INSTITUTO DE BIOCIÊNCIAS

PROGRAMA DE PÓS-GRADUAÇÃO EM BIOLOGIA ANIMAL

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ESTRUTURA TAXONÔMICA, FUNCIONAL E FILOGENÉTICA DE METACOMUNIDADES DE ANUROS DO EXTREMO SUL DO BRASIL

Porto Alegre, Rio Grande do Sul, Brasil.

2019

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Tese apresentada ao Programa de Pós-Graduação
em Biologia Animal, Instituto de Biociências da Universidade
Federal do Rio Grande do Sul, como requisito parcial à obtenção
do título de Doutor em Biologia Animal.

Área de concentração: Biodiversidade

Orientadora: Profa. Dra. Maria João Ramos Pereira

Co-orientador: Prof. Dr. Alexandro Marques Tozetti

Porto Alegre

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ESTRUTURA TAXONÔMICA, FUNCIONAL E FILOGENÉTICA DE METACOMUNIDADES DE ANUROS DO EXTREMO SUL DO BRASIL

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Sumário

ESTRUTURA TAXONÔMICA, FUNCIONAL E FILOGENÉTICA DE METACOMUNIDADES DE ANUROS DO EXTREMO SUL DO BRASIL

AGRADECIMENTOS

Começarei esta seção da tese de uma forma que pode parecer clichê, mas que na verdade representa o mix de sensações, pensamentos e memórias que pairam sobre mim quando começo a pensar nas transformações que a minha vida sofreu nestes últimos anos, grande parte delas influenciadas pelo doutorado.

Meu primeiro e maior agradecimento vai para a Profa. Maria João Ramos Pereira, que para mim representou muito mais do que a figura de orientadora, e sim de um exemplo de pessoa a ser seguida. Maria, tu foste minha amiga, minha guia e maior conselheira durante estes últimos anos (seja na parte profissional ou pessoal). Posso afirmar sem dúvida alguma que você é e sempre será uma das minhas maiores fontes de inspiração. Eu jamais vou esquecer da paciência que tiveste comigo no meu processo de amadurecimento, da empatia para comigo nas minhas fases mais sombrias, do reconhecimento que sempre deixou transparecer pelo meu trabalho, e pela confiança depositada em mim desde o início. Nossa relação aluno-orientador ultrapassou qualquer barreira, inclusive da história evolutiva, pois esta tese demonstra que sapos e morcegos podem sim ter sucesso quando o objetivo de ambos é produzir ciência e evoluir no conhecimento. Obrigado por tudo, minha eterna amiga!

Agradeço também ao meu co-orientador, amigo e parceiro de grupo, Prof. Alexandro Tozetti. Creio que o principal a ser destacado é que nós aqui provamos que distância geográfica não é uma barreira para o conhecimento e para formar parcerias de sucesso. Tozetti, muito obrigado por ter aceito este desafio e por ser o meu guia nesta jornada, por ter contribuído no meu conhecimento, especialmente da ecologia de anuros, por fazer produtivo e descontraído todo e qualquer momento em que estivemos reunidos.

Aos membros da minha banca de acompanhamento, Dr. Márcio Borges Martins e Dr. Vinicius Bastazini, o meu muito obrigado pelo tempo dedicado a mim e por sempre contribuírem para a melhoria deste trabalho. Todas considerações dadas por vocês em cada um de nossos encontros fizeram com que a qualidade desta tese fosse cada vez maior. Obrigado também pelos conselhos profissionais, sempre presentes e muito válidos.

Agradeço a toda a "galerinha" do BIMALab por estes anos de excelente convívio. Estar num ambiente de trabalho que permita a cada um crescer profissionalmente e ainda ter colegas que sempre estão disponíveis para auxiliar pode sim ser considerado uma utopia. Então, no BIMALab eu vivi isto. Colegas, obrigado por todos os momentos quer vivi ao lado de vocês. Colegas, obrigado pelas horas de café (sempre muito produtivas), por sempre serem meus conselheiros, "meu ombro amigo", por terem dividido a vida de vocês comigo, por terem sido a minha família. Eu jamais teria vencido esta etapa jamais sema ajuda de vocês. Vou aqui deixar o meu agradecimento especial às colegas e amigas que estão comigo desde a minha chegada ao BIMALab, lá em 2015 e que me receberam de braços abertos: Adri (Adriana Arias), Aninha (Ana Mastela, a "mana"), Cintia Costa, Dani (Danielle Franco, a "passarinha"), Lana Resende, Mari (Mariana Mazzochi) e Tatá (Thais Chaves).

Aos meus parceiros de campo: Luiza Machado, Mateus Zimmer, Amrita Menon, Camila Melo e Pedro Fisher, obrigado pela ajuda essencial na fase de coleta de dados em campo e por terem dedicado seu tempo ao meu trabalho.

Não posso deixar de agradecer aos gestores e funcionários do Parque Nacional da Lagoa do Peixe (PNLP) e do ICMBio, que muito cordialmente nos receberam e permitiram que eu realizasse a fase amostral desta tese.

Aos colegas de curso, professores e funcionários do Instituto de Biociências e dos Programas de Pós-Graduação em Biologia Animal e Ecologia da UFRGS, obrigado por todo o apoio e suporte técnico-científico. Agradeço em especial a dois colegas, Dra. Talita Roell e Dr. William Dröse que desde 2013 trilharam este caminho comigo e acompanharam de perto a minha jornada.

A todos os meus amigos, obrigado pelo suporte e por terem compreendido a minha ausência em muitos momentos. Em especial agradeço aos grandes amigos que fiz aqui em Porto Alegre: Eduardo Marchioro, Cassia Maciel, Renata Webster Duarte e Laura Ferrugem.

Meu maior agradecimento vai para os amigos de longa data. Marilene Ulmi, Carlos Eduardo Ulmi, Keila Ody e ao meu pequenino João Carlos Ulmi, que são minha família do peito há quase 20 anos. Às minhas colegas biólogas e melhores amigas, Fabiele Brandt e Giseli Buffon, obrigado por sempre terem me incentivado e pelos momentos únicos que me proporcionaram desde a época de graduação na UNIVATES.

Ao José Cristiano Mengue Model, meu companheiro e maior incentivador. Obrigado por ter compartilhado tua vida comigo nos últimos anos, por sempre me apoiar, por me ajudar a ser uma pessoa melhor e por muitas vezes ter sido o motivo para eu não desistir. Se eu cheguei até aqui certamente foi por ter contado com o teu apoio.

Um agradecimento especial à minha família, pelo suporte afetivo e pelas lições de vida. Ao meu pai, Flávio Antônio Dalmolin, obrigado por tudo, em especial por ter compartilhado comigo o amor pelos animais. Ao meu tio Márcio José Dalmolin, por ser o meu exemplo e maior incentivador nos estudos.

Aos meus filhos de quatro patas, Marvin, Kevin, Candy e Cindy. Gatos não leem, mas sentem, e eles sempre estiveram comigo, me apoiando, me fazendo descontrair, vivendo comigo. Meus espíritos de luz, obrigado por existirem.

Meu último e mais especial agradecimento vai para a minha mãe, Marizete Baldo Dalmolin. Mãe, o agradecimento e o amor que sinto por ti são imensuráveis, e expressá-los em folhas de papel é algo bem difícil. Obrigado por ter me apoiado desde o inicio da minha jornada lá em 1994, quando me acompanhou para o meu primeiro dia na escola. Desde então você tem feito de tudo para que eu alcançasse os meus sonhos e objetivos, e hoje consagro mais este sonho também graças a ti. Obrigado também por ter me ensinado a ser sensível para com os outros e por todo e qualquer conselho que tenha me dado nestes mais de 30 anos de convivência. Dedico a ti esta conquista!

