et al., 2009; Xiao et al., 2022), while environmental gradients structure them according to their habitat and resource requirements (Beaugrand et al., 2024). This is intricately tied to migratory capabilities and resource accessibility (Ilg et al., 2008; Lambeets et al., 2009; Xiao et al., 2020). Arthropods with robust dispersal abilities can successfully evade unfavourable conditions, contrasting with species that have limited dispersal, for example, most flightless epigeic invertebrate groups, which may perish (Xiao et al., 2022). This emphasizes that disturbance can introduce physical barriers in an ecosystem (Kennedy and Turner, 2011; Wang et al., 2019). Moreover, simplification of their habitat structure leads to habitat homogeneity and fragmentation. Seasonality can facilitate connectivity between ecosystems while temporarily filtering species, while distance promotes habitat heterogeneity, reflecting different habitat conditions (Surmacz et al., 2024).

4.2 Contributions of the study

To the best of my knowledge, this study is the first to document the terrestrial arthropods along the grassland riparian zones in South Africa and systematically review the effects of flooding, river engineering, and alien plant invasion on terrestrial arthropods at a global scale. This thereby provides insights into geographical and taxonomic gaps in ecological research, while theoretically advancing our understanding of the Flood Pulse Concept by further highlighting how flood dynamics affect riparian arthropod biodiversity. Moreover, the findings advocate for integrated riparian management and restoration as they have shown that arthropods move between riparian habitats and adjacent uplands, highlighting ecosystem connectivity and need to consider adjacent uplands in conservation efforts. It also highlights the efficacy of arthropods

as indicators of ecosystem health, as they easily reflect changes in environmental conditions and resources. At a broad scale, the study aligns with national imperatives and sustainable development goals, particularly clean water and sanitation; climate change; life on land, and geographic advantage-biodiversity.

However, this study had limitations, as it had a short duration, used only pitfall traps to sample and focused on two sampling locations. In addition, environmental factors such as vegetation, soil properties and temperature were not directly measured. While spatial and seasonal patterns in ant and spider assemblages were identified, the relative importance of specific environmental drivers such as vegetation, soil properties and temperature were not directly tested. The results therefore remain descriptive of community patterns rather than explanations of the processes shaping them.

4.3 Future directions

Although this study has successfully determined the how disturbance, stressors and environmental gradients affect arthropod biodiversity, more work is still required to effectively manage riparian ecosystems and their biodiversity. Therefore, future studies should:

- Incorporate supplementary sampling methods other than pitfall traps to capture more diverse arthropods, including arboreal species.
- Prioritise long-term monitoring of biodiversity in riparian zones using standardized methods to better understand the effects of land use and climate change.
- Sustain baseline monitoring of riparian biodiversity to allow post-disturbance assessments when such events occur.
- Consider the influence of microclimatic factors, soil properties, and vegetation structure on arthropod biodiversity along environmental gradients to enhance understanding of these dynamics.
- Collaborate with policymakers, researchers, and communities to develop effective, holistic strategies to contribute to knowledge gaps in riparian zones from developing countries and prevent further threats to riparian biodiversity and function.

4.4 References

- Achieng, A.O., Arhonditsis, G.B., Mandrak, N., Febria, C., Opaa, B., Coffey, T.J., Masese, F.O., Irvine, K., Ajode, Z.M., Obiero, K., Barasa, J.E., 2023. Monitoring biodiversity loss in rapidly changing Afrotropical ecosystems: an emerging imperative for governance and research. *Philosophical Transactions of the Royal Society B* 378(1881), 20220271.
- Beaugrand, G., Kléparski, L., Luczak, C., Goberville, E., Kirby, R.R., 2024. A niche-based theory of island biogeography. *Ecology and Evolution* 14(6), e11540.
- Ilg, C., Dziock, F., Foeckler, F., Follner, K., Gerisch, M., Glaeser, J., Rink, A., Schanowski, A., Scholz, M., Deichner, O., Henle, K., 2008. Long-term reactions of plants and macroinvertebrates to extreme floods in floodplain grasslands. *Ecology* 89(9), 2392-2398.
- Kennedy, T.L., Turner, T.F., 2011. River channelization reduces nutrient flow and macroinvertebrate diversity at the aquatic terrestrial transition zone. *Ecosphere* 2(3), 1-13.
- Lambeets, K., Vandegehuchte, M.L., Maelfait, J.P., Bonte, D., 2009. Integrating environmental conditions and functional life-history traits for riparian arthropod conservation planning. *Biological Conservation* 142(3), 625-637.
- Soykan, C.U., Brand, L.A., Ries, L., Stromberg, J.C., Hass, C., Simmons Jr, D.A., Patterson, W.J., Sabo, J.L., 2012. Multitaxonomic diversity patterns along a desert riparian–upland gradient. *PLoS One* 7(1), e28235.
- Surmacz, B., Foremnik, K., Pielech, R., 2024. Along the river: Longitudinal patterns of functional and taxonomic diversity of plants in riparian forests. *Journal of Vegetation Science* 35(1), e13225.
- Wang, K., Yuan, X., Wu, S., Zhang, G., Liu, H., Zhou, L., Zhang, M., 2019. Effects of river damming on ground-dwelling arthropods along riparian–upland habitats. *Ecohydrology* 12(3), e2073.
- Xiao, H., Du, C., Yuan, X., Li, B., 2020. Multiple floods affect composition and community structure of the ground-dwelling arthropods in the riparian zone of the Three Gorges Reservoir. *Ecological Indicators* 113, 106220.
- Xiao, H., Li, B., Willison, J.M., Wang, Y., 2022. Habitat change and interspecific associations mediate the response of riparian ground-dwelling arthropod assemblages to flooding in the Three Gorges Reservoir. *Ecological Engineering* 185, 106812.

Yoshioka, A., Kadoya, T., Suda, S.I., Washitani, I., 2010. Impacts of weeping lovegrass (*Eragrostis curvula*) invasion on native grasshoppers: responses of habitat generalist and specialist species. *Biological Invasions* 12(3), 531-539.

Supplementary material

Chapter 2 material

Table S 1: The response of arthropod orders and classes to natural and anthropogenically altered disturbance and stress regimes: a compilation of findings from eligible studies.

Author	Country	Taxon/guild/species	Uniform identification (orders/ classes)	Disturbance	Parameter	Response	Parameter	Response
Paetzold et al. (2008)	Switzerland and Italy	Spider	Araneae	River engineering	Richness	Negative	Abundance	Negative
Paetzold et al. (2008)	Switzerland and Italy	Beetle (Ground)	Coleoptera	River engineering	Richness	No effect	Abundance	No effect
Paetzold et al. (2008)	Switzerland and Italy	Beetle (Rove)	Coleoptera	River engineering	Richness	Negative	Abundance	Negative
Wang et al. (2019a)	China	Predators	Predators	River engineering	Abundance	Positive		
Wang et al., (2019a)	China	Herbivores	Herbivores	River engineering	Abundance	Positive		
Wang et al. (2019a)	China	Omnivores	Omnivore	River engineering	Abundance	Negative		
Wang et al. (2019a)	China	Ground-dwelling arthropods	Arthropoda	River engineering	Richness	Negative	Assemblage composition	Changed
Wang et al. (2019a)	China	Detritivores	Detritivores	River engineering	Abundance	Positive		
Zulka (1994)	Austria	Beetles	Coleoptera	Flooding	Assemblage composition	Changed		
Zulka (1994)	Austria	Beetles	Coleoptera	Flooding	Abundance	Positive	Richness	Unclear
Yoshioka et al. (2009)	Japan	<i>Locusta migratoria</i> L.	Orthoptera	Alien plant invasion	Abundance	Negative		
Yoshioka et al. (2009)	Japan	<i>Eusphingonotus japonicus</i>	Orthoptera	Alien plant invasion	Abundance	Negative		

Yoshioka et al. (2009)	Japan	<i>Shirakiacris shirakii</i>	Orthoptera	Alien plant invasion	Abundance	Negative		
Yoshioka et al. (2009)	Japan	<i>Gonista bicolor</i>	Orthoptera	Alien plant invasion	Abundance	Negative		
Yoshioka et al. (2009)	Japan	<i>Mongolotettix japonicus</i>	Orthoptera	Alien plant invasion	Abundance	Negative		
Yoshioka et al. (2009)	Japan	<i>Atractomorpha lata</i>	Orthoptera	Alien plant invasion	Abundance	Positive		
Yoshioka et al. (2009)	Japan	<i>Patanga japonica</i>	Orthoptera	Alien plant invasion	Abundance	Positive		
Yoshioka et al. (2009)	Japan	<i>Oxya yezoensis</i>	Orthoptera	Alien plant invasion	Abundance	Negative		
Yoshioka et al. (2009)	Japan	<i>Acrida cinerea</i>	Orthoptera	Alien plant invasion	Abundance	Positive		
Yoshioka et al. (2009)	Japan	<i>Glyptobothrus maritimus</i>	Orthoptera	Alien plant invasion	Abundance	Positive		
Yoshioka et al. (2009)	Japan	<i>Gastrimargus marmoratus</i>	Orthoptera	Alien plant invasion	Abundance	Positive		
Yoshioka et al. (2009)	Japan	<i>Oedaleus infernalis</i>	Orthoptera	Alien plant invasion	Abundance	Negative		
Xiao et al. (2020)	China	Ground-dwelling arthropods	Arthropoda	Flooding	Assemblage composition	Changed		
Xiao et al. (2022)	China	Ground-dwelling arthropods	Arthropoda	Flooding	Assemblage composition	Changed		
Uhey et al. (2020)	United States of America	Ant	Hymenoptera	Alien plant invasion	Abundance	Negative	Richness	Negative
Uhey et al. (2020)	United States of America	Beetle	Coleoptera	Alien plant invasion	Abundance	Positive	Richness	Negative
Uhey et al. (2020)	United States of America	Orthoptera	Orthoptera	Alien plant invasion	Abundance	Positive	Richness	Positive
Uhey et al. (2020)	United States of America	Hemiptera	Hemiptera	Alien plant invasion	Abundance	Positive	Richness	Negative
Uhey et al. (2020)	United States of America	Arachnida	Arachnida	Alien plant invasion	Abundance	Negative	Richness	Negative
Uhey et al. (2020)	United States of America	Non-ant hymenopteran	Hymenoptera	Alien plant invasion	Abundance	Negative	Richness	Negative
Uhey et al. (2020)	United States of America	<i>Armadillidium vulgare</i>	Isopoda	Alien plant invasion	Abundance	Positive	Richness	

Uhey et al. (2020)	United States of America	<i>Pseudochoratus sp.</i>	Archaeognatha	Alien plant invasion	Abundance	Negative	Richness	
Uhey et al. (2020)	United States of America	<i>Entomobryidae</i>	Collembola	Alien plant invasion	Abundance	Negative	Richness	
Uhey et al. (2020)	United States of America	<i>Sminthuridae</i>	Collembola	Alien plant invasion	Abundance	No effect	Richness	
Uhey et al. (2020)	United States of America	<i>Mesomachilis sp.</i>	Archaeognatha	Alien plant invasion	Abundance	Negative	Richness	
Uhey et al. (2020)	United States of America	Predator	Predators	Alien plant invasion	Abundance	Negative	Richness	Positive
Uhey et al. (2020)	United States of America	Pollinator	Pollinators	Alien plant invasion	Abundance	Negative	Richness	Positive
Uhey et al. (2020)	United States of America	Detritivores	Detritivores	Alien plant invasion	Abundance	Positive	Richness	Positive
Uhey et al. (2020)	United States of America	Herbivores	Herbivores	Alien plant invasion	Abundance	Negative	Richness	Negative
Uhey et al. (2020)	United States of America	Parasitic	Parasites	Alien plant invasion	Abundance	Negative	Richness	Negative
Uhey et al. (2020)	United States of America	Fungivore	Fungivores	Alien plant invasion	Abundance	No effect	Richness	No effect
Uhey et al. (2020)	United States of America	Arthropods	Arthropoda	Alien plant invasion	Assemblage composition	Changed		
Uhey et al. (2020)	United States of America	Arthropods	Arthropoda	Alien plant invasion	Abundance	No effect	Richness	No effect
Uetz et al. (1979)	United States of America	Arthropods	Arthropoda	Flooding	Assemblage composition	Changed		
Uetz et al. (1979)	United States of America	Spiders	Spiders	Flooding	Abundance	Negative	Richness	Negative
Truxa and Fiedler (2012)	Austria	Moth	Lepidoptera	Flooding	Assemblage composition	Changed	Diversity	No effect
Topp et al. (2008)	Germany	Beetles	Coleoptera	Alien plant invasion	Assemblage composition	Changed	Diversity	Negative
Topp et al. (2008)	Germany	Detritivores	Detritivores	Alien plant invasion	Abundance	Positive		
Topp et al. (2008)	Germany	Predators	Predators	Alien plant invasion	Abundance	Negative		
Topp et al. (2008)	Germany	Herbivores	Herbivores	Alien plant invasion	Abundance	Negative		