"Sábio é o ser humano que tem coragem de ir diante

do espelho da sua alma para reconhecer seus erros

e fracassos e utilizá-los para plantar as mais

belas sementes no terreno de sua inteligência".

Augusto Cury

Introdução Geral

Evoluindo conceitos: de comunidades a metacomunidades

Em 2004, Leibold e colaboradores definiram metacomunidades como sendo conjuntos de comunidades locais que estão conectadas entre si pela dispersão das espécies que ocorrem em uma determinada região e que podem potencialmente interagir entre si. Esta teoria foi considerada um grande avanço já que, ao contrário da teoria de comunidades, não considera apenas os processos locais – interações bióticas e espécie-ambiente – como determinantes da composição comunitária, mas também os processos que ocorrem em escalas mais amplas (Dray et al., 2012; Funk, Shiemer & Reckendorfer, 2013; Eros et al., 2014; Brown et al., 2016). Com efeito, aos olhos desta teoria as comunidades não são mais vistas como entidades isoladas, e sim como componentes de uma entidade ainda maior que pode sofrer a influência de mecanismos que operam em múltiplas escalas (Leibold et atl., 2004; Dray et al., 2012; Peres-Neto et al., 2012).

A teoria de metacomunidades fornece uma sólida estrutura teórica que integra diferentes processos ecológicos como determinantes dos padrões de diversidade observados na natureza (Hill et al., 2017). Contudo, o conhecimento produzido a partir desta teoria ainda ocasiona debates entre ecologistas (por exemplo, Tonkin et al., 2016). Dentre os temas de maior discussão está o grau relativo em que os processos determinísticos e os estocásticos influenciam as comunidades (Cottenie, 2005; Hoverman et al., 2011; Yang et al., 2015). Por processos determinísticos entendemos todas as forças que geram respostas não-aleatórias das espécies aos seus meios biótico e abiótico e que acabam promovendo diferenciações ecológico-evolutivas entre as espécies (Leibold et al., 2004; Yang et al., 2015). Já os processos estocásticos consideram os eventos aleatórios e de dispersão (emigração e imigração) como estruturadores das comunidades (Hubbel et al., 2001).

Os quatro paradigmas da Teoria das Metacomunidades

A teoria de metacominidades está organizada de acordo com quatro principais modelos – mais conhecidos como os Quatro Paradigmas da Teoria de Metacomunidades. Estes paradigmas compartilham a premissa básica das metacomunidades – processos estruturantes abrangendo múltiplas escalas – mas divergem na importância relativa que atribuem à diferenciação (ou não) dos atributos e história evolutiva das espécies, bem como da importância dos processos locais, regionais e dos distúrbios naturais na organização das metacomunidaes (Leibold et al., 2004Chase 2005; Brown et al., 2016).

Teoria Neutra

A teoria neutra (*Neutral theory*; Figura 1) postula que as espécies são ecologicamente semelhantes de tal forma que não haveria diferenças entre as espécies em suas capacidades de dispersão (Hubbell, 2001; Cottenie, 2005). Além disto, não haveria nenhuma relação entre as características das espécies (morfo-fisiológicas, evolutivas e comportamentais) e as características dos ambientes (Hubbell, 2001). Assim, as diferenças na composição das comunidades seriam promovidas por eventos de dispersão, colonização e processos demográficos estocásticos (Brown et al., 2016). Contudo, revisões recentes envolvendo esta teoria contestaram a suposição de equivalência ecológica entre espécies, visto que as habilidades de dispersão variam amplamente entre espécies, frequentemente até entre espécies filogeneticamente próximas (por exemplo, De Bie et al., 2012; Brown et al., 2016). De qualquer forma, a teoria neutra é plausível em metacomunidades onde se observa a dominância de efeitos espaciais, ou seja, quando se observa um decaimento da similaridade em relação à distância geográfica (Thompson & Townsend, 2006).

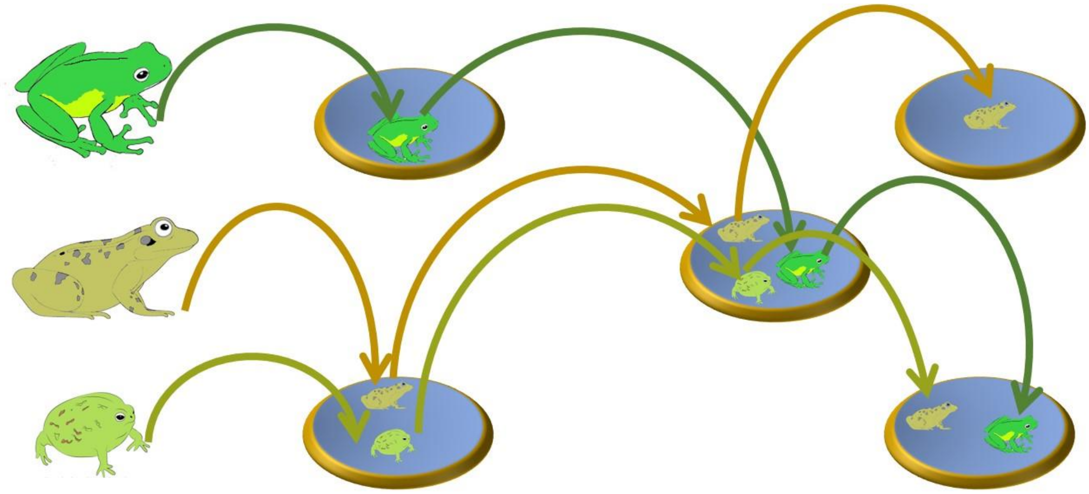

Figura 1 – Representação do modelo de organização metacomunitária previsto pela Teoria Neutra. Adaptado de ....

Dinâmica de Fragmentos

O modelo de dinâmica de fragmentos (*Patch Dynamics*; Figura 2) dita que os fragmentos (ou manchas) são ambientalmente redundantes, ou seja, que não haveria quaisquer propulsores ambientais agindo sobre a organização dos fragmentos (Leibold et al., 2004; Gothe et al., 2013). Com isto, a dinâmica das comunidades seria o resultado do trade-off entre as habilidades de competição e colonização mediadas pelas capacidades de dispersão das espécies (Heino et al., 2015). Consequentemente, os melhores dispersores seriam os primeiros a colonizar e se estabelecer nos fragmentos e ali permaneceriam até à chegada de um competidor superior (Leibold et al., 2004; Datry et al., 2016).

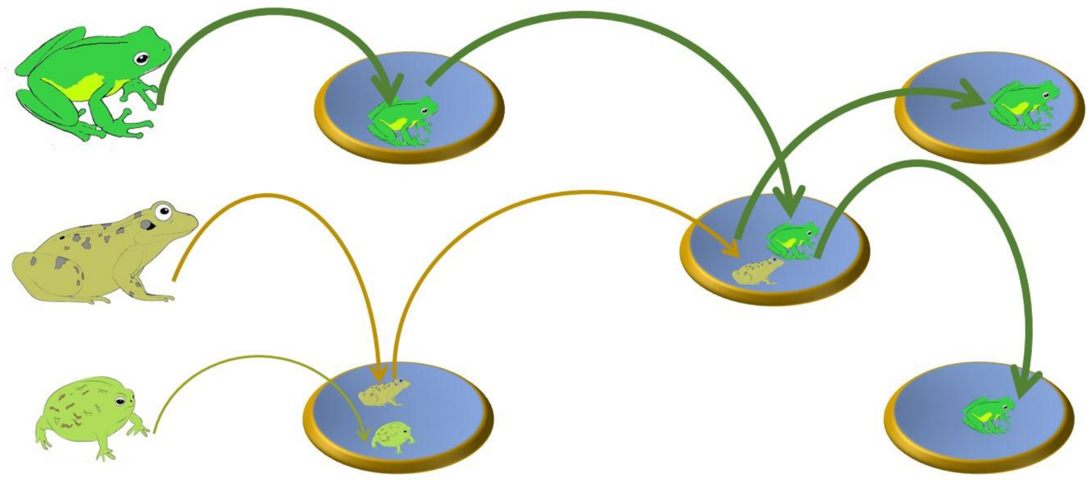

Figura 2 – Representação do modelo de organização metacomunitária previsto pela Dinâmica de Fragmentos.

Ordenação de Espécies

O modelo de ordenação de espécies (*Species Sorting*; Figura 3) tem em seu cerne as diferenças ecológico-evolutivas entre as espécies que fazem com que estas sejam ordenadas ao longo dos gradientes ambientais (ou seja, supondo diferenças ambientais entre os diferentes locais; Leibold et al., 2004). Mais precisamente, esta teoria defende a existência de uma forte correlação entre a composição das comunidades e os descritores ambientais (Ernest & Rodel, 2008). Esta ordenação (ou classificação) estaria diretamente relacionada com os níveis de tolerância das espécies às condições locais, mediada por determinados atributos funcionais (por exemplo, tolerância fisiológica; Dallas & Drake, 2014), tolerância essa que ditaria quais as espécies capazes de se estabelecer e persistir em determinado local ao longo do gradiente ambiental (Kraft, Godoy & Levine, 2015). Além disso, o modelo postula a necessidade de uma capacidade de dispersão no mínimo moderada para garantir que todas as espécies tenham possibilidade de alcançar todos os conjuntos de comunidades de uma determinada área, sendo posteriormente selecionadas de acordo com as suas capacidades de tolerância e persistência nesses ambientes (Gothe et al., 2013).

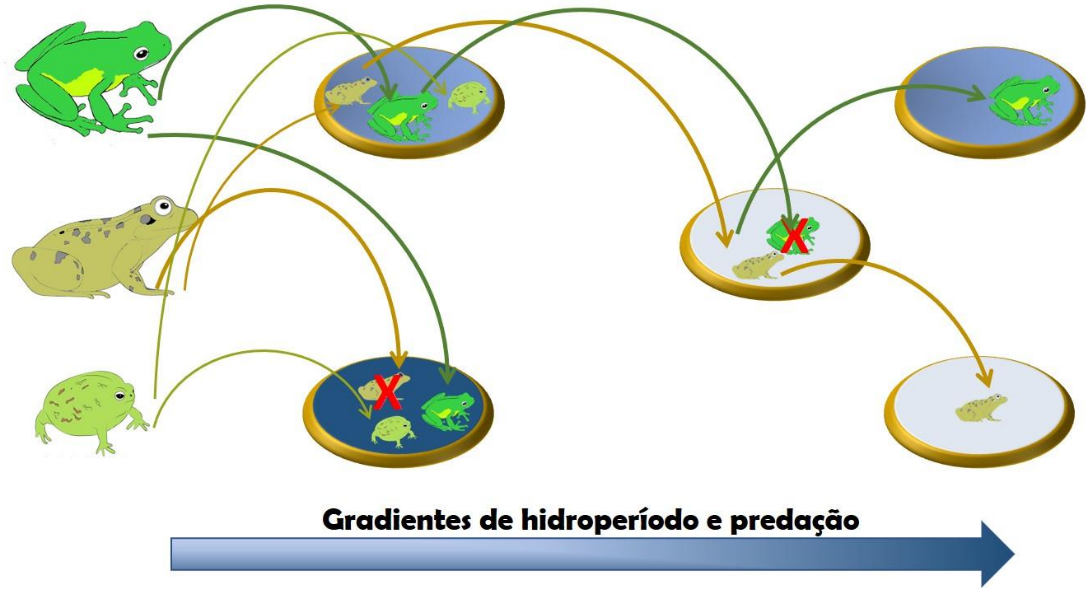

Figura 3 – Representação do modelo de organização metacomunitária previsto pela Classificação de espécies.

Efeitos de Massa

O modelo de efeitos de massa (*Mass Effects*; Figura 4), assim como o modelo de ordenação de espécies, reconhece a existência de diferenças ambientais entre os locais. Contudo, altas taxas de dispersão das espécies seriam os principais condutores das variações de composição entre comunidades podendo até mesmo obscurecer os efeitos dos filtros ambientais (Heino et al., 2015; Datry et al., 2016). Assim, os indivíduos migrariam de locais onde estão mal adaptados (promovendo extinções locais) para outros locais, sendo esta dinâmica conhecida como fonte-dreno (Cottenie, 2005; Gothe et al., 2013).

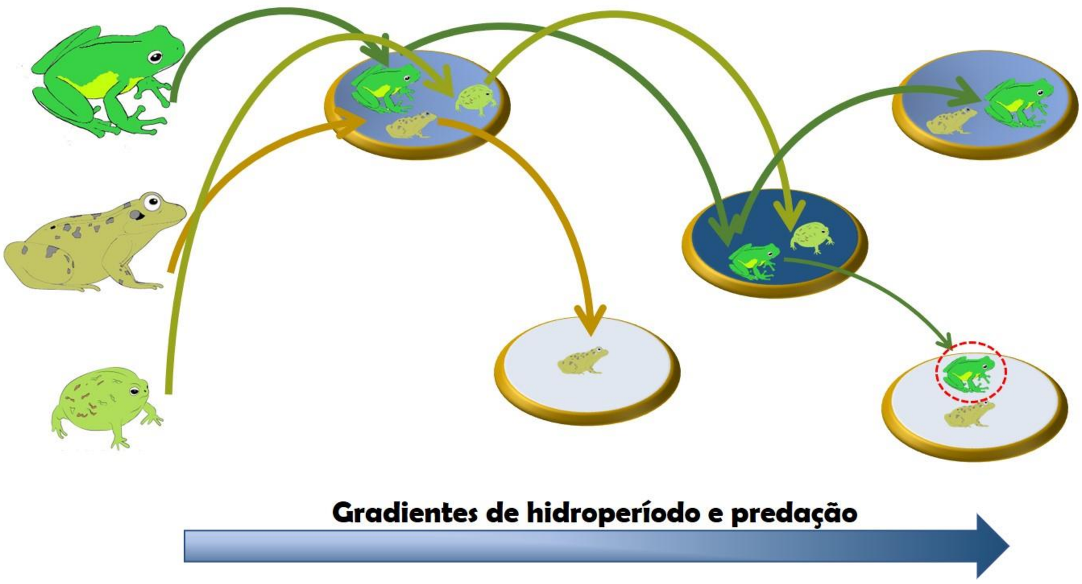

Figura 4 – Representação do modelo de organização metacomunitária previsto pelo modelo Efeitos de Massa.

Quatro paradigmas excludentes ou complementares?

Por muitos anos os ecólogos tentaram determinar de acordo com qual dos quatro grandes paradigmas estariam estruturadas metacomunidades de diversos grupos de organismos. Como relatado nas seções anteriores, os quatro paradigmas divergem nas ênfases dadas aos diferentes preditores ecológicos (Figura 5).