Topp et al. (2008)	Germany	Fungivore	Fungivores	Alien plant invasion	Abundance	No effect		
Bush et al. (2020)	United States of America	Invertebrates	Insecta	Alien plant invasion	Assemblage composition	Unchanged		
Borges et al. (2021)	Brazil	Odonata	Odonata	Alien plant invasion	Abundance	Negative	Richness	Negative
Herrera and Dudley (2003)	United States of America	Arthropods	Arthropoda	Alien plant invasion	Abundance	Negative	Diversity	Negative
Gutiérrez-López et al. (2014)	Spain	Springtails	Collembola	Alien plant invasion	Abundance	Negative		
Gutiérrez-López et al. (2014)	Spain	Mites	Arachnida	Alien plant invasion	Abundance	Negative		
Gutiérrez-López et al. (2014)	Spain	Spiders	Araneae	Alien plant invasion	Abundance	Negative		
Gutiérrez-López et al. (2014)	Spain	Pseudoscorpionids	Arachnida	Alien plant invasion	Abundance	Negative		
Gutiérrez-López et al. (2014)	Spain	Isopods	Isopoda	Alien plant invasion	Abundance	Negative		
Gutiérrez-López et al. (2014)	Spain	Insects	Insecta	Alien plant invasion	Abundance	Negative		
Gutiérrez-López et al. (2014)	Spain	Actinedida mites	Arachnida	Alien plant invasion	Abundance	Positive		
Wang et al. (2019b)	China	Arthropods	Arthropoda	Flooding	Assemblage composition	Changed		
Lafage et al. (2015)	France	Spiders	Araneae	Flooding	No clear effects			
Lafage et al. (2015)	France	Beetles	Coleoptera	Flooding	No clear effects			
Maceda-Veiga et al. (2016)	Spain	arthropod	Arthropoda	Alien plant invasion	Assemblage composition	Changed	Diversity	Negative

Nienhuis et al. (2009)	Ireland	Bees	Hymenoptera	Alien plant invasion	Abundance	No effect	Functional diversity	No effect
Juen et al. (2016)	Brazil	Odonata	Odonata	Alien plant invasion	Richness	Negative		
Juen et al. (2016)	Brazil	Heteroptera	Hemiptera	Alien plant invasion	Richness	Negative		
Lambeets et al. (2009)	Belgium, Netherlands	Spiders	Araneae	Flooding	Assemblage composition	Changed	Richness	Negative
Lambeets et al. (2009)	Belgium, Netherlands	Beetles	Coleoptera	Flooding	Assemblage composition	Changed	Richness	Negative
Ilg et al. (2008)	Europe, Germany	Mollusk	Mollusca	Flooding	Assemblage composition	Changed	Richness	Positive
Ilg et al. (2008)	Europe, Germany	Beetle	Coleoptera	Flooding	Assemblage composition	Changed	Richness	Negative
Ilg et al. (2008)	Europe, Germany	Mollusk	Mollusca	Flooding	Abundance	Positive		
Ilg et al. (2008)	Europe, Germany	Beetle	Coleoptera	Flooding	Abundance	Negative		
Talley et al. (2012)	United States of America	Invertebrates	Insecta	Alien plant invasion	Assemblage composition	Changed		
Talley et al. (2012)	United States of America	Invertebrates	Insecta	Alien plant invasion	Abundance	Unclear		
Aranda and Aoki (2018)	Brazil	Bees	Hymenoptera	Flooding	Abundance	Unclear		
Aranda and Aoki (2018)	Brazil	Wasp	Hymenoptera	Flooding	Abundance	Unclear		
Greenwood et al. (2004)	Australia	Arthropods	Arthropoda	Alien plant invasion	Assemblage composition	Changed		
Greenwood et al. (2004)	Australia	Coleoptera	Coleoptera	Alien plant invasion	Abundance	Negative	Richness	Negative
Greenwood et al. (2004)	Australia	Hemiptera	Hemiptera	Alien plant invasion	Abundance	Negative	Richness	Negative
Greenwood et al. (2004)	Australia	Diptera	Diptera	Alien plant invasion	Abundance	Negative	Richness	Unclear
Greenwood et al. (2004)	Australia	Hymenoptera	Hymenoptera	Alien plant invasion	Abundance	Unclear	Richness	Unclear

Greenwood et al. (2004)	Australia	Araneae	Araneae	Alien plant invasion	Abundance	Negative	Richness	Unclear
Gerber et al. (2008)	Switzerland,Germany,France	Invertebrates	Insecta	Alien plant invasion	Abundance	Negative	Richness	Negative
Gerber et al. (2008)	Switzerland,Germany,France	Herbivores	Herbivores	Alien plant invasion	Abundance	Negative		
Gerber et al. (2008)	Switzerland,Germany,France	Predators	Predators	Alien plant invasion	Abundance	Negative		
Gerber et al. (2008)	Switzerland,Germany,France	Detritivores	Detritivores	Alien plant invasion	Abundance	Negative		
Durst et al. (2008)	United States of America	Arthropod	Arthropoda	Alien plant invasion	Assemblage composition	Changed		
Durst et al. (2008)	United States of America	Arthropod	Arthropoda	Alien plant invasion	Abundance	No effect	Richness	No effect
Durst et al. (2008)	United States of America	Diptera	Diptera	Alien plant invasion	Abundance	Positive		
Durst et al. (2008)	United States of America	Homoptera	Hemiptera	Alien plant invasion	Abundance	Negative		
Durst et al. (2008)	United States of America	Hymenoptera	Hymenoptera	Alien plant invasion	Abundance	Negative		
Peterson et al. (2021)	Ecuador, United States of America	Carabids	Coleoptera	Flooding	Abundance	No effect	Richness	Positive
Peterson et al. (2021)	Ecuador, United States of America	Carabids	Coleoptera	Flooding	Assemblage composition	Changed		
Fies et al. (2016)	Europe	Butterflies	Lepidoptera	Flooding	Abundance	Negative	Richness	Negative
Fies et al. (2016)	Europe	Butterflies	Lepidoptera	Flooding	Assemblage composition	Changed	Diversity	Negative
Fies et al. (2016)	Europe	Herbivores	Herbivores	Flooding	Abundance	Negative		
Fies et al. (2016)	Europe	Herbivores	Herbivores	Flooding	Abundance	Positive		
Fies et al. (2016)	Europe	Herbivores	Herbivores	Flooding	Abundance	Negative		
Gerisch et al. (2010)	Germany	Beetles	Coleoptera	Flooding	Abundance	Negative	Richness	Negative
Gerisch et al. (2010)	Germany	Beetles	Coleoptera	Flooding	Diversity	Negative	Assemblage composition	Changed

Bonn et al. (2002)	Germany	Spiders	Araneae	River engineering	Abundance	Unclear	Richness	No effect
Bonn et al. (2002)	Germany	Beetles	Coleoptera	River engineering	Abundance	Unclear	Richness	Negative
Bonn et al. (2002)	Germany	Beetles	Coleoptera	River engineering	Assemblage composition	Changed		
Bonn et al. (2002)	Germany	Generalist	Generalist	River engineering	Abundance	Positive		
Bonn et al. (2002)	Germany	Spiders	Araneae	River engineering	Assemblage composition	Unchanged		
Bonn et al. (2002)	Germany	Specialist	Specialist	River engineering	Abundance	Negative		
Bonn et al. (2002)	Germany	Generalist	Generalist	River engineering	Abundance	Positive		
Bonn et al. (2002)	Germany	Specialist	Specialist	River engineering	Abundance	Positive		
Fellendorf et al. (2004)	Europe	Bees	Hymenoptera	Flooding	Abundance	Negative		
Sienkiewicz and Zmihorski (2012)	Europe (Poland)	Beetles	Coleoptera	Flooding	Abundance	Positive	Richness	No effect
Sienkiewicz and Zmihorski (2012)	Europe(Poland)	Beetles	Coleoptera	Flooding	Assemblage composition	Changed		
Oliveira et al. (2023)	Brazil	Butterflies	Lepidoptera	Flooding	Abundance	Negative	Richness	Negative
Oliveira et al. (2023)	Brazil	Butterflies	Lepidoptera	Flooding	Assemblage composition	Changed		
Kjar and Park (2016)	United States of America	Ants	Hymenoptera	Alien plant invasion	Abundance	Positive	Richness	Positive
Araujo et al. (2022)	Brazil	Dragonfly	Odonata	River engineering	Abundance		Richness	Negative
Araujo et al. (2022)	Brazil	Dragonfly	Odonata	River engineering	Assemblage composition	Changed		
Ralston et al. (2017)	United States of America	Arthropods	Arthropoda	River engineering	Abundance	Negative		

Ralston et al. (2017)	United States of America	Beetles	Coleoptera	River engineering	Abundance	Negative		
Ralston et al. (2017)	United States of America	Ants	Hymenoptera	River engineering	Abundance	Negative		
Ralston et al. (2017)	United States of America	Omnivores	Omnivore	River engineering	Abundance	Negative		
Ralston et al. (2017)	United States of America	Detritivores	Detritivores	River engineering	Abundance	Negative		
Ralston et al. (2017)	United States of America	Arachnida	Arachnida	River engineering	Abundance	Positive		
Ralston et al. (2017)	United States of America	Predators	Predators	River engineering	Abundance	No effect		
Slupik et al. (2022)	Canada	Bees	Hymenoptera	Flooding	Abundance	Negative	Richness	Negative
Slupik et al. (2022)	Canada	Hoverflies	Diptera	Flooding	Abundance	No effect	Richness	No effect
Smith et al. (2006)	United States of America	Isopods	Isopoda	Flooding	Abundance	Negative		
Smith et al. (2006)	United States of America	Cricket	Orthoptera	Flooding	Abundance	Positive		
Wenninger and Fagan (2000)	United States of America	Spiders	Araneae	River engineering	Abundance	Positive	Diversity	Positive
Wenninger and Fagan (2000)	United States of America	Spiders	Araneae	River engineering	Assemblage composition	Changed		
Ballinger et al. (2007)	Australia	Ants	Hymenoptera	Flooding	Abundance	Unclear	Richness	Negative
Ballinger et al. (2007)	Australia	Ants	Hymenoptera	Flooding	Assemblage composition	Changed		
Gratzer et al. (2013)	Australia	Bugs	Hemiptera	Flooding	Abundance	Negative	Richness	Negative
Ellis et al. (2001)	United States of America	Arthropods	Arthropoda	Flooding	Richness	No effect	Assemblage composition	Changed
Ellis et al. (2001)	United States of America	Beetles	Coleoptera	Flooding	Abundance	No effect		
Ellis et al. (2001)	United States of America	Spiders	Araneae	Flooding	Abundance	Negative		

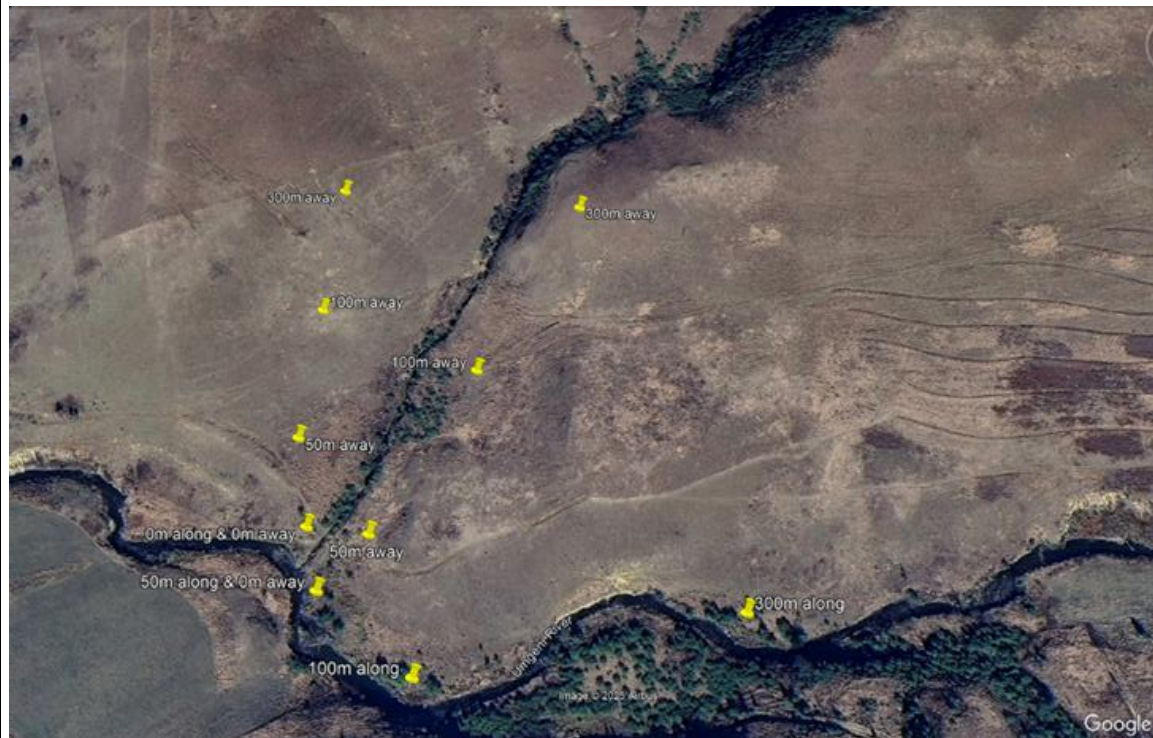
Ellis et al. (2001)	United States of America	Ants	Hymenoptera	Flooding	Abundance	Unclear		
Ellis et al. (2001)	United States of America	Isopods	Isopoda	Flooding	Abundance	Negative		
Ellis et al. (2001)	United States of America	Cricket	Orthoptera	Flooding	Abundance	Positive		
Lambeets et al. (2008b)	Netherlands, Belgium	Arthropods	Arthropoda	Flooding	Assemblage composition	Changed		
Lambeets et al. (2008b)	Netherlands, Belgium	Beetles	Coleoptera	Flooding	Abundance	Positive	Richness	Positive
Lambeets et al. (2008b)	Netherlands, Belgium	Spiders	Araneae	Flooding	Abundance	Negative	Richness	Negative
Kennedy and Turner (2011)	Mexico	Invertebrates	Insecta	River engineering	Abundance	Negative	Richness	Negative
Kennedy and Turner (2011)	Mexico	Predators	Predators	River engineering	Abundance	Negative		
Kennedy and Turner (2011)	Mexico	Invertebrates	Insecta	River engineering	Assemblage composition	Changed		
Meriste et al. (2016)	Estonia (Europe)	Spiders	Araneae	Flooding	Assemblage composition	Changed	Abundance	Unclear
Van Looy et al. (2007)	Netherlands, Belgium	Beetles	Coleoptera	River engineering	Assemblage composition	Changed		
Rensburg et al. (2008)	South Africa	Dragonfly	Odonata	Alien plant invasion	Abundance	Negative	Richness	No effect
Rensburg et al. (2008)	South Africa	Dragonfly	Odonata	Alien plant invasion	Abundance	Positive		
Skalski et al. (2016)	Poland	Beetles	Coleoptera	River engineering	Abundance	Negative	Richness	Negative
Skalski et al. (2016)	Poland	Beetles	Coleoptera	River engineering	Abundance	Positive		
Skalski et al. (2016)	Poland	Beetles	Coleoptera	River engineering	Assemblage composition	Changed		
Andersen (1968)	Norway	Beetles	Coleoptera	Flooding	Abundance	No effect		

Maher et al. (2014)	Ireland	Syrphid	Diptera	Flooding	Abundance	Negative	Richness	Negative
Maher et al. (2014)	Ireland	Sciomyzid	Diptera	Flooding	Abundance	Positive	Richness	Positive
Whiles and Goldowitz (2005)	United States of America	Arthropods	Arthropoda	Flooding	Abundance	Positive		
Lambeets et al. (2008a)	Belgium	Arthropods	Arthropoda	Flooding	Assemblage composition	Changed	Diversity	Negative
Lambeets et al. (2008a)	Belgium	Spiders	Araneae	Flooding	Abundance	Negative	Richness	Negative
Lambeets et al. (2008a)	Belgium	Beetles	Coleoptera	Flooding	Abundance	Negative	Richness	Negative
Tajovsky (1999)	Czech Republic	Millipedes	Diplopoda	Flooding	Abundance	Negative	Richness	Negative
Tajovsky (1999)	Czech Republic	Isopods	Isopoda	Flooding	Abundance	Negative	Richness	Negative
Tajovsky (1999)	Czech Republic	Collembola	Collembola	Flooding	Abundance	Negative	Richness	Negative
Tajovsky (1999)	Czech Republic	Carabids	Coleoptera	Flooding	Abundance	Negative	Richness	Negative
Tajovsky (1999)	Czech Republic	Ants	Hymenoptera	Flooding	Abundance	Negative	Richness	Negative
Tajovsky (1999)	Czech Republic	Arthropods	Arthropoda	Flooding	Assemblage composition	Changed		
Sterzyńska et al. (2017)	Poland	Detritivores	Detritivores	Alien plant invasion	Abundance	No effect		
Sterzyńska et al. (2017)	Poland	Predators	Predators	Alien plant invasion	Abundance	No effect		
Sterzyńska et al. (2017)	Poland	Collembola	Collembola	Alien plant invasion	Assemblage composition	Changed		
Sterzyńska et al. (2017)	Poland	Protura	Protura	Alien plant invasion	Assemblage composition	Unchanged		
Rabelo et al. (2021)	Brazil	Butterflies	Lepidoptera	Flooding	Abundance	Positive	Richness	No effect
Rabelo et al. (2021)	Brazil	Butterflies	Lepidoptera	Flooding	Diversity	Negative	Assemblage composition	Changed

Santos-Silva et al. (2018)	Brazil	Myriapoda	Hymenoptera	Flooding	Abundance	No effect	Richness	No effect
Santos-Silva et al. (2018)	Brazil	Myriapoda	Myriapodaa	Flooding	Assemblage composition	Changed		
Riedl et al. (2019)	United States of America	Arthropods	Arthropoda	Flooding	Abundance	Negative	Richness	Negative
Roeder et al. (2018)	United States of America	Invertebrates	Insecta	Flooding	Abundance	Negative	Richness	Negative
Roeder et al. (2018)	United States of America	Invertebrates	Insecta	Flooding	Abundance	Negative	Richness	Negative
Roeder et al. (2018)	United States of America	Invertebrates	Insecta	Flooding	Assemblage composition	Changed		
Roeder et al. (2018)	United States of America	Invertebrates	Insecta	Flooding	Assemblage composition	Changed		
Milford (1999)	United States of America	Ants	Hymenoptera	Flooding	Abundance	No effect	Richness	Negative
Milford (1999)	United States of America	Ants	Hymenoptera	Flooding	Assemblage composition	Changed		
Lessel et al. (2011)	Germany	Beetles	Coleoptera	Flooding	Abundance	Unclear	Richness	No effect
Lessel et al. (2011)	Germany	Beetles	Coleoptera	Flooding	Assemblage composition	Unchanged	Diversity	No effect
Lessel et al. (2011)	Germany	Springtails	Collembola	Flooding	Abundance	Positive	Richness	Positive
Lessel et al. (2011)	Germany	Springtails	Collembola	Flooding	Assemblage composition	Changed		

Chapter 3 material

a)



b)



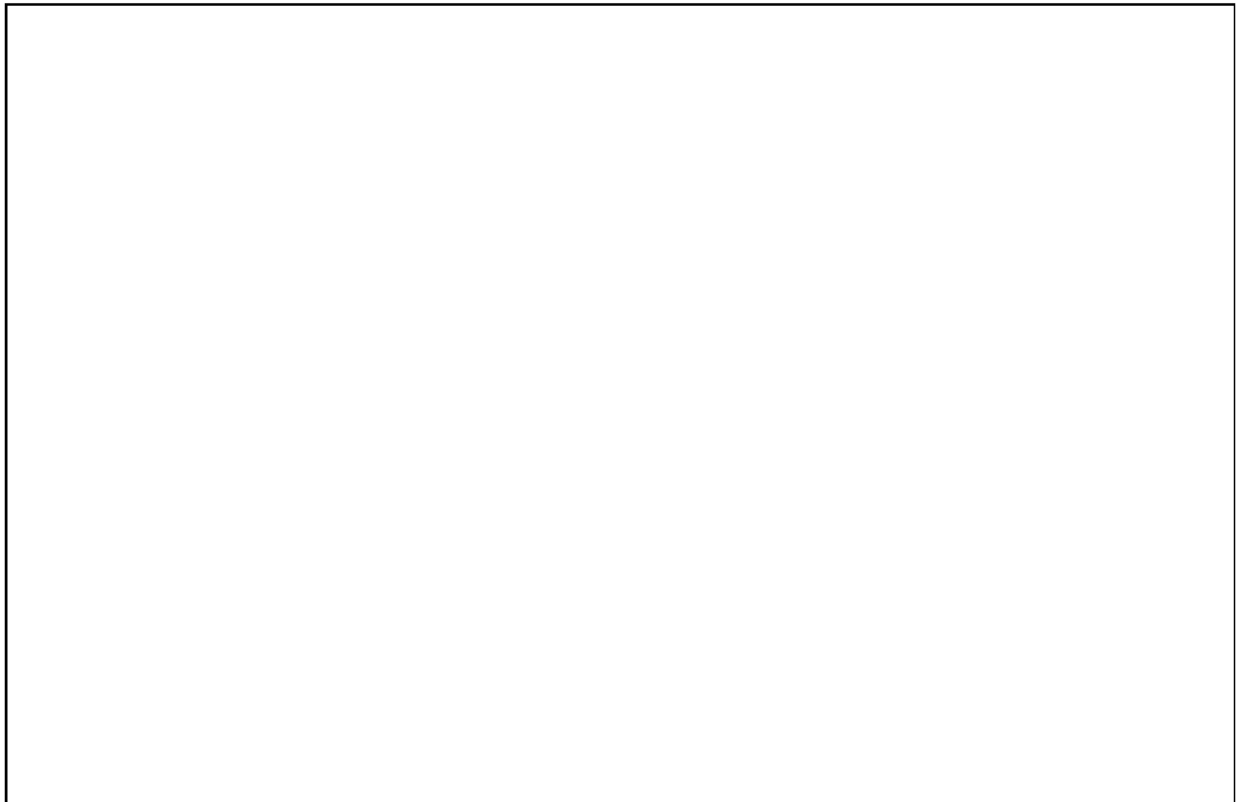


Figure S1: Google Earth satellite image showing the landscape of UMngenipoort Research Facility (a), Doreen Clark Nature Reserve (Hilton, b) and sampled plots.

Table S2: Ants collected in the distance from the riparian zones to the uplands

Foraging strategy, family, species name	Location: Hilton	Location: Umgenipoort	Total
Granivore	407	350	757
Myrmicinae	407	350	757
<i>Monomorium damarensense</i>	13	22	35
<i>Monomorium junodi</i>	0	1	1
<i>Monomorium</i> UKZN_01	0	9	9
<i>Monomorium</i> UKZN_02 (<i>monomorium</i> gp.)	3	41	44
<i>Monomorium</i> UKZN_03	1	0	1
<i>Monomorium</i> UKZN_04	7	10	17
<i>Monomorium</i> UKZN_13	9	1	10
<i>Tetramorium</i> sp.07 (<i>weitzackeri</i> gp.)	17	0	17
<i>Tetramorium</i> UKZN_02 (<i>notiale</i> gp.)	12	1	13
<i>Tetramorium</i> UKZN_03 (<i>setigerum</i> gp.)	85	184	269

<i>Tetramorium</i> UKZN_15 (sericeiventris gp.)	35	11	46
<i>Tetramorium</i> UKZN_18 (squaminode gp.)	0	8	8
<i>Tetramorium</i> UKZN_20 (squaminode gp.)	5	30	35
<i>Tetramorium</i> UKZN_21 (squaminode gp.)	0	11	11
<i>Tetramorium</i> UKZN_25 (gabonense gp.)	203	7	210
<i>Tetramorium</i> UKZN_26	17	14	31
Honeydew	3	10	13
Dolichoderinae	3	10	13
<i>Tapinoma</i> UKZN_01	0	2	2
<i>Technomyrmex</i> cf. <i>pallipes</i>	3	8	11
Nectarivore	77	132	209
Formicinae	41	120	161
<i>Camponotus</i> UKZN_02 (cintellus gp.)	38	100	138
<i>Camponotus</i> UKZN_01 (maculatus gp.)	3	20	23
Myrmicinae	36	12	48
<i>Tetramorium</i> UKZN_09 (simillimum gp.)	36	10	46
<i>Tetramorium</i> UKZN_35 (simillimum gp.)	0	2	2
Omnivore	515	748	1263
Formicinae	480	272	752
<i>Lepisiota</i> UKZN_01 (<i>capensis</i> gp.)	320	94	414
<i>Lepisiota</i> UKZN_04	1	11	12
<i>Lepisiota</i> UKZN_07	0	6	6
<i>Nylanderia</i> UKZN_01	157	161	318
<i>Polyrhachis schistacea</i>	2	0	2
Myrmicinae	0	434	434
<i>Meranoplus</i> UKZN_01	0	434	434
Ponerinae	35	42	77
<i>Mesoponera</i> UKZN_01	35	42	77
Predator	138	1093	1231
Dorylinae	55	55	110
<i>Dorylus</i> UKZN_01	55	53	108
<i>Aenictus rotundatus</i>	0	2	2
<i>Cerapachys</i> UKZN_01	0	1	1

Formicinae	20	814	834
<i>Anoplolepis custodiens</i>	20	814	834
Myrmicinae	21	201	222
<i>Carebara</i> UKZN_01	1	2	3
<i>Crematogaster</i> UKZN_01	0	38	38
<i>Crematogaster</i> UKZN_02	18	71	89
<i>Crematogaster</i> UKZN_03	2	53	55
<i>Solenopsis</i> UKZN_01	0	15	15
<i>Solenopsis</i> UKZN_02	0	15	15
<i>Solenopsis</i> UKZN_03	0	7	7
Ponerinae	42	21	63
<i>Hypoponera</i> UKZN_01	8	0	8
<i>Leptogenys schwabi</i>	33	1	34
<i>Plectroctena mandibularis</i>	1	8	9
<i>Paltothyreus tarsatus</i>	0	12	12
Scavenger	784	155	939
Myrmicinae	784	155	939
<i>Myrmicaria</i> UKZN_01	259	1	260
<i>Pheidole</i> UKZN_01 (megacephala gp.)	463	143	606
<i>Pheidole</i> UKZN_03	60	4	64
<i>Pheidole</i> UKZN_04	2	7	9