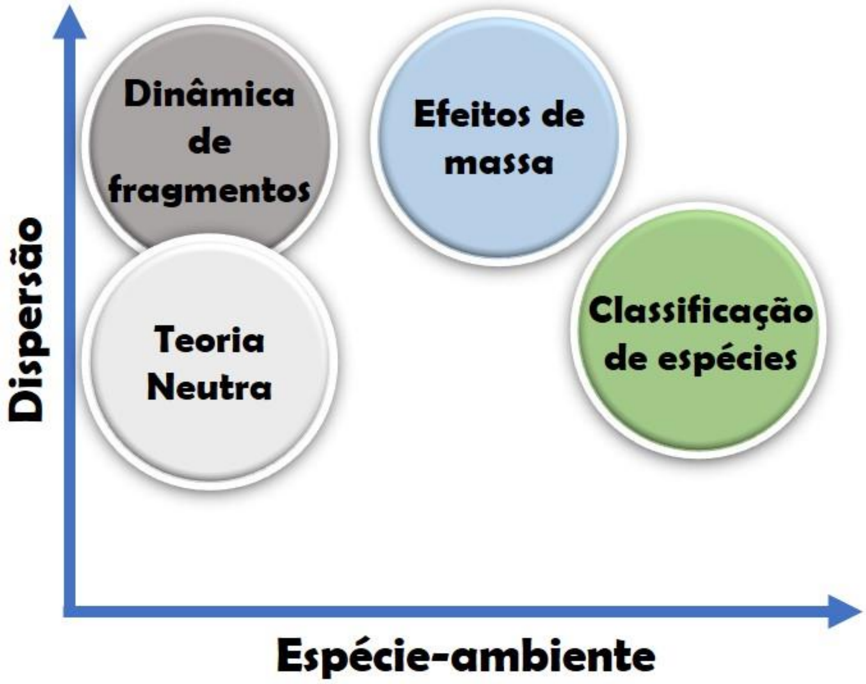

Figura 5 – Relação entre os quatro principais paradigmas da Teoria de Metacomunidades e de suas premissas quanto às diferenças promovidas pela dispersão e pela relação espécie-ambiente.

Trabalhos mais recentes, no entanto, sugerem que a estruturação das metacomunidades resulta não de um, mas sim de um conjunto de processos ecológicos e, consequentemente, reflete mais de um modelo metacomunitário atuando de forma sinergética (Brown et al., 2016; Datry et al., 2016). Além disto, a importância relativa de cada um dos modelos seria dependente dos tipos de organismos, ecossistemas e escalas espaciais e temporais em observação (Cavender-Bares et al., 2009; Chase & Myers, 2011; Wang, 2013; Hoverman et al., 2011; Araújo-Martins et al., 2015; Heino et al., 2015). Mais importante, os quatro paradigmas não são mutuamente exclusivos, já que levam em consideração os mesmos mecanismos ecológicos – embora que com pesos diferenciados – e também porque seus arcabouços teóricos representam apenas uma porção do espaço de inferência que pode ser construído para explicar a estrutura de metacomunidades (Logue et al., 2011; Brown et al., 2016). Esta última constatação parece muito plausível, já que muitos estudos podem não conseguir incorporar a totalidade de informações necessárias para construir modelos preditivos robustos capazes de detectar com sucesso os padrões de organização metacomunitária.

Dentre os fatores que podem levar a erros na detecção e interpretação de padrões metacomunitários estão:

i) Falhas no processo de amostragem;

ii) Grupos de espécies difíceis de serem identificados ou ainda pouco conhecidos (ausência de informações de aspectos básicos de biologia e história de vida);

iii) Dificuldades na mensuração de variáveis relevantes ou até mesmo a sua desconsideração;

iv) Utilização de dados obtidos em estudos publicados de pouca credibilidade ou que não reproduzam fielmente o tipo de ambiente-foco do estudo;

v) Inferências feitas a partir de dados estáticos, ou seja, baseados em uma única amostragem no tempo;

vi) Autocorrelação espacial ou ausência de independência amostral

Uma das falhas de interpretação que pode ser facilmente cometida é, por exemplo, uma superestimação da importância das variáveis espaciais em decorrência de variáveis ambientais não avaliadas (Dray et al., 2012). Como consequência, os processos neutros podem ser erroneamente identificados como os que melhor explicam determinados padrões metacomunitários quando, na verdade, um ou um conjunto dos demais paradigmas seriam melhores para explicar a estrutura metacomunitária encontrada (Brown et al., 2016). Outra “armadilha” possível de ocorrer em estudos metacomunitários está associada à dispersão dos organismos (De Bie et al., 2012). Por exemplo, o poder preditivo do modelo de classificação de espécies pode ser suprimido se o desenho amostral não considerar as distâncias mínimas e máximas de dispersão (deslocamento) dos organismos-alvo.

Componentes da Diversidade em Metacomunidades

Níveis da diversidade

A diversidade de espécies observada em metacomunidades compreende três níveis ou componentes. O primeiro é a diversidade alfa, que compreende a riqueza ou diversidade de espécies presentes em uma determinada comunidade. Já a diversidade total presente na região determina a diversidade gamma. Por fim, o terceiro componente é a diversidade beta, que pode ser definida como a diferença de composição entre sítios presentes dentro de uma mesma região (Tuomisto, 2010; Baselga et al., 2010; Soininen, Heino & Wang, 2018). A figura 6 demonstra graficamente estes diferentes componentes de diversidade.

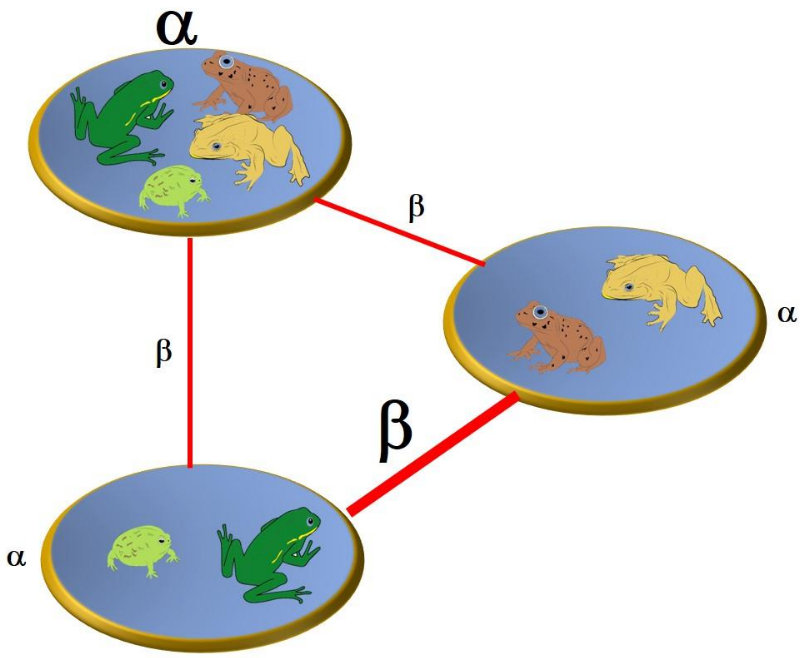

Figura 6 – Exemplo das diferenças nos padrões de diversidade alfa e beta que podem ser observados em metacomunidades.

É de referir que, quanto maior a diversidade local e entre locais, maior será o tamanho de α e β. A partir do exemplo apresentado na Figura 6 podemos concluir que o local que contém a maior riqueza de espécies também possui a maior diversidade α. Porém, os maiores valores de diversidade β são observados para as outras duas comunidades que, apesar de conterem um número menor de espécies, acabam não compartilhando nenhuma espécie entre si, ou seja, apresentam alta dissimilaridade.