Table S3: Ants collected along the riparian zones of uMgeni River

Foraging strategy, family, species name	Location: Hilton	Location: Umgenipoort	Total
Granivore	94	107	201
Myrmicinae	94	107	201
<i>Monomorium damarense</i>	7	8	15
<i>Monomorium junodi</i>	0	1	1
<i>Monomorium</i> UKZN_01	1	7	8
<i>Monomorium</i> UKZN_02 (monomorium gp.)	0	5	5

<i>Monomorium</i> UKZN_04	7	0	7
<i>Monomorium</i> UKZN_13	3	1	4
<i>Tetramorium</i> sp.07 (<i>weitzeckeri</i> gp.)	3	0	3
<i>Tetramorium</i> UKZN_02 (<i>notiale</i> gp.)	2	1	3
<i>Tetramorium</i> UKZN_03 (<i>setigerum</i> gp.)	45	64	109
<i>Tetramorium</i> UKZN_15 (<i>sericeiventre</i> gp.)	9	0	9
<i>Tetramorium</i> UKZN_18 (<i>squaminode</i> gp.)	0	2	2
<i>Tetramorium</i> UKZN_20 (<i>squaminode</i> gp.)	3	2	5
<i>Tetramorium</i> UKZN_21 (<i>squaminode</i> gp.)	0	10	10
<i>Tetramorium</i> UKZN_25 (<i>gabonense</i> gp.)	13	0	13
<i>Tetramorium</i> UKZN_26	1	6	7
Honeydew	0	1	1
Dolichoderinae	0	1	1
<i>Tapinoma</i> UKZN_01	0	1	1
Nectarivore	57	57	114
Formicinae	34	52	86
<i>Camponotus</i> UKZN_02 (<i>cintellus</i> gp.)	33	44	77
<i>Camponotus</i> UKZN_01 (<i>maculatus</i> gp.)	1	8	9
Myrmicinae	23	5	28
<i>Tetramorium</i> UKZN_09 (<i>simillimum</i> gp.)	23	3	26
<i>Tetramorium</i> UKZN_35 (<i>simillimum</i> gp.)	0	2	2
Omnivore	162	277	439
Formicinae	161	103	264
<i>Lepisiota</i> UKZN_01 (<i>capensis</i> gp.)	133	66	199
<i>Lepisiota</i> UKZN_04	0	4	4
<i>Lepisiota</i> UKZN_07	0	1	1
<i>Nylanderia</i> UKZN_01	27	32	59
<i>Polyrhachis schistacea</i>	1	0	1
Myrmicinae	0	168	168
<i>Meranoplus</i> UKZN_01	0	168	168
Ponerinae	1	6	7
<i>Mesoponera</i> UKZN_01	1	6	7
Predator	329	919	1248

Dorylinae	57	91	148
<i>Dorylus</i> UKZN_01	57	90	147
<i>Cerapachys</i> UKZN_01	0	1	1
Formicinae	138	722	860
<i>Anoplolepis custodiens</i>	138	722	860
Myrmicinae	13	103	116
<i>Crematogaster</i> UKZN_01	0	3	3
<i>Crematogaster</i> UKZN_02	9	81	90
<i>Crematogaster</i> UKZN_03	4	6	10
<i>Solenopsis</i> UKZN_01	0	5	5
<i>Solenopsis</i> UKZN_02	0	1	1
<i>Solenopsis</i> UKZN_03	0	7	7
Ponerinae	121	3	124
<i>Hypoponera</i> UKZN_01	1	0	1
<i>Leptogenys schwabi</i>	119	0	119
<i>Paltothyreus tarsatus</i>	0	2	2
<i>Plectroctena mandibularis</i>	1	1	2
Scavenger	406	86	492
Myrmicinae	406	86	492
<i>Myrmecaria</i> UKZN_01	63	0	63
<i>Pheidole</i> UKZN_03	11	1	12
<i>Pheidole</i> UKZN_01 (megacephala gp.)	332	85	417

Table S4: Spiders collected in the distance from the riparian zones to the uplands.

Foraging strategies, species name	family, Location:Hilton	Location: Umgenipoort	Total
Burrow Dwellers	46	20	66
Bemmeridae	5	3	8
<i>Homostola zebrina</i>	3	3	6
<i>Spiroctenus</i> sp.	2	0	2
Cyrtachenidiidae	14	2	16
<i>Ancylotrypa</i> sp.	14	2	16

Entypesidae	2	10	12
<i>Afropesa schoutedeni</i>	2	0	2
<i>Brachytheliscus sp.</i>	0	10	10
Idiopidae	2	1	3
<i>Ctenolophus pectinipalpis</i>	1	1	2
<i>Ctenolophus sp.</i>	1	0	1
Lycosidae	23	4	27
<i>Hogna spenceri</i>	4	4	8
<i>Lycosa pachana</i>	19	0	19
Free-living Ground Wanderers	228	606	834
Archaeidae	1	0	1
<i>Afrarchaea godfreyi</i>	1	0	1
Corinnidae	3	0	3
<i>Copa flavoplumosa</i>	2	0	2
<i>Copa kei</i>	1	0	1
Gallieniellidae	0	3	3
<i>Drassodella melana</i>	0	3	3
Gnaphosidae	9	18	27
<i>Camillina maun</i>	0	1	1
<i>Haplodrassodes sp.</i>	3	0	3
<i>Haplodrassodes splendens</i>	2	2	4
<i>Micaria beaufortia</i>	0	6	6
<i>Zelotes fuliginus</i>	2	0	2
<i>Zelotes humilis</i>	0	1	1
<i>Zelotes natalensis</i>	1	1	2
<i>Zelotes sp. 1</i>	1	7	8
Hersiliidae	1	0	1
<i>Tyrotama sp.</i>	1	0	1
Liocranidae	0	4	4
<i>Rhaeboctesis exilis</i>	0	4	4
Lycosidae	173	572	745
<i>Allocosa aurata</i>	41	1	42
<i>Allocosa exserta</i>	0	3	3

<i>Allocosa lawrencei</i>	5	2	7
<i>Allocosa sp.</i>	13	4	17
<i>Amblyothele latedissipata</i>	0	2	2
<i>Arctosa sp. 1</i>	0	6	6
<i>Foveosa foveolata</i>	12	325	337
<i>Pardosa crassipalpis</i>	70	155	225
<i>Pardosa leipoldti</i>	0	65	65
<i>Pardosa sp.</i>	21	0	21
<i>Proevippa fascicularis</i>	4	4	8
<i>Proevippa wanlessi</i>	7	0	7
<i>Trabea purcelli</i>	0	5	5
Salticidae	3	2	5
<i>Phlegra bresnieri</i>	3	2	5
Scytodidae	2	1	3
<i>Scytodes elizabethae</i>	0	1	1
<i>Scytodes maritima</i>	2	0	2
Trachelidae	2	1	3
<i>Orthobula sp.</i>	0	1	1
<i>Spinotrachelas montanus</i>	1	0	1
<i>Trachelas sp.</i>	1	0	1
Zodariidae	34	5	39
<i>Asceua foordi</i>	6	0	6
<i>Caesetius bevisi</i>	10	3	13
<i>Caesetius sp.</i>	0	1	1
<i>Cydrela sp.</i>	1	0	1
<i>Cydrela spinimana</i>	17	1	18
Free-living Ground/ Plant Wanderers	0	1	1
Salticidae	0	1	1
<i>Heliophamus patellaris</i>	0	1	1
Free-living Plant Wanderers	9	7	16
Clubionidae	1	0	1
<i>Clubiona sp.</i>	1	0	1

Macrobunidae	2	6	8
<i>Chresiona invalida</i>	1	1	2
<i>Chresiona sp.</i>	1	5	6
Mimetidae	1	0	1
<i>Ero lawrencei</i>	1	0	1
Oxyopidae	1	0	1
<i>Oxyopes bothai</i>	1	0	1
Salticidae	3	1	4
<i>Dendryphantes sp.</i>	3	1	4
Thomisidae	1	0	1
<i>Pactactes obesus</i>	1	0	1
Funnel-Web Builders	3	1	4
Ischnothelidae	2	0	2
<i>Thelechoris striatipes</i>	2	0	2
Lycosidae	1	1	2
<i>Hippasa funerea</i>	0	1	1
<i>Hippasa sp.</i>	1	0	1
Gumfoot Web Builders	8	4	12
Theridiidae	8	4	12
<i>Coleosoma blandum</i>	0	1	1
<i>Euryopsis episinoides</i>	0	3	3
<i>Steatoda capensis</i>	1	0	1
<i>Theridion purcelli</i>	7	0	7
Orb-Web Builders	9	2	11
Anapidae	1	0	1
<i>Crozetulus rhodesiensis</i>	1	0	1
Araneidae	1	0	1
<i>Hypsosinga holzapfelae</i>	1	0	1
Tetragnathidae	7	2	9
<i>Diphya simoni</i>	1	1	2
<i>Leucauge festiva</i>	1	0	1
<i>Pachygnatha zappa</i>	5	1	6
Retreat-Web Builders	3	0	3

Zoropsidae	3	0	3
<i>Griswoldia urbana</i>	3	0	3
Sheet-Web Builders	21	12	33
Hahniidae	2	1	3
<i>Hahnia tabulicola</i>	2	1	3
Linyphiidae	19	11	30
<i>Agyneta natalensis</i>	3	11	14
<i>Agyneta sp.</i>	1	0	1
<i>Mermessus fradeorum</i>	15	0	15

Table S5: Spiders collected along the riparian zones of uMgeni River

Foraging strategy, species name	family, Hilton	Location: Umgenipoort	Total
Burrow Dwellers	14	11	25
Bemmeridae	0	6	6
<i>Homostola zebrina</i>	0	6	6
Cyrtachenidae	5	1	6
<i>Ancylotrypa sp.</i>	5	1	6
Entypesidae	1	1	2
<i>Afropesa schoutedeni</i>	1	0	1
<i>Brachytheliscus sp.</i>	0	1	1
Idiopidae	1	0	1
<i>Ctenolophus pectinipalpis</i>	1	0	1
Lycosidae	7	3	10
<i>Hippasosa sp.</i>	0	2	2
<i>Hogna sp.</i>	0	1	1
<i>Hogna spenceri</i>	2	0	2
<i>Lycosa pachana</i>	5	0	5
Free-living Ground Wanderers	92	314	406
Archaeidae	2	0	2
<i>Afrarchaea godfreyi</i>	2	0	2
Corinnidae	4	0	4

<i>Copa flavoplumosa</i>	4	0	4
Gallieniellidae	0	3	3
<i>Drassodella melana</i>	0	3	3
Gnaphosidae	1	4	5
<i>Micaria beaufortia</i>	0	2	2
<i>Zelotes sp. 1</i>	1	2	3
Hersiliidae	1	0	1
<i>Tyrotama sp.</i>	1	0	1
Liocranidae	3	2	5
<i>Rhaeboctesis exilis</i>	0	2	2
<i>Rhaeboctesis secundus</i>	3	0	3
Lycosidae	64	300	364
<i>Allocosa lawrencei</i>	2	0	2
<i>Allocosa sp.</i>	0	9	9
<i>Arctosa sp. 1</i>	0	3	3
<i>Foveosa foveolata</i>	5	132	137
<i>Pardosa leipoldti</i>	0	56	56
<i>Pardosa sp.</i>	11	0	11
<i>Proevippa fascicularis</i>	0	1	1
<i>Proevippa wanlessi</i>	4	0	4
<i>Pardosa crassipalpis</i>	42	99	141
Salticidae	2	0	2
<i>Phlegra sp.</i>	2	0	2
Scytodidae	2	1	3
<i>Scytodes elizabethae</i>	0	1	1
<i>Scytodes maritima</i>	2	0	2
Thomisidae	0	1	1
<i>Xysticus sp.</i>	0	1	1
Trachelidae	1	0	1
<i>Spinotrachelas montanus</i>	1	0	1
Zodariidae	12	3	15
<i>Asceua foordi</i>	6	0	6
<i>Caesetius bevisi</i>	3	2	5

<i>Cydrela spinimana</i>	3	1	4
Free-living Ground/ Plant Wanderers	0	3	3
Philodromidae	0	1	1
<i>Thanatus vulgaris</i>	0	1	1
Salticidae	0	2	2
<i>Heliophanus patellaris</i>	0	2	2
Free-living Plant Wanderers	9	2	11
Macrobunidae	1	0	1
<i>Chresiona invalida</i>	1	0	1
Salticidae	6	1	7
<i>Baryphas ahenus</i>	0	1	1
<i>Dendryphantes sp.</i>	4	0	4
<i>Hyllus brevitarsis</i>	1	0	1
<i>Veisella durbani</i>	1	0	1
Thomisidae	2	1	3
<i>Hewittia gracilis</i>	0	1	1
<i>Pactactes obesus</i>	1	0	1
<i>Runcinia aethiops</i>	1	0	1
Funnel-Web Builders	2	0	2
Ischnothelidae	2	0	2
<i>Thelechoris striatipes</i>	2	0	2
Gumfoot Web Builders	1	3	4
Theridiidae	1	3	4
<i>Euryopsis episinoides</i>	0	3	3
<i>Rhomphaea nasica</i>	1	0	1
Orb-Web Builders	5	2	7
Tetragnathidae	4	2	6
<i>Diphya simoni</i>	1	0	1
<i>Leucauge festiva</i>	3	0	3
<i>Leucauge thomeensis</i>	0	2	2
Uloboridae	1	0	1
<i>Uloborus plumipes</i>	1	0	1

Retreat-Web Builders	6	0	6
Zoropsidae	6	0	6
<i>Griswoldia urbensis</i>	6	0	6
Sheet-Web Builders	8	9	17
Linyphiidae	8	9	17
<i>Agyneta natalensis</i>	2	6	8
<i>Agyneta sp.</i>	1	1	2
<i>Mermessus fradeorum</i>	5	2	7

Table S6: Results of pairwise comparison of ant abundance between distance from the riparian to the uplands within each season and location.