A quantificação da diversidade beta é considerada proeminente quando se busca identificar os processos que operam as metacomunidades em escalas espaciais mais amplas (Gutiérrez-Cánovas et al., 2013). Em um estudo publicado em 2010 Baselga e colavoradores ressaltaram a importância da beta diversidade para a ecologia e ainda propuseram o particionamento da diversidade beta em dois componentes distintos: a substituição de espécies (*turnover*) e o aninhamento (*nestedness*). A substituição de espécies resulta em alterações na composição de uma comunidade para outra ao longo da metacomunidade, de modo que mesmo os locais que apresentam riquezas similares irão conter conjuntos de espécies com identidades completamente diferentes (Figura 7a). O aninhamento ocorre quando algumas comunidades representam conjuntos pobres de espécies oriundos de comunidades mais ricas (Figura 7b; Ulrich, Almeida-Neto & Gotelli, 2009; Baselga et al., 2010). Mais precisamente, o aninhamento indica a perda ou ganho de espécies, ou seja, as diferenças de riqueza entre comunidades (Baselga et al., 2010).

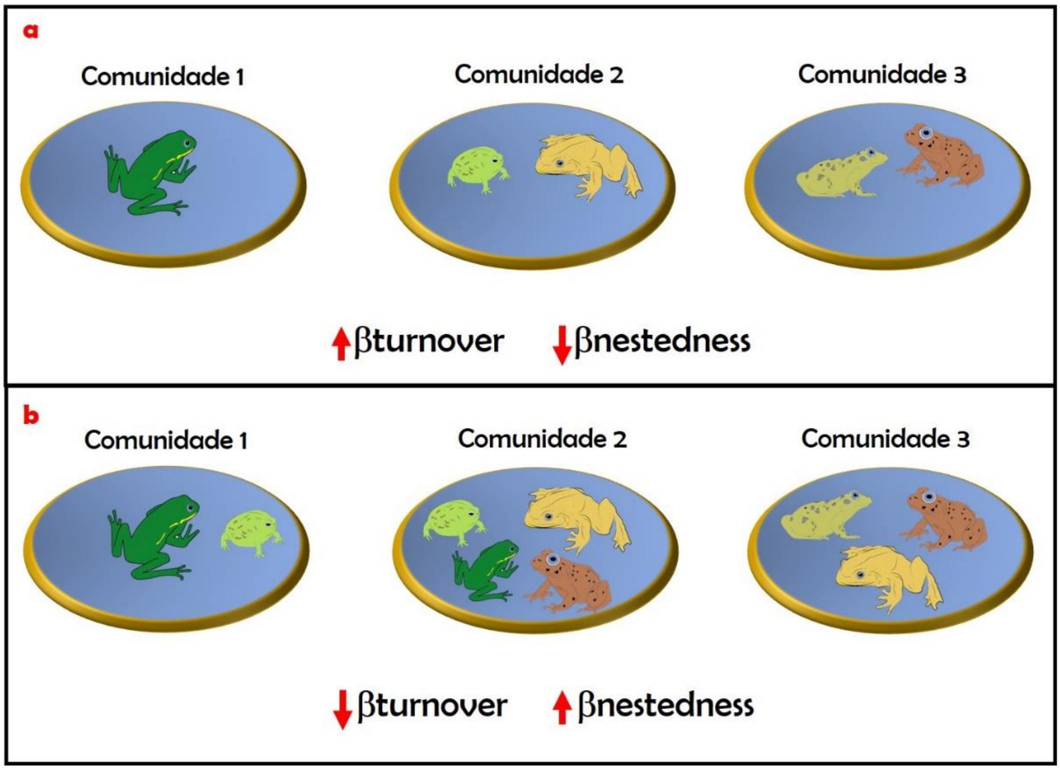

Figura 7 – Exemplo das diferenças nas contribuições da substituição de espécies e do aninhamento para os padrões de diversidade beta que podem ser observados em metacomunidades.

Os dois componentes da diversidade beta podem ainda divergir em relação à sua resposta aos processos ecológicos. Enquanto o aninhamento está mais relacionado com a dinâmica de extinção ordenada, ou seja, a desagregação biótica das comunidades, a substituição de espécies está mais associada à ordenação de espécies (filtragem ambiental) e aos processos de dispersão (Baselga et al., 2010; Hill et al., 2017; Soininen, Heino & Wang, 2018). Apesar destas distinções, é importante compreender que os dois componentes da diversidade beta são complementares, de modo que raramente as comunidades vão estar organizadas por apenas um dos dois componentes (Hill et al., 2017).

Facetas da diversidade em metacomunidades

Os estudos metacomunitários realizados nas últimas décadas vêm demonstrando que os processos ecológicos que estruturam as comunidades não se refletem unicamente na riqueza de espécies ou seja, na diversidade taxonômica, mas também nas diferenças ecológico-evolutivas acumuladas nas comunidades (Swenson, 2011; Meynard et al., 2011; Wang et al., 2015; Tonkin et al., 2016). Estas diferenças entre locais são quantificadas na forma de atributos funcionais – diversidade funcional (McGill et al., 2006; Villéger, Mason & Mouillot, 2008; Mouchet et al., 2010) ou de relações filogenéticas entre os pares de espécies – diversidade filogenética (Webb et al., 2002; Cavender-Bares et al., 2009) que ocorrem em cada comunidade. Um dos grandes propulsores da utilização destas informações foi o aumento considerável do número de hipóteses filogenéticas e bancos de dados de atributos funcionais disponíveis para muitos taxa. A incorporação das informações funcionais e filogenéticas em estudos metacomunitários mostrou-se muito promissora já que, em muitos casos, estas facetas concentram a boa parte do potencial explicativo gerado pelos modelos em muitos grupos de organismos (por exemplo, Spasojevick et al., 2016).

Atributos funcionais são quaisquer características (morfológicas, fisiológicas, comportamentais ou outras) que são expressas na forma de fenótipo e que geralmente estão associadas à ocorrência das espécies em determinados locais, ou seja, que refletem processos adaptativos (Gerhold et al., 2015; Spasojevick et al., 2016). Uma questão fundamental para estudos que almejam incluir a diversidade funcional é a escolha do conjunto de atributos (Pillar et al., 2013). Primeiramente, nem todo o fenótipo pode ser considerado um atributo a ser inserido nas análises, já que uma das premissas deste tipo de abordagem é que as características necessitam ter alguma relevância em relação aos processos ecológicos, o que frequentemente é difícil ou mesmo impossível de identificar. Além disso, é importante ter a ciência de que os atributos podem estar associados a diferentes funções e, assim, pertencer a duas classes distintas: de efeito e de resposta (Figura 8). Os atributos de efeito são aqueles que determinam como e em que extensão os organismos influenciam os processos ecossistêmicos (por exemplo, ciclo de energia e transformação da biomassa); já os atributos de resposta estão associados à forma como os organismos (ou comunidades) respondem aos condutores ambientais (Violle et al., 2007; Raffard et al., 2017). Estas distinções são importantes, pois a escolha de atributos deve refletir o tipo de pergunta de interesse do estudo (Pillar et al., 2013).

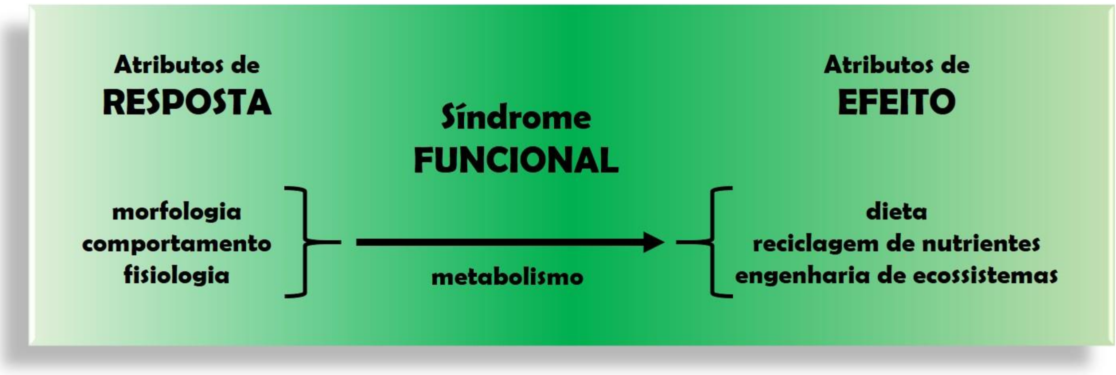

Figura 8 – Representação conceitual das classes de atributo e da Síndrome Funcional (adaptado de Raffard et al., 2017). A covariação entre características morfo-fisiológicas e comportamentais gera as síndromes de feito e de resposta. O efeito conjunto destas síndromes gera, por sua vez, a Síndrome Funcional, que emerge de processos eco-evolutivos (Raffard et al., 2017).

Por sua vez, as relações filogenéticas entre espécies que são expressas na forma de hipóteses filogenéticas são a base da diversidade filogenética (Faith, 1992). Assim como a diversidade funcional, a diversidade filogenética permite uma distinção mais precisa dos papéis ecológicos de cada espécie, já que estas são vistas como entidades que carregam histórias evolutivas únicas e, assim, não são consideradas totalmente redundantes (Faith, 1992; Pellens & Grandcolas, 2016). De maneira simples, a diversidade filogenética de uma dada comunidade é igual a soma dos comprimentos dos ramos da filogenia que abrangem as espécies ocorrentes na comunidade. Em teoria, os comprimentos dos ramos da filogenia informam o número relativo de novos recursos que surgem a partir de cada ramificação (Faith, 1992; Pellens & Grandcolas, 2016).

A diversidade filogenética tem sido vista como um reflexo da diversidade funcional, permitindo incluir aspectos adaptativos não mensurados nas variáveis fenotípicas disponíveis (Cadotte et al., 2009). Os defensores desta ideia argumentam que muito pouco se sabe sobre os verdadeiros atributos funcionais que estão associados aos processos de adaptação às condições ambientais locais (por exemplo, Cadotte et al., 2009; Meynard et al., 2011). Assim, a diversidade filogenética seria uma medida mais integradora do que a diversidade funcional, pois a história evolutiva dos atributos funcionais (ou seja, a forma como estes variaram ao longo do tempo desde o surgimento de cada espécie) estaria contida ao longo dos ramos da filogenia (clados evolutivos; Srivastava et al., 2012). Porém, estas suposições apenas podem ser feitas se os atributos funcionais apresentarem sinal filogenético, ou seja, se forem conservados ao longo da filogenia (Flynn et al., 2011; Srivastava et al., 2012).

Contudo, se muitos grupos possuem elevados graus de conservação filogenética de suas características (por exemplo, anfíbios; Lourenço-de-Morais, 2019), outros há que divergem muito funcionalmente, embora sejam filogeneticamente próximos ou, outros ainda, apresentam convergência fenotípica sendo filogeneticamente distantes. Cabe ressaltar que alguns atributos funcionais podem variar amplamente ao longo da filogenia (ou seja, são instáveis), e isto pode reduzir a detecção de sinal filogenético (Srivastava et al., 2012). Ainda, o grau de conservadorismo de nicho depende da robustez da filogenia e da quantidade de informações relativas aos valores de atributos que estão disponíveis para os clados de interesse. Assim, a utilização da diversidade filogenética como *proxy* da diversidade funcional deve ser vista com cautela e, de preferência, deverão ser utilizadas concomitantemente.

Fato consagrado na ecologia é que os padrões de ocorrência de linhagens evolutivas e de atributos funcionais muito podem nos informar acerca dos processos ecológicos atuantes nas comunidades (Tonkin et al., 2016; Pellens & Grandcolas, 2016). Por exemplo, uma alta diversidade de atributos e linhagens evolutivas (ou seja, alta divegência funcional e filogenética) pode indicar a dominância de processos competitivos, enquanto que uma baixa diversidade (agrupamento funcional e filogenético) pode indicar o efeito da filtragem ambiental sobre as espécies (Peres-Neto et al., 2012; Dainese, Lepš, de Bello, 2015; Gerhold et al., 2015; Kraft, Godoy & Levine, 2015). As diversidades funcional e filogenética refletem, no seu conjunto, a capacidade de uma dada comunidade para gerar novas soluções evolutivas e para persistir frente aos mais variados distúrbios (Meynard et al., 2011). Muitos estudos vislumbram, inclusive, um interesse particular destas duas facetas da diversidade para os esforços de conservação de espécies (Cadotte et al., 2009; Meynard et al., 2011; Funk, Shiemer & Reckendorfer, 2013; Pellens & Grandcolas, 2016).

A utilização da abordagem integradora em estudos metacomunitários (ou seja, integrando avaliação concomitante das diversidades taxonômica, funcional e filoegenética) demonstrou ser importante e, ao mesmo tempo, promissora. Apesar de possíveis congruências das facetas da diversidade em suas respostas ao mesmo conjunto de preditores ecológicos (por exemplo, Meynard et al., 2011; Heino e Tolonen, 2017), há também casos em que o efeito relativo de cada preditor muda de acordo com a faceta de diversidade considerada (Mouchet et al., 2010, Cavender-Bares et al., 2009; Wang et al., 2015). Assim, a avaliação dos processos comunitários baseados em uma única métrica poderia reduzir a força de predição e comprometer a integridade dos estudos.

Metacomunidades de Poças

Os sistemas aquáticos representam uma fonte de oportunidades para a realização de estudos metacomunitários (Heino et al., 2015; Delatorre et al., 2015). Entre estes encontram-se poças, persistentes ou temporárias. Poças compreendem corpos d’água que variam de 1 m^2 a dois hectares e representam um tipo especial e ao mesmo tempo desafiador de sistema aquático dulcícola (Williams, 2006). Nestes ambientes é possível observar uma considerável heterogenia na estrutura das comunidades mesmo em pequenas escalas espaciais e temporais (Heino et al., 2015). Esta heterogenia é impulsionada pela presença de diversos gradientes ambientais, tais como de hidroperíodo (Welborn et al., 1996; Werner et al., 2007), de morfologia do hábitat (Garmendia & Pedrola-Monfort, 2010; Gallego et al., 2014; Provete et al., 2014) e de conectividade (Hill et al., 2017). O interesse nestes ambientes não é recente, pois além de desempenharem importantes funções ecossistêmicas, estes ambientes estão sendo diretamente impactados por modificações provocadas pela ação do homem (por exemplo, uso da terra e poluição da água; De Marco Jr. et al., 2014; Felda et al., 2016).

Aspectos ambientais e espaciais muito contribuem para a estruturação de comunidades de poças (Parris, 2004). Porém, os processos de organização das comunidades de poças podem variar sazonalmente (por exemplo, Strauβ et al., 2016; Florêncio et al., 2016). Em casos onde há variação temporal, esta é impulsionada por modificações sazonais da estrutura ambiental (por exemplo, nos pulsos de volume total de água), as quais geram diferentes níveis de perturbação (Vanshoenwinkel et al., 2013; Gallego et al., 2014). Para ocorrer nestes ambientes, as espécies geralmente precisam apresentar histórias de vida e atributos funcionais únicos e adaptados a estas condições (por exemplo, no caso de anfíbios, rápida metamorfose e estágios de vida resistentes à dessecação), tornando a biota de poças singular (Wellborn et al., 1996; Williams, 2006). É possível observar ainda que processos como o de controle fisiológico e de dispersão podem variar amplamente mesmo nos organismos adaptados a poças, e isto pode refletir-se nos padrões alfa e beta, e consequentemente gamma, da diversidade (Florêncio et al., 2016).