Location	Season	Comparison	Estimate	SE	z-ratio	p-value
Hilton	Dry	0 m vs 50 m	0.901	0.0438	20.561	<0.0001
Hilton	Dry	0 m vs 100 m	1.060	0.0477	22.229	<0.0001
Hilton	Dry	0 m vs 300 m	0.214	0.0367	5.823	<0.0001
Hilton	Dry	50 m vs 100 m	0.159	0.0555	2.870	0.0214
Hilton	Dry	50 m vs 300 m	-0.687	0.0464	-14.804	<0.0001
Hilton	Dry	100 m vs 300 m	-0.846	0.0499	-16.953	<0.0001
Hilton	Wet	0 m vs 50 m	0.901	0.0438	20.561	<0.0001
Hilton	Wet	0 m vs 100 m	1.060	0.0477	22.229	<0.0001
Hilton	Wet	0 m vs 300 m	0.214	0.0367	5.823	<0.0001
Hilton	Wet	50 m vs 100 m	0.159	0.0555	2.870	0.0214
Hilton	Wet	50 m vs 300 m	-0.687	0.0464	-14.804	<0.0001
Hilton	Wet	100 m vs 300 m	-0.846	0.0499	-16.953	<0.0001
Umgenipoort	Dry	0 m vs 50 m	0.901	0.0438	20.561	<0.0001
Umgenipoort	Dry	0 m vs 100 m	1.060	0.0477	22.229	<0.0001
Umgenipoort	Dry	0 m vs 300 m	0.214	0.0367	5.823	<0.0001

Umgenipoort	Dry	50 m vs 100 m	0.159	0.0555	2.870	0.0214
Umgenipoort	Dry	50 m vs 300 m	-0.687	0.0464	-14.804	<0.0001
Umgenipoort	Dry	100 m vs 300 m	-0.846	0.0499	-16.953	<0.0001
Umgenipoort	Wet	0 m vs 50 m	0.901	0.0438	20.561	<0.0001
Umgenipoort	Wet	0 m vs 100 m	1.060	0.0477	22.229	<0.0001
Umgenipoort	Wet	0 m vs 300 m	0.214	0.0367	5.823	<0.0001
Umgenipoort	Wet	50 m vs 100 m	0.159	0.0555	2.870	0.0214
Umgenipoort	Wet	50 m vs 300 m	-0.687	0.0464	-14.804	<0.0001
Umgenipoort	Wet	100 m vs 300 m	-0.846	0.0499	-16.953	<0.0001

Table S7: Results of pairwise comparison of ant richness between distance from the riparian to the uplands within each season and location.

Location	Season	Comparison	Estimate	SE	z-ratio	p-value
Hilton	Dry	0 m vs 50 m	0.0426	0.119	0.357	0.9844
Hilton	Dry	0 m vs 100 m	0.1161	0.124	0.936	0.7856
Hilton	Dry	0 m vs 300 m	-0.2283	0.116	-1.962	0.2025
Hilton	Dry	50 m vs 100 m	0.0736	0.125	0.587	0.9360
Hilton	Dry	50 m vs 300 m	-0.2708	0.118	-2.302	0.0975
Hilton	Dry	100 m vs 300 m	-0.3444	0.122	-2.820	0.0248
Hilton	Wet	0 m vs 50 m	0.0426	0.119	0.357	0.9844
Hilton	Wet	0 m vs 100 m	0.1161	0.124	0.936	0.7856
Hilton	Wet	0 m vs 300 m	-0.2283	0.116	-1.962	0.2025
Hilton	Wet	50 m vs 100 m	0.0736	0.125	0.587	0.9360

Hilton	Wet	50 m vs 300 m	-0.2708	0.118	-2.302	0.0975
Hilton	Wet	100 m vs 300 m	-0.3444	0.122	-2.820	0.0248
Umgenipoort	Dry	0 m vs 50 m	0.0426	0.119	0.357	0.9844
Umgenipoort	Dry	0 m vs 100 m	0.1161	0.124	0.936	0.7856
Umgenipoort	Dry	0 m vs 300 m	-0.2283	0.116	-1.962	0.2025
Umgenipoort	Dry	50 m vs 100 m	0.0736	0.125	0.587	0.9360
Umgenipoort	Dry	50 m vs 300 m	-0.2708	0.118	-2.302	0.0975
Umgenipoort	Dry	100 m vs 300 m	-0.3444	0.122	-2.820	0.0248
Umgenipoort	Wet	0 m vs 50 m	0.0426	0.119	0.357	0.9844
Umgenipoort	Wet	0 m vs 100 m	0.1161	0.124	0.936	0.7856
Umgenipoort	Wet	0 m vs 300 m	-0.2283	0.116	-1.962	0.2025
Umgenipoort	Wet	50 m vs 100 m	0.0736	0.125	0.587	0.9360
Umgenipoort	Wet	50 m vs 300 m	-0.2708	0.118	-2.302	0.0975
Umgenipoort	Wet	100 m vs 300 m	-0.3444	0.122	-2.820	0.0248

Table S8: Results of the multinomial logistic regression testing the effect of distance from the riparian habitat to the uplands, season and location on the distribution of ant foraging strategies.

Foraging strategy	Predictor	Estimate	SE
Honeydew	Intercept	-5.178	0.878
	50 m	1.161	0.724
	100 m	0.584	0.831
	300 m	-1.640	1.165
	Umgenipoort	1.116	0.699
	Wet season	0.538	0.638
Nectarivore	Intercept	-1.581	0.214
	50 m	-0.223	0.229

Foraging strategy	Predictor	Estimate	SE
Omnivore	100 m	-0.358	0.245
	300 m	-0.999	0.204
	Umgenipoort	0.239	0.172
	Wet season	1.009	0.186
	Intercept	0.737	0.122
Predator	50 m	0.012	0.144
	100 m	-0.084	0.151
	300 m	-0.956	0.125
	Umgenipoort	0.502	0.101
	Wet season	-0.269	0.100
Scavenger	Intercept	0.068	0.140
	50 m	-1.545	0.163
	100 m	-1.395	0.166
	300 m	-2.088	0.133
	Umgenipoort	1.744	0.125
	Wet season	0.318	0.110
	Intercept	1.471	0.124
	50 m	-0.967	0.163
	100 m	-1.249	0.179
	300 m	-1.090	0.130
	Umgenipoort	-1.708	0.124
	Wet season	0.097	0.108

Table S9: Results of pairwise comparison of spider abundance between distance from the riparian to the uplands within each season and location.

Location	Season	Comparison	Estimate	SE	z-ratio	p-value
Hilton	Dry	0 m vs 50 m	0.1452	0.241	0.601	0.9317
Hilton	Dry	0 m vs 100 m	0.1769	0.243	0.727	0.8865
Hilton	Dry	0 m vs 300 m	0.2436	0.248	0.982	0.7596
Hilton	Dry	50 m vs 100 m	0.0318	0.252	0.126	0.9993

Hilton	Dry	50 m vs 300 m	0.0984	0.256	0.384	0.9808
Hilton	Dry	100 m vs 300 m	0.0667	0.258	0.258	0.9940
Hilton	Wet	0 m vs 50 m	0.2814	0.209	1.344	0.5350
Hilton	Wet	0 m vs 100 m	-0.0728	0.191	-0.381	0.9811
Hilton	Wet	0 m vs 300 m	0.0991	0.199	0.497	0.9597
Hilton	Wet	50 m vs 100 m	-0.3542	0.206	-1.717	0.3146
Hilton	Wet	50 m vs 300 m	-0.1823	0.214	-0.852	0.8296
Hilton	Wet	100 m vs 300 m	0.1719	0.196	0.877	0.8167
Umgenipoort	Dry	0 m vs 50 m	0.3948	0.224	1.761	0.2923
Umgenipoort	Dry	0 m vs 100 m	0.0732	0.202	0.363	0.9837
Umgenipoort	Dry	0 m vs 300 m	0.7239	0.215	3.361	0.0043
Umgenipoort	Dry	50 m vs 100 m	-0.3216	0.244	-1.319	0.5510
Umgenipoort	Dry	50 m vs 300 m	0.3291	0.258	1.277	0.5773
Umgenipoort	Dry	100 m vs 300 m	0.6507	0.238	2.728	0.0323
Umgenipoort	Wet	0 m vs 50 m	0.1001	0.129	0.774	0.8661
Umgenipoort	Wet	0 m vs 100 m	-0.0982	0.123	-0.798	0.8553
Umgenipoort	Wet	0 m vs 300 m	0.3704	0.139	2.657	0.0394
Umgenipoort	Wet	50 m vs 100 m	-0.1983	0.126	-1.569	0.3963

Umgenipoort	Wet	50 m vs 300 m	0.2703	0.142	1.899	0.2286
Umgenipoort	Wet	100 m vs 300 m	0.4686	0.137	3.428	0.0034

Table S10: Results of the multinomial logistic regression testing the effect of distance from the riparian habitat to the uplands, season and location on the distribution of spider foraging strategies.

Foraging strategy	Predictor	Estimate	SE
Free-living Ground Wanderers	Intercept	1.140	0.301
	50 m	-0.148	0.399
	100 m	0.246	0.419
	300 m	-0.993	0.360
	Umgenipoort	1.636	0.287
	Wet season	1.596	0.290
Free-living Ground/Plant Wanderers	Intercept	-59.983	0.358
	50 m	-16.530	0.00003
	100 m	-11.653	363.019
	300 m	-10.961	177.700
	Umgenipoort	21.498	0.358
	Wet season	38.075	0.358
Free-living Plant Wanderers	Intercept	-2.279	0.802
	50 m	-0.545	1.279
	100 m	1.633	0.894
	300 m	0.684	0.880
	Umgenipoort	0.571	0.575
	Wet season	-0.085	0.607
Funnel-Web Builders	Intercept	-1.695	0.815

Foraging strategy	Predictor	Estimate	SE
	50 m	-16.518	0.00001
	100 m	0.467	1.077
	300 m	-11.433	181.377
	Umgenipoort	-0.282	1.194
	Wet season	-10.693	162.347
	Intercept	-3.012	0.914
Gumfoot Web Builders	50 m	0.172	0.906
	100 m	0.203	0.915
	300 m	-0.661	0.890
	Umgenipoort	-0.095	0.677
	Wet season	2.498	0.825
	Intercept	-13.421	113.237
Orb-Web Builders	50 m	11.621	113.237
	100 m	11.048	113.237
	300 m	-3.811	549.512
	Umgenipoort	-1.051	0.842
	Wet season	2.594	0.847
	Intercept	-13.804	201.297
Retreat-Web Builders	50 m	0.317	1.480
	100 m	-11.439	329.743
	300 m	-0.782	1.467
	Umgenipoort	-10.516	142.673
	Wet season	12.810	201.296
	Intercept	-2.461	0.699
Sheet-Web Builders	50 m	0.172	0.599
	100 m	-0.333	0.664
	300 m	-1.045	0.609
	Intercept	-2.461	0.699

Foraging strategy	Predictor	Estimate	SE
	Umgenipoort	-0.013	0.464
	Wet season	3.226	0.667

Table S11: Results of pairwise comparison of ant abundance between distance along the riparian habitat within each season and location.