A maioria dos estudos realizados até ao momento sugere que a estrutura das comunidades de poças é, fundamentalmente, conduzida por processos determinísticos (Heino et al., 2015; Schalk et al., 2017). Entretanto, algumas comunidades foram consideradas como sendo estruturadas por processos estocásticos (Chase, 2007; Araújo-Martins et al., 2015; Delatorre et al., 2015). A alternância na dominância destes dois processos obedeceria a uma hierarquia, onde poças com tamanhos maiores e hidroperíodo mais longo estariam organizadas de acordo com os processos determinísticos (por exemplo, interações bióticas), ao passo que poças menores e efêmeras estariam mais sujeitas a eventos aleatórios (Chase, 2007). Heino e colaboradores (2015) revisaram este tópico e apontaram que a boa capacidade de dispersão é uma característica-chave para este tipo de ambiente, especialmente para os efêmeros. A dispersão está intimamente relacionada à recuperação das comunidades após eventos de perturbação. Porém, os próprios autores afirmam que, devido à alta heterogeneidade ambiental e à estocasticidade, explicar os efeitos de tais padrões relacionados à dispersão a partir de preditores espaciais pode ser uma tarefa difícil. Por fim, as comunidades de poças podem ser organizadas de acordo com eventos de longo prazo (eventos históricos) que tiveram seu início em tempos pretéritos e que continuam a influenciar os padrões atuais (por exemplo, Felda et al., 2016).

Anfíbios Anuros

Anfíbios anuros possuem um ciclo de vida bifásico que alterna de um estágio larval altamente dependente de ambientes aquáticos para uma fase adulta que transita entre os hábitats aquático e terrestre e cuja dependência da existência permanente de água é altamente variável entre taxa (Figura 9; da Silva et al., 2012). Além disso, possuem uma pele altamente permeável e fisiologia ectotérmica, ou seja, seus controles fisiológicos dependem das condições e são fortemente influenciados por elas, o que os torna altamente dependentes da qualidade ambiental (Niemi & McDonald 2004).

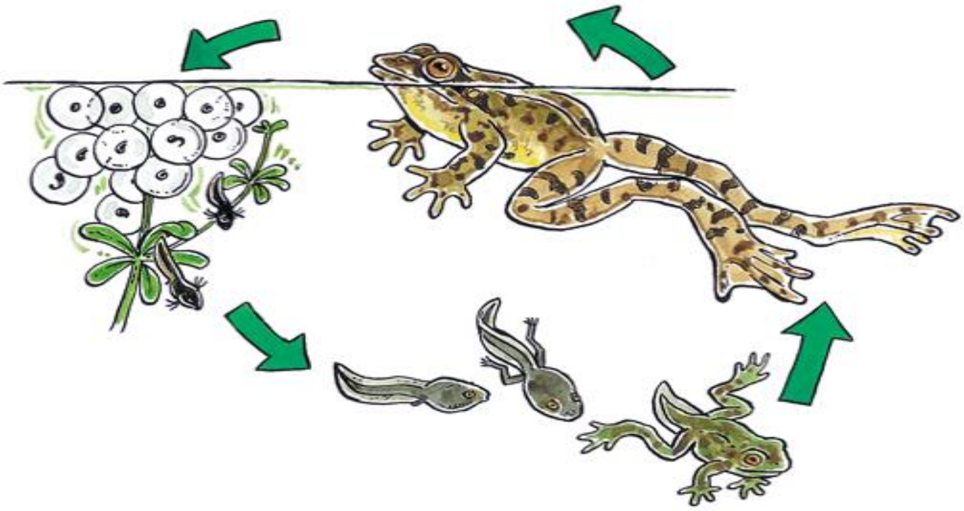

Figura 9 – O ciclo de vida bifásico dos anuros. Retirado de thinglink.com

Anuros também desempenham muitas funções ecossistêmicas nos locais onde ocorrem (Rowland et al., 2015). Por exemplo, eles representam grande parte da biomassa dos ambientes e muito contribuem no ciclo de nutrientes, além de ocupar diferentes níveis ao longo da cadeia trófica (Gibbons et al., 2006; Rowland et al., 2015; Schalk et al., 2017; Ribeiro et al., 2017). Além disto, sua grande diversidade de modos reprodutivos aumenta a resistência das comunidades e garante a resiliência em situações de distúrbio (Figura 10; Davic & Welsh, 2004; Haddad & Prado, 2005).

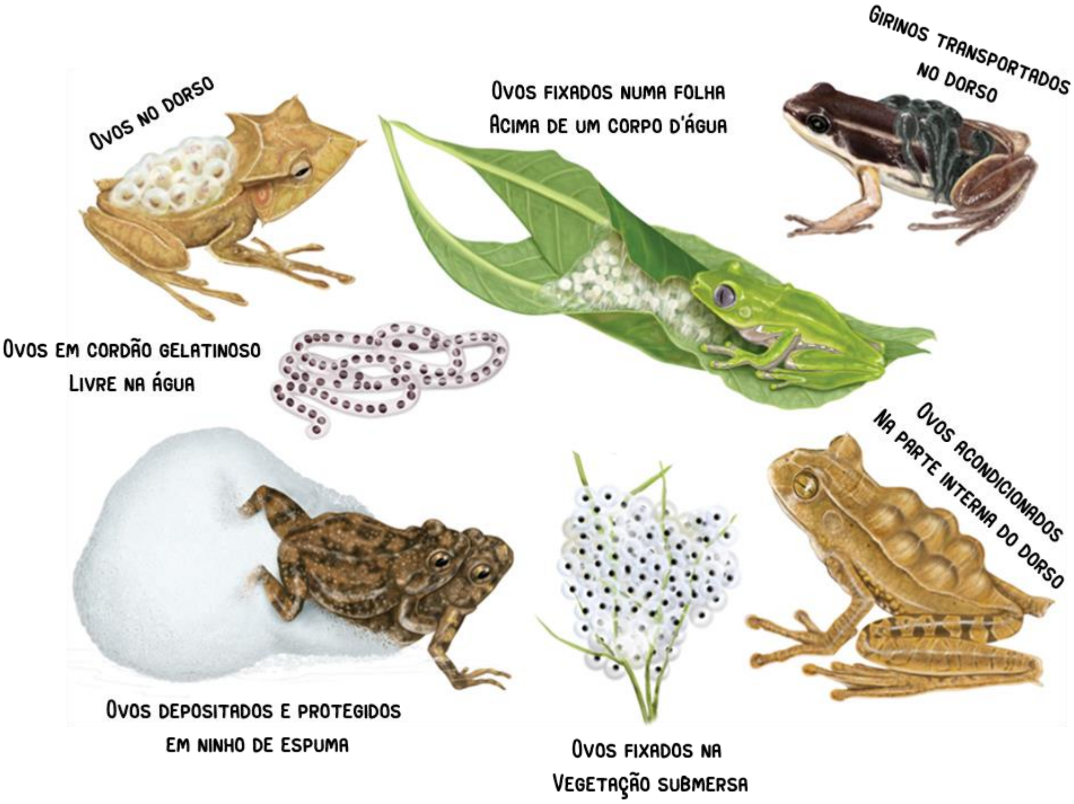

Figura 10 – Diversidade de modos reprodutivos em anuros. Retirado de www.britannica.com

Anuros também são considerados excelentes modelos para se testar hipóteses ecológicas. Eles utilizam diversos tipos de ambientes dulcícolas para se reproduzir, onde tendem a ocorrer de forma abundante (Eterovick & Barros, 2003).