Location	Season	Distance comparison	SE	z-ratio	p-value
Hilton	Dry	0m vs 50m	2.0454	3.341	0.0147
Hilton	Dry	0m vs 100m	2.4195	3.205	0.0229
Hilton	Dry	0m vs 300m	1.8299	2.656	0.1097
Hilton	Dry	0m vs 700m	5.7439	4.827	<0.0001
Hilton	Dry	0m vs 1000m	0.8001	0.997	0.9547
Hilton	Dry	0m vs 2200m	2.0868	3.384	0.0127
Hilton	Dry	50m vs 100m	0.5384	0.154	1.0000
Hilton	Dry	50m vs 300m	0.4072	-0.401	0.9997
Hilton	Dry	50m vs 700m	1.2779	1.819	0.5349
Hilton	Dry	50m vs 1000m	0.1781	-2.065	0.3734
Hilton	Dry	50m vs 2200m	0.4649	0.043	1.0000
Hilton	Dry	100m vs 300m	0.3995	-0.524	0.9985
Hilton	Dry	100m vs 700m	1.2513	1.578	0.6967
Hilton	Dry	100m vs 1000m	0.1748	-2.095	0.3555
Hilton	Dry	100m vs 2200m	0.4712	-0.114	1.0000
Hilton	Dry	300m vs 700m	1.6442	2.098	0.3537
Hilton	Dry	300m vs 1000m	0.2297	-1.573	0.6998
Hilton	Dry	300m vs 2200m	0.6189	0.441	0.9994
Hilton	Dry	700m vs 1000m	0.0762	-3.652	0.0049

Location	Season	Distance comparison	SE	z-ratio	p-value
Hilton	Dry	700m vs 2200m	0.2057	-1.780	0.5618
Hilton	Dry	1000m vs 2200m	1.3989	2.105	0.3494
Hilton	Wet	0m vs 50m	2.0454	3.341	0.0147
Hilton	Wet	0m vs 100m	2.4195	3.205	0.0229
Hilton	Wet	0m vs 300m	1.8299	2.656	0.1097
Hilton	Wet	0m vs 700m	5.7439	4.827	<0.0001
Hilton	Wet	0m vs 1000m	0.8001	0.997	0.9547
Hilton	Wet	0m vs 2200m	2.0868	3.384	0.0127
Hilton	Wet	50m vs 100m	0.5384	0.154	1.0000
Hilton	Wet	50m vs 300m	0.4072	-0.401	0.9997
Hilton	Wet	50m vs 700m	1.2779	1.819	0.5349
Hilton	Wet	50m vs 1000m	0.1781	-2.065	0.3734
Hilton	Wet	50m vs 2200m	0.4649	0.043	1.0000
Hilton	Wet	100m vs 300m	0.3995	-0.524	0.9985
Hilton	Wet	100m vs 700m	1.2513	1.578	0.6967
Hilton	Wet	100m vs 1000m	0.1748	-2.095	0.3555
Hilton	Wet	100m vs 2200m	0.4712	-0.114	1.0000
Hilton	Wet	300m vs 700m	1.6442	2.098	0.3537
Hilton	Wet	300m vs 1000m	0.2297	-1.573	0.6998
Hilton	Wet	300m vs 2200m	0.6189	0.441	0.9994
Hilton	Wet	700m vs 1000m	0.0762	-3.652	0.0049
Hilton	Wet	700m vs 2200m	0.2057	-1.780	0.5618
Hilton	Wet	1000m vs 2200m	1.3989	2.105	0.3494
Umgenipoort	Dry	0m vs 50m	2.0454	3.341	0.0147
Umgenipoort	Dry	0m vs 100m	2.4195	3.205	0.0229
Umgenipoort	Dry	0m vs 300m	1.8299	2.656	0.1097
Umgenipoort	Dry	0m vs 700m	5.7439	4.827	<0.0001

Location	Season	Distance comparison	SE	z-ratio	p-value
Umgenipoort	Dry	0m vs 1000m	0.8001	0.997	0.9547
Umgenipoort	Dry	0m vs 2200m	2.0868	3.384	0.0127
Umgenipoort	Dry	50m vs 100m	0.5384	0.154	1.0000
Umgenipoort	Dry	50m vs 300m	0.4072	-0.401	0.9997
Umgenipoort	Dry	50m vs 700m	1.2779	1.819	0.5349
Umgenipoort	Dry	50m vs 1000m	0.1781	-2.065	0.3734
Umgenipoort	Dry	50m vs 2200m	0.4649	0.043	1.0000
Umgenipoort	Dry	100m vs 300m	0.3995	-0.524	0.9985
Umgenipoort	Dry	100m vs 700m	1.2513	1.578	0.6967
Umgenipoort	Dry	100m vs 1000m	0.1748	-2.095	0.3555
Umgenipoort	Dry	100m vs 2200m	0.4712	-0.114	1.0000
Umgenipoort	Dry	300m vs 700m	1.6442	2.098	0.3537
Umgenipoort	Dry	300m vs 1000m	0.2297	-1.573	0.6998
Umgenipoort	Dry	300m vs 2200m	0.6189	0.441	0.9994
Umgenipoort	Dry	700m vs 1000m	0.0762	-3.652	0.0049
Umgenipoort	Dry	700m vs 2200m	0.2057	-1.780	0.5618
Umgenipoort	Dry	1000m vs 2200m	1.3989	2.105	0.3494
Umgenipoort	Wet	0m vs 50m	2.0454	3.341	0.0147
Umgenipoort	Wet	0m vs 100m	2.4195	3.205	0.0229
Umgenipoort	Wet	0m vs 300m	1.8299	2.656	0.1097
Umgenipoort	Wet	0m vs 700m	5.7439	4.827	<0.0001
Umgenipoort	Wet	0m vs 1000m	0.8001	0.997	0.9547
Umgenipoort	Wet	0m vs 2200m	2.0868	3.384	0.0127
Umgenipoort	Wet	50m vs 100m	0.5384	0.154	1.0000
Umgenipoort	Wet	50m vs 300m	0.4072	-0.401	0.9997
Umgenipoort	Wet	50m vs 700m	1.2779	1.819	0.5349
Umgenipoort	Wet	50m vs 1000m	0.1781	-2.065	0.3734

Location	Season	Distance comparison	SE	z-ratio	p-value
Umgenipoort	Wet	50m vs 2200m	0.4649	0.043	1.0000
Umgenipoort	Wet	100m vs 300m	0.3995	-0.524	0.9985
Umgenipoort	Wet	100m vs 700m	1.2513	1.578	0.6967
Umgenipoort	Wet	100m vs 1000m	0.1748	-2.095	0.3555
Umgenipoort	Wet	100m vs 2200m	0.4712	-0.114	1.0000
Umgenipoort	Wet	300m vs 700m	1.6442	2.098	0.3537
Umgenipoort	Wet	300m vs 1000m	0.2297	-1.573	0.6998
Umgenipoort	Wet	300m vs 2200m	0.6189	0.441	0.9994
Umgenipoort	Wet	700m vs 1000m	0.0762	-3.652	0.0049
Umgenipoort	Wet	700m vs 2200m	0.2057	-1.780	0.5618
Umgenipoort	Wet	1000m vs 2200m	1.3989	2.105	0.3494

Table S12: Results of pairwise comparison of ant richness between distance along the riparian habitat within each season and location.

Location	Season	Contrast	SE	z.ratio	p.value
Hilton	Dry	0m vs 50m	0.2734	1.248	0.8754
Hilton	Dry	0m vs 100m	0.3118	1.128	0.9197
Hilton	Dry	0m vs 300m	1.1146	3.595	0.0060
Hilton	Dry	0m vs 700m	0.4047	1.832	0.5262
Hilton	Dry	0m vs 1000m	0.4296	1.977	0.4294
Hilton	Dry	0m vs 2200m	0.3651	2.161	0.3171
Hilton	Dry	50m vs 100m	0.2517	0.026	1.0000
Hilton	Dry	50m vs 300m	0.8792	2.741	0.0882
Hilton	Dry	50m vs 700m	0.3249	0.766	0.9881
Hilton	Dry	50m vs 1000m	0.3445	0.921	0.9694

Location	Season	Contrast	SE	z.ratio	p.value
Hilton	Dry	50m vs 2200m	0.2965	0.941	0.9659
Hilton	Dry	100m vs 300m	0.9058	2.626	0.1182
Hilton	Dry	100m vs 700m	0.3426	0.699	0.9927
Hilton	Dry	100m vs 1000m	0.3626	0.846	0.9800
Hilton	Dry	100m vs 2200m	0.3258	0.826	0.9823
Hilton	Dry	300m vs 700m	0.1753	-2.012	0.4068
Hilton	Dry	300m vs 1000m	0.1846	-1.877	0.4957
Hilton	Dry	300m vs 2200m	0.1718	-2.038	0.3906
Hilton	Dry	700m vs 1000m	0.3118	0.149	1.0000
Hilton	Dry	700m vs 2200m	0.2823	0.072	1.0000
Hilton	Dry	1000m vs 2200m	0.2735	-0.087	1.0000
Hilton	Wet	0m vs 50m	0.2734	1.248	0.8754
Hilton	Wet	0m vs 100m	0.3118	1.128	0.9197
Hilton	Wet	0m vs 300m	1.1146	3.595	0.0060
Hilton	Wet	0m vs 700m	0.4047	1.832	0.5262
Hilton	Wet	0m vs 1000m	0.4296	1.977	0.4294
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Hilton	Wet	100m vs 300m	0.9058	2.626	0.1182
Hilton	Wet	100m vs 700m	0.3426	0.699	0.9927
Hilton	Wet	100m vs 1000m	0.3626	0.846	0.9800
Hilton	Wet	100m vs 2200m	0.3258	0.826	0.9823

Location	Season	Contrast	SE	z.ratio	p.value
Hilton	Wet	300m vs 700m	0.1753	-2.012	0.4068
Hilton	Wet	300m vs 1000m	0.1846	-1.877	0.4957
Hilton	Wet	300m vs 2200m	0.1718	-2.038	0.3906
Hilton	Wet	700m vs 1000m	0.3118	0.149	1.0000
Hilton	Wet	700m vs 2200m	0.2823	0.072	1.0000
Hilton	Wet	1000m vs 2200m	0.2735	-0.087	1.0000
Umgenipoort	Dry	0m vs 50m	0.2734	1.248	0.8754
Umgenipoort	Dry	0m vs 100m	0.3118	1.128	0.9197
Umgenipoort	Dry	0m vs 300m	1.1146	3.595	0.0060
Umgenipoort	Dry	0m vs 700m	0.4047	1.832	0.5262
Umgenipoort	Dry	0m vs 1000m	0.4296	1.977	0.4294
Umgenipoort	Dry	0m vs 2200m	0.3651	2.161	0.3171
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Umgenipoort	Dry	50m vs 1000m	0.3445	0.921	0.9694
Umgenipoort	Dry	50m vs 2200m	0.2965	0.941	0.9659
Umgenipoort	Dry	100m vs 300m	0.9058	2.626	0.1182
Umgenipoort	Dry	100m vs 700m	0.3426	0.699	0.9927
Umgenipoort	Dry	100m vs 1000m	0.3626	0.846	0.9800
Umgenipoort	Dry	100m vs 2200m	0.3258	0.826	0.9823
Umgenipoort	Dry	300m vs 700m	0.1753	-2.012	0.4068
Umgenipoort	Dry	300m vs 1000m	0.1846	-1.877	0.4957
Umgenipoort	Dry	300m vs 2200m	0.1718	-2.038	0.3906
Umgenipoort	Dry	700m vs 1000m	0.3118	0.149	1.0000

Location	Season	Contrast	SE	z.ratio	p.value
Umgenipoort	Dry	700m vs 2200m	0.2823	0.072	1.0000
Umgenipoort	Dry	1000m vs 2200m	0.2735	-0.087	1.0000
Umgenipoort	Wet	0m vs 50m	0.2734	1.248	0.8754
Umgenipoort	Wet	0m vs 100m	0.3118	1.128	0.9197
Umgenipoort	Wet	0m vs 300m	1.1146	3.595	0.0060
Umgenipoort	Wet	0m vs 700m	0.4047	1.832	0.5262
Umgenipoort	Wet	0m vs 1000m	0.4296	1.977	0.4294
Umgenipoort	Wet	0m vs 2200m	0.3651	2.161	0.3171
Umgenipoort	Wet	50m vs 100m	0.2517	0.026	1.0000
Umgenipoort	Wet	50m vs 300m	0.8792	2.741	0.0882
Umgenipoort	Wet	50m vs 700m	0.3249	0.766	0.9881
Umgenipoort	Wet	50m vs 1000m	0.3445	0.921	0.9694
Umgenipoort	Wet	50m vs 2200m	0.2965	0.941	0.9659
Umgenipoort	Wet	100m vs 300m	0.9058	2.626	0.1182
Umgenipoort	Wet	100m vs 700m	0.3426	0.699	0.9927
Umgenipoort	Wet	100m vs 1000m	0.3626	0.846	0.9800
Umgenipoort	Wet	100m vs 2200m	0.3258	0.826	0.9823
Umgenipoort	Wet	300m vs 700m	0.1753	-2.012	0.4068
Umgenipoort	Wet	300m vs 1000m	0.1846	-1.877	0.4957
Umgenipoort	Wet	300m vs 2200m	0.1718	-2.038	0.3906
Umgenipoort	Wet	700m vs 1000m	0.3118	0.149	1.0000
Umgenipoort	Wet	700m vs 2200m	0.2823	0.072	1.0000
Umgenipoort	Wet	1000m vs 2200m	0.2735	-0.087	1.0000

Table S13: Results of the multinomial logistic regression testing the effect of distance along the riparian habitat, season and location on the distribution of ant foraging strategies.

Foraging strategy	Predictor	Estimate	SE
Honeydew	Intercept	-24.011	0.010
	50 m	-0.000416	0.003
	Umgenipoort	5.352	0.010
	Wet season	14.562	0.010
Nectarivore	Intercept	-1.012	0.202
	50 m	0.000064	0.000
	Umgenipoort	-0.520	0.155
	Wet season	1.254	0.253
Omnivore	Intercept	0.714	0.136
	50 m	-0.000348	0.000
	Umgenipoort	0.235	0.120
	Wet season	0.091	0.177
Predator	Intercept	0.742	0.124
	50 m	0.000511	0.000
	Umgenipoort	0.999	0.101
	Wet season	0.450	0.158
Scavenger	Intercept	0.919	0.134
	50 m	-0.000309	0.000
	Umgenipoort	-2.405	0.138
	Wet season	1.726	0.181

Table S14: Results of pairwise comparison of spider abundance between distance along the riparian habitat within each season and location.

Location	Season	Distance comparison	SE	z-ratio	p-value
Hilton	Dry	0 m vs 50 m	0.509	0.369	0.9998
Hilton	Dry	0 m vs 100 m	0.414	-0.092	1.0000
Hilton	Dry	0 m vs 300 m	0.473	0.207	1.0000
Hilton	Dry	0 m vs 700 m	0.681	0.994	0.9555
Hilton	Dry	0 m vs 1000 m	0.479	0.233	1.0000
Hilton	Dry	0 m vs 2200 m	0.906	1.578	0.6965
Hilton	Dry	50 m vs 100 m	0.324	-0.504	0.9988
Hilton	Dry	50 m vs 300 m	0.371	-0.177	1.0000
Hilton	Dry	50 m vs 700 m	0.535	0.683	0.9935
Hilton	Dry	50 m vs 1000 m	0.375	-0.148	1.0000
Hilton	Dry	50 m vs 2200 m	0.714	1.320	0.8429
Hilton	Dry	100 m vs 300 m	0.449	0.328	0.9999
Hilton	Dry	100 m vs 700 m	0.648	1.186	0.8998
Hilton	Dry	100 m vs 1000 m	0.454	0.357	0.9998
Hilton	Dry	100 m vs 2200 m	0.864	1.818	0.5356
Hilton	Dry	300 m vs 700 m	0.572	0.859	0.9784
Hilton	Dry	300 m vs 1000 m	0.401	0.029	1.0000
Hilton	Dry	300 m vs 2200 m	0.763	1.495	0.7482
Hilton	Dry	700 m vs 1000 m	0.289	-0.831	0.9818
Hilton	Dry	700 m vs 2200 m	0.549	0.640	0.9955
Hilton	Dry	1000 m vs 2200 m	0.755	1.466	0.7650
Hilton	Wet	0 m vs 50 m	0.509	0.369	0.9998
Hilton	Wet	0 m vs 100 m	0.414	-0.092	1.0000
Hilton	Wet	0 m vs 300 m	0.473	0.207	1.0000
Hilton	Wet	0 m vs 700 m	0.681	0.994	0.9555

Location	Season	Distance comparison	SE	z-ratio	p-value
Hilton	Wet	0 m vs 1000 m	0.479	0.233	1.0000
Hilton	Wet	0 m vs 2200 m	0.906	1.578	0.6965
Umgenipoort	Dry	0 m vs 50 m	0.509	0.369	0.9998
Umgenipoort	Dry	0 m vs 100 m	0.414	-0.092	1.0000
Umgenipoort	Dry	0 m vs 300 m	0.473	0.207	1.0000
Umgenipoort	Dry	0 m vs 700 m	0.681	0.994	0.9555
Umgenipoort	Dry	0 m vs 1000 m	0.479	0.233	1.0000
Umgenipoort	Dry	0 m vs 2200 m	0.906	1.578	0.6965
Umgenipoort	Wet	0 m vs 50 m	0.509	0.369	0.9998
Umgenipoort	Wet	0 m vs 100 m	0.414	-0.092	1.0000
Umgenipoort	Wet	0 m vs 300 m	0.473	0.207	1.0000
Umgenipoort	Wet	0 m vs 700 m	0.681	0.994	0.9555
Umgenipoort	Wet	0 m vs 1000 m	0.479	0.233	1.0000
Umgenipoort	Wet	0 m vs 2200 m	0.906	1.578	0.6965

Table S15: Results of the multinomial logistic regression testing the effect of distance along the riparian habitat, season and location on the distribution of spider foraging strategies.

Foraging strategy	Predictor	Estimate	SE
Free-living Ground Wanderers	Intercept	1.380	0.286
	Longitudinal distance	0.00025	0.00042
	Umgenipoort	1.189	0.365
	Wet season	1.152	0.353
Free-living Ground/ Plant Wanderers	Intercept	-25.547	0.375
	Longitudinal distance	0.00096	0.00082
	Umgenipoort	22.993	0.375
	Wet season	1.049	0.340

Foraging strategy	Predictor	Estimate	SE
Free-living Plant Wanderers	Intercept	-2.086	0.663
	Longitudinal distance	0.00149	0.00055
	Umgenipoort	-1.956	0.846
	Wet season	1.707	0.686
Funnel-Web Builders	Intercept	-0.677	0.992
	Longitudinal distance	-0.0114	0.0135
	Umgenipoort	-11.098	0.000005
	Wet season	-6.361	0.0006
Gumfoot Web Builders	Intercept	-31.234	0.338
	Longitudinal distance	-0.00091	0.00135
	Umgenipoort	0.855	0.338
	Wet season	30.293	0.338
Orb-Web Builders	Intercept	-3.028	0.380
	Longitudinal distance	0.00116	0.00063
	Umgenipoort	-1.349	0.358
	Wet season	2.560	0.358
Retreat-Web Builders	Intercept	-2.493	0.614
	Longitudinal distance	0.00167	0.00063
	Umgenipoort	-21.664	0.0000007
	Wet season	1.414	0.555
Sheet-Web Builders	Intercept	-1.647	0.635
	Longitudinal distance	-0.00026	0.00067
	Umgenipoort	-0.021	0.593
	Wet season	2.328	0.679

Table S16: Ants collected from the gradient between riparian zones and uplands

Species name	Hilton				Umgenipoort			
	0m	50m	100m	300m	0m	50m	100m	300m
<i>Aenictus rotundatus</i>	0	0	0	0	0	0	0	2
<i>Anoplolepis custodiens</i>	6	12	1	1	721	24	47	22
<i>Camponotus</i> UKZN_02 (<i>cintellus</i> gp.)	6	3	1	28	47	29	4	20
<i>Camponotus</i> UKZN_01 (<i>maculatus</i> gp.)	0	1	0	2	8	2	6	4
<i>Carebara</i> UKZN_01	0	0	1	0	0	2	0	0
<i>Cerapachys</i> UKZN_01	0	0	0	0	1	0	0	0
<i>Crematogaster</i> UKZN_01	0	0	0	0	3	28	7	0
<i>Crematogaster</i> UKZN_02	6	5	1	6	22	17	18	14
<i>Crematogaster</i> UKZN_03	1	0	1	0	1	1	12	39
<i>Dorylus</i> UKZN_01	27	0	1	27	27	0	8	18
<i>Hypoponera</i> UKZN_01	0	4	0	4	0	0	0	0
<i>Lepisiota</i> UKZN_01 (<i>capensis</i> gp.)	100	105	78	37	56	14	8	16
<i>Lepisiota</i> UKZN_04	0	0	0	1	5	3	0	3
<i>Lepisiota</i> UKZN_07	0	0	0	0	1	0	0	5
<i>Leptogenys schwabi</i>	10	6	1	16	0	1	0	0
<i>Meranoplus</i> UKZN_01	0	0	0	0	178	73	53	130
<i>Mesoponera</i> UKZN_01	0	12	10	13	2	17	9	14
<i>Monomorium damarensense</i>	6	1	1	5	3	12	2	5
<i>Monomorium junodi</i>	0	0	0	0	1	0	0	0
<i>Monomorium</i> UKZN_01	0	0	0	0	5	0	0	4
<i>Monomorium</i> UKZN_02 (<i>monomorium</i> gp.)	0	1	2	0	5	5	9	22
<i>Monomorium</i> UKZN_03	0	1	0	0	0	0	0	0
<i>Monomorium</i> UKZN_04	0	1	2	4	0	10	0	0
<i>Monomorium</i> UKZN_13	1	0	4	4	1	0	0	0
<i>Myrmecaria</i> UKZN_01	59	37	36	127	0	0	1	0

<i>Nylanderia</i> UKZN_01	23	69	23	42	23	15	58	65
<i>Paltothyreus tarsatus</i>	0	0	0	0	2	1	7	2
<i>Pheidole</i> UKZN_01 (<i>megacephala</i> gp.)	189	60	25	189	87	31	13	12
<i>Pheidole</i> UKZN_03	2	13	13	32	0	0	0	4
<i>Pheidole</i> UKZN_04	0	0	0	2	0	0	0	7
<i>Plectroctena</i> <i>mandibularis</i>	0	1	0	0	1	2	0	5
<i>Polyrhachis schistacea</i>	1	0	0	1	0	0	0	0
<i>Solenopsis</i> UKZN_01	0	0	0	0	5	4	0	6
<i>Solenopsis</i> UKZN_02	0	0	0	0	1	0	7	7
<i>Solenopsis</i> UKZN_03	0	0	0	0	7	0	0	0
<i>Tapinoma</i> UKZN_01	0	0	0	0	1	0	0	1
<i>Technomyrmex</i> cf. <i>pallipes</i>	0	0	3	0	2	6	0	0
<i>Tetramorium</i> sp.07 (<i>weitzeckeri</i> gp.)	2	0	14	1	0	0	0	0
<i>Tetramorium</i> UKZN_02 (<i>notiale</i> gp.)	0	4	2	6	1	0	0	0
<i>Tetramorium</i> UKZN_03 (<i>setigerum</i> gp.)	28	26	16	15	63	45	22	54
<i>Tetramorium</i> UKZN_09 (<i>simillimum</i> gp.)	13	4	19	0	3	3	3	1
<i>Tetramorium</i> UKZN_15 (<i>sericeiventris</i> gp.)	8	2	6	19	0	3	3	5
<i>Tetramorium</i> UKZN_18 (<i>squaminode</i> gp.)	0	0	0	0	2	1	1	4
<i>Tetramorium</i> UKZN_20 (<i>squaminode</i> gp.)	0	4	1	0	0	2	11	17
<i>Tetramorium</i>	0	0	0	0	10	0	0	1

<i>UKZN_21</i> (<i>squaminode</i> gp.)								
<i>Tetramorium</i>	13	1	1	188	0	2	4	1
<i>UKZN_25</i> (<i>gabonense</i> gp.)								
<i>Tetramorium</i> UKZN_26	1	4	7	5	5	3	1	5
<i>Tetramorium</i>	0	0	0	0	2	0	0	0
<i>UKZN_35</i> (<i>simillimum</i> gp.)								

Table S17: Spiders collected from the gradient between riparian zones and uplands

Species name	Hilton				Umgenipoort			
	0	50	100	300	0	50	100	300
<i>Asceua foordi</i>	1	2	2	1	0	0	0	0
<i>Afrarchaea godfreyi</i>	1	0	0	0	0	0	0	0
<i>Afropesa</i> <i>schoutedeni</i>	1	1	0	0	0	0	0	0
<i>Agyneta natalensis</i>	0	0	0	3	4	6	1	0
<i>Agyneta</i> sp.	1	0	0	0	0	0	0	0
<i>Allocosa aurata</i>	0	8	29	4	0	1	0	0
<i>Allocosa exserta</i>	0	0	0	0	1	0	2	0
<i>Allocosa lawrencei</i>	1	3	0	1	1	0	0	1
<i>Allocosa</i> sp.	0	9	3	1	2	0	1	1
<i>Amblyothele</i> <i>latedissipata</i>	0	0	0	0	0	2	0	0
<i>Ancylotrypa</i> sp.	0	0	3	6	1	0	1	0
<i>Arctosa</i> sp. 1	0	0	0	0	2	0	2	2
<i>Brachytheliscus</i> sp.	0	0	0	0	0	3	1	6
<i>Caesetius bevisi</i>	2	2	4	2	1	0	2	0
<i>Caesetius</i> sp.	0	0	0	0	0	0	1	0
<i>Camillina maun</i>	0	0	0	0	0	1	0	0
<i>Chresiona invalida</i>	0	0	0	1	0	0	1	0

<i>Chresiona sp.</i>	0	0	0	1	0	0	4	1
<i>Clubiona sp.</i>	0	1	0	0	0	0	0	0
<i>Coleosoma</i>	0	0	0	0	0	0	1	0
<i>blandum</i>								
<i>Copa flavoplumosa</i>	1	1	0	0	0	0	0	0
<i>Copa kei</i>	0	0	1	0	0	0	0	0
<i>Crozetulus</i>	0	1	0	0	0	0	0	0
<i>rhodesiensis</i>								
<i>Ctenolophus</i>	1	0	0	0	0	0	1	0
<i>pectinipalpis</i>								
<i>Ctenolophus sp.</i>	0	0	1	0	0	0	0	0
<i>Cydrela sp.</i>	0	0	0	1	0	0	0	0
<i>Cydrela spinimana</i>	2	3	9	3	0	0	0	1
<i>Dendryphantes sp.</i>	2	0	1	0	0	0	0	1
<i>Diphyia simoni</i>	0	0	1	0	0	1	0	0
<i>Drassodella melana</i>	0	0	0	0	3	0	0	0
<i>Ero lawrencei</i>	0	0	1	0	0	0	0	0
<i>Euryopis</i>	0	0	0	0	3	0	0	0
<i>episinoides</i>								
<i>Foveosa foveolata</i>	5	3	1	3	57	68	125	75
<i>Griswoldia urbensis</i>	1	1	0	1	0	0	0	0
<i>Hahnia tabulicola</i>	0	0	0	2	0	0	1	0
<i>Haplodrassodes sp.</i>	0	0	0	3	0	0	0	0
<i>Haplodrassodes</i>	0	2	0	0	0	1	1	0
<i>splendens</i>								
<i>Heliophanus</i>	0	0	0	0	1	0	0	0
<i>patellaris</i>								
<i>Hippasa funerea</i>	0	0	0	0	0	0	1	0
<i>Hippasa sp.</i>	0	0	1	0	0	0	0	0
<i>Hogna spenceri</i>	2	0	1	1	0	1	1	2
<i>Homostola zebrina</i>	0	2	0	1	1	0	0	2
<i>Hypsosinga</i>	0	1	0	0	0	0	0	0
<i>holzapfelae</i>								

<i>Leucauge festiva</i>	0	0	1	0	0	0	0	0
<i>Lycosa pachana</i>	5	5	2	7	0	0	0	0
<i>Mermessus</i>	5	4	4	2	0	0	0	0
<i>fradeorum</i>								
<i>Micaria beaufortia</i>	0	0	0	0	2	2	0	2
<i>Orthobula sp.</i>	0	0	0	0	0	1	0	0
<i>Oxyopes bothai</i>	0	0	0	1	0	0	0	0
<i>Pachygnatha zappa</i>	0	4	1	0	0	0	1	0
<i>Pactactes obesus</i>	0	0	0	1	0	0	0	0
<i>Pardosa</i>	38	8	9	15	70	50	24	11
<i>crassipalpis</i>								
<i>Pardosa leipoldti</i>	0	0	0	0	35	12	8	10
<i>Pardosa sp.</i>	8	2	5	6	0	0	0	0
<i>Phlegma bresnieri</i>	0	0	0	3	0	1	0	1
<i>Proevippa</i>	0	1	0	3	0	1	3	0
<i>fascicularis</i>								
<i>Proevippa wanlessi</i>	2	2	2	1	0	0	0	0
<i>Rhaeboctesis exilis</i>	0	0	0	0	2	0	0	2
<i>Scytodes</i>	0	0	0	0	1	0	0	0
<i>elizabethae</i>								
<i>Scytodes maritima</i>	1	0	1	0	0	0	0	0
<i>Spinotrachelas</i>	1	0	0	0	0	0	0	0
<i>montanus</i>								
<i>Spiroctenus sp.</i>	0	2	0	0	0	0	0	0
<i>Steatoda capensis</i>	0	0	0	1	0	0	0	0
<i>Thelechoris</i>	2	0	0	0	0	0	0	0
<i>striatipes</i>								
<i>Theridion purcelli</i>	0	3	2	2	0	0	0	0
<i>Trabea purcelli</i>	0	0	0	0	0	1	3	1
<i>Trachelas sp.</i>	0	0	1	0	0	0	0	0
<i>Tyrotama sp.</i>	1	0	0	0	0	0	0	0
<i>Zelotes fuliginus</i>	0	0	2	0	0	0	0	0
<i>Zelotes humilis</i>	0	0	0	0	1	0	0	0

<i>Zelotes natalensis</i>	0	1	0	0	0	0	1	0
<i>Zelotes sp. 1</i>	1	0	0	0	2	2	3	0

Table S18: Spiders collected along the riparian zones of uMgeni River

	Hilton							Umgenipoort						
Species name	0 m	50 m	100 m	300 m	700 m	1000 m	2200 m	0 m	50 m	100 m	300 m	700 m	1000 m	2200 m
<i>Asceua foordi</i>	0	0	5	1	0	0	0	0	0	0	0	0	0	0
<i>Afrarchaea godfreyi</i>	0	0	0	1	0	1	0	0	0	0	0	0	0	0
<i>Afropesa schoutedeni</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agyneta natalensis</i>	0	0	1	0	0	0	1	3	0	2	1	0	0	0
<i>Agyneta sp.</i>	0	1	0	0	0	0	0	0	0	0	0	0	1	0
<i>Allocosa lawrencei</i>	1	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Allocosa sp.</i>	0	0	0	0	0	0	0	0	2	0	0	4	1	2
<i>Ancylotrypa sp.</i>	3	2	0	0	0	0	0	0	1	0	0	0	0	0
<i>Arctosa sp. 1</i>	0	0	0	0	0	0	0	1	1	0	0	0	0	1
<i>Baryphas ahenus</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0
<i>Brachytheliscus sp.</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0

<i>Caesetius bevisi</i>	0	0	1	1	1	0	0	0	1	0	1	0	0	0
<i>Chresiona invalida</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Copa flavoplumosa</i>	0	0	2	0	1	0	1	0	0	0	0	0	0	0
<i>Ctenolophus pectinipalpis</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cydrela spiniimana</i>	0	2	1	0	0	0	0	0	0	0	1	0	0	0
<i>Dendryphantes sp.</i>	0	0	0	1	1	0	2	0	0	0	0	0	0	0
<i>Diphyia simoni</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Drassodella melana</i>	0	0	0	0	0	0	0	0	2	1	0	0	0	0
<i>Euryopsis episinooides</i>	0	0	0	0	0	0	0	1	2	0	0	0	0	0
<i>Foveosa foveolata</i>	4	0	0	0	1	0	0	6	7	6	7	24	66	16
<i>Griswoldia urbensis</i>	0	0	2	1	0	0	3	0	0	0	0	0	0	0
<i>Heliophanus patellaris</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	1
<i>Hewittia gracilis</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0

<i>Hippasosa sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>Hogna sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0
<i>Hogna spenceri</i>	0	0	0	2	0	0	0	0	0	0	0	0	0	0
<i>Homostola zebrina</i>	0	0	0	0	0	0	0	0	1	4	0	0	0	1
<i>Hyllus brevitarsis</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Leucauge festiva</i>	0	0	0	0	0	3	0	0	0	0	0	0	0	0
<i>Leucauge thomeensis</i>	0	0	0	0	0	0	0	0	0	2	0	0	0	0
<i>Lycosa pachana</i>	4	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Mermessus fradeorum</i>	4	1	0	0	0	0	0	0	0	1	0	0	0	1
<i>Micaria beaufortia</i>	0	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>Pactactes obesus</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Pardosa crassipalpis</i>	3	3	4	29	3	0	0	12	23	28	3	15	14	4
<i>Pardosa leipoldti</i>	0	0	0	0	0	0	0	16	16	10	5	4	3	2
<i>Pardosa sp.</i>	0	4	1	2	2	2	0	0	0	0	0	0	0	0
<i>Phlegra sp.</i>	0	0	2	0	0	0	0	0	0	0	0	0	0	0

<i>Proevippa fascicularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Proevippa wanlessi</i>	1	0	0	0	1	2	0	0	0	0	0	0	0	0
<i>Rhaeboctesis exilis</i>	0	0	0	0	0	0	0	0	1	0	0	0	1	0
<i>Rhaeboctesis secundus</i>	0	0	3	0	0	0	0	0	0	0	0	0	0	0
<i>Rhomphaea nasica</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Runcinia aethiops</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Scytodes elizabethae</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Scytodes maritima</i>	0	1	0	0	0	0	1	0	0	0	0	0	0	0
<i>Spinotrachelas montanus</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Thanatus vulgaris</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Thelechoris striatipes</i>	0	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tyrotama sp.</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Uloborus plumipes</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0

<i>Veisella durbani</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Xysticus sp.</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Zelotes sp. 1</i>	0	0	0	1	0	0	0	1	0	0	1	0	0	0

Table S19: Ants collected along the riparian zones of uMgeni River.

Species name	Hilton							Umgenipoort						
	0m	50m	100m	300m	700m	1000m	2200m	0m	50m	100m	300m	700mm	1000m	2200m
<i>Anoplolepis custodiens</i>	0	1	1	1	4	131	0	715	5	0	0	0	0	2
<i>Camponotus UKZN_02 (cintellus gp.)</i>	1	1	18	2	2	9	0	32	1	3	1	1	2	4
<i>Camponotus UKZN_01 (maculatus gp.)</i>	0	0	0	0	0	0	1	4	1	0	0	0	0	3
<i>Cerapachys UKZN_01</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Crematogaster UKZN_01</i>	0	0	0	0	0	0	0	2	1	0	0	0	0	0

<i>Crematogaster</i> <i>UKZN_02</i>	1	4	1	0	1	2	0	6	5	3	0	0	1	66
<i>Crematogaster</i> <i>UKZN_03</i>	0	0	3	0	1	0	0	1	0	0	0	0	5	0
<i>Dorylus</i> <i>UKZN_01</i>	1	0	2	14	12	1	27	3	0	0	0	0	82	5
<i>Hypoponera</i> <i>UKZN_01</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Lepisiota</i> <i>UKZN_01</i> (<i>capensis</i> gp)	12	13	30	74	1	1	2	8	47	0	0	0	0	11
<i>Lepisiota</i> <i>UKZN_04</i>	0	0	0	0	0	0	0	4	0	0	0	0	0	0
<i>Lepisiota</i> <i>UKZN_07</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Leptogenys</i> <i>schwabi</i>	0	5	0	5	0	75	34	0	0	0	0	0	0	0
<i>Meranoplus</i> <i>UKZN_01</i>	0	0	0	0	0	0	0	145	3	15	0	5	0	0
<i>Mesoponera</i> <i>UKZN_01</i>	0	0	0	0	0	0	1	0	2	0	4	0	0	0

<i>Monomorium damarense</i>	0	6	1	0	0	0	0	1	0	1	0	0	0	6
<i>Monomorium junodi</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Monomorium UKZN_01</i>	0	0	1	0	0	0	0	0	5	0	0	0	0	2
<i>Monomorium UKZN_02</i> (<i>monomorium</i> gp.)	0	0	0	0	0	0	0	5	0	0	0	0	0	0
<i>Monomorium UKZN_04</i>	0	0	7	0	0	0	0	0	0	0	0	0	0	0
<i>Monomorium UKZN_13</i>	0	1	1	0	0	0	1	1	0	0	0	0	0	0
<i>Myrmecaria UKZN_01</i>	58	1	4	0	0	0	0	0	0	0	0	0	0	0
<i>Nylanderia UKZN_01</i>	4	19	4	0	0	0	0	2	5	4	0	1	3	17
<i>Paltothyreus tarsatus</i>	0	0	0	0	0	0	0	0	2	0	0	0	0	0
<i>Pheidole</i>	2	0	6	0	0	0	3	0	0	0	0	1	0	0

<i>UKZN_03</i>														
<i>Pheidole</i>	63	0	11	119	7	88	44	38	45	0	0	2	0	0
<i>UKZN_01</i>														
<i>(megacephala</i>														
<i>gp.)</i>														
<i>Plectroctena</i>	0	0	0	0	0	0	1	1	0	0	0	0	0	0
<i>mandibularis</i>														
<i>Polyrhachis</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>schistacea</i>														
<i>Solenopsis</i>	0	0	0	0	0	0	0	5	0	0	0	0	0	0
<i>UKZN_01</i>														
<i>Solenopsis</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>UKZN_02</i>														
<i>Solenopsis</i>	0	0	0	0	0	0	0	7	0	0	0	0	0	0
<i>UKZN_03</i>														
<i>Tapinoma</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>UKZN_01</i>														
<i>Tetramorium</i>	0	0	0	0	0	3	0	0	0	0	0	0	0	0
<i>sp.07</i>														
<i>(weitzeckeri gp)</i>														
<i>Tetramorium</i>	0	0	2	0	0	0	0	1	0	0	0	0	0	0

<i>UKZN_02</i> (<i>notiale</i> gp.) <i>Tetramorium</i>	15	10	10	0	3	4	3	19	26	5	3	1	2	8
<i>UKZN_03</i> (<i>setigerum</i> gp.) <i>Tetramorium</i>	4	3	2	0	6	6	2	2	1	0	0	0	0	0
<i>UKZN_09</i> (<i>simillimum</i> gp.) <i>Tetramorium</i>	6	1	1	0	1	0	0	0	0	0	0	0	0	0
<i>UKZN_15</i> (<i>sericeventre</i> gp.) <i>Tetramorium</i>	0	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>UKZN_18</i> (<i>squaminode</i> gp.) <i>Tetramorium</i>	0	0	1	0	0	2	0	0	0	0	0	0	2	0
<i>UKZN_20</i> (<i>squaminode</i> gp.) <i>Tetramorium</i>	0	0	0	0	0	0	0	0	10	0	0	0	0	0
<i>UKZN_21</i> (<i>squaminode</i> gp.) <i>Tetramorium</i>	0	0	0	0	13	0	0	0	0	0	0	0	0	0

<i>UKZN_25</i> <i>(gabonense gp.)</i>														
<i>Tetramorium</i>	0	1	0	0	0	0	0	3	2	0	0	1	0	0
<i>UKZN_26</i>														
<i>Tetramorium</i>	0	0	0	0	0	0	0	0	2	0	0	0	0	0
<i>UKZN_35</i> <i>(simillimum gp.)</i>														