As diferentes espécie e ciclos de vida estão ainda expostos a diferentes aspectos ambientais e espaciais (De Bie et al., 2012; Landeiro, Waldez & Menin, 2014; Melo et al., 2014; Provete et al., 2014; Delatorre et al., 2015). A estruturação de muitas metacomunidades de anuros parece responder fundamentalmente a filtros ambientais (por exemplo, Hampel et al., 2012; Prado & Rossa-Feres, 2014; Almeida et al., 2015; Melchior et al., 2017; Ribeiro et al., 2017; Knauth et al., 2018). Porém, os processos espaciais relacionados com a dispersão também demonstraram ser importantes na organização da diversidade alfa e beta das metacomunidades (por exemplo, Provete et al., 2014; Luiz et al., 2016), incluindo a sua estrutura funcional e filogenética (Araújo-Martins et al., 2015; Leão-Pires et al., 2018).

A capacidade de dispersão em anuros é considerada limitada (Duellman & Trueb, 1986; Smith & Green, 2005). Grande parte desta limitação está associada à morfologia de seus membros locomotores, os quais são relativamente curtos e pequenos em relação ao tamanho do seu corpo. Além disto, inúmeros fatores intrínsecos (por exemplo, fisiológicos e comportamentais) e extrínsecos podem atuar como barreiras à dispersão (Nowakowski et al., 2017). Por exemplo, a distribuição espacial das manchas florestais e/ou poças e a permeabilidade da matriz circundante podem alterar substancialmente o sucesso da dispersão de diversos grupos (Richter-Boix, Llorente & Montori, 2007; Hampel et al., 2012; Landeiro, Waldez & Menin, 2014). Outros fatores não necessariamente ligados à dispersão também podem contribuir para a dominância dos processos espaciais sobre a estrutura de algumas comunidades de anuros. Este é o caso do comportamento filopátrico (alta fidelidade ao sítio de reprodução), que é muito comum em anuros (Blaustein et al., 1994). Smith e Green (2005) realizaram uma extensa revisão deste tópico na literatura, e encontraram que a grande maioria das espécies têm deslocamentos inferiores a 1 Km relativamente ao seu local de nascimento. Além disto, muitos indivíduos permanecem nos mesmos locais por vários anos, inclusive retornando aos mesmos locais após eventos de seca.

Anuros apresentam uma estreita relação atributo-ambiente que varia ao longo da ontogenia (Van Buskirk & Arioli, 2005; Michel, 2011; Marques & Nomura, 2015; 2019). Experimentos realizados com girinos permitiram verificar que estas relações estão atreladas principalmente a dois gradientes ecológicos: de predação e de hidroperíodo (Van Buskirk & Arioli, 2005; Michel, 2011). Os predadores têm potencial para selecionar atributos funcionais em comunidades de girinos (Van Buskirk & Arioli, 2005). Eles podem, inclusive, conduzir a modificações em diversos atributos, tais como as morfologias do corpo e da cauda e taxas de crescimento e sobrevivência (Van Buskirk & Arioli, 2005; Nomura et al., 2011). O hidroperíodo também influencia as taxas de crescimento e desenvolvimento, mas atua diretamente na proporção em que os girinos transformam a biomassa do ambiente (ou seja, na intensidade de forrageio; Van Buskirk & Arioli, 2005; Shclak et al., 2017), no tempo de metamorfose (Wellborn et al., 1996), e na massa seca pós-metamorfose (Peltzer & Lajmanovich, 2004).

Em adultos, a relação atributo-ambiente é mais evidente nas características reprodutivas e de controle de água e de temperatura (da Silva et al., 2012; Schalk & Saenz, 2016). Os níveis de precipitação e de umidade relativa do ar foram considerados fatores-chave para a distribuição de modos reprodutivos e de linhagens evolutivas ao longo da Mata Atlântica (da Silva et al., 2012; da Silva et al., 2014). Mais precisamente, apenas as espécies com modos reprodutivos mais generalistas ou adaptados à dessecação poderiam ocorrer em porções do bioma com chuvas mais imprevisíveis (Haddad & Prado, 2005; da Silva et al., 2012). Adicionalmente, os adultos podem ter suas distribuições temporais moldadas pelo fotoperíodo (por exemplo, Both et al., 2008; Canaveiro et al., 2009; Schalk & Saenz, 2016), embora esta variável não atue necessariamente na ocorrência de atributos, mas sim potencialmente na distribuição temporal das espécies.

Devido a várias das características citadas acima, os anuros são atualmente considerados o grupo de vertebrados mais ameaçados de extinção no planeta (Ilg & Oerteli, 2016). As mudanças climáticas (da Silva et al., 2014), a fragmentação e a destruição dos hábitats (da Silva et al., 2011; Rowland et al., 2015; Ilg & Oerteli, 2016), incluindo alargada supressão de zonas úmidas e a degradação ambiental em geral por poluição (Rowland et al., 2015; Costa, Solé & Nomura, 2017) e o surgimento de doenças associadas a todos os fatores anteriores estão conduzindo ao declínio e extinção de muitas populações de anuros. Para tal, pesquisas que produzam conhecimento e cubram as lacunas de informação acerca da biologia dos anuros devem ser prioritárias.

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Objetivos gerais e organização da Tese

O objetivo geral desta tese foi avaliar a estrutura de metacomunidades de anuros que ocorrem em poças do extremo sul do Brasil. Para tal, utilizamos diferentes abordagens para determinar como variáveis ambientais, espaciais e temporais influenciam a organização taxonômica, funcional e filogenética das comunidades em ambos as fases do ciclo de vida de anuros: girino e adulto.

O núcleo da tese é composto por quatro capítulos que correspondem a manuscritos já aceitos, submetidos ou em preparação para submissão a periódicos científicos indexados com revisão por pares.

No primeiro capítulo avaliamos quando e quais variáveis ambientais determinam a estrutura multifacetada (ou seja, taxonômica, funcional e filogenética) da diversidade alfa de girinos de dez poças temporárias. A profundidade da água mostrou-se como o principal condutor da diversidade de girinos, especialmente para a diversidade filogenética. O manuscrito correspondente a este capítulo foi já submetido e está em revisão no periódico Hydrobiologia. Ao final deste caítulo adicionamos, também, um infográfico com as principais informações tratadas neste capítulo e que foi compartilhado em redes sociais para estimular a divulgação científica do nosso trabalho e também a transmissão de conhecimento entre indivíduos.

Já no segundo capítulo investigamos a distribuição de adultos em 33 poças e determinamos a relação entre variáveis ambientais e espaciais e os padrões de diversidade beta e seus componentes: substituição de espécies e aninhamento. Os principais achados foram que os padrões de variação da diversidade beta taxonômica foram mais explicados pelos preditores ambientais e espaciais, enquanto que a diversidade beta funcional respondeu mais fortemente aos preditores espaciais. Este manuscrito foi aceito para publicação na PLoS One.

No terceiro capítulo averiguamos a existência de relações entre os atributos morfológicos dos anuros e os descritores ambientais locais de poças. Selecionamos oito espécies de anuros e as separamos em dois principais grupos, de acordo com o tipo de uso de hábitat – arbóreo ou aquático-terrestre. Em seguida determinamos em que níveis ecológicos (intra ou interespecífico) se dão as principais variações dos atributos. Os padrões de variação intra e interespecífica parecem depender do tipo de atributo e do grupo de organismos em análise. O manuscrito correspondente a este capítulo foi já submetido e está em revisão no periódico Aquatic Sciences.

Por fim, no quarto capítulo determinamos a influência relativa de preditores ambientais, espaciais e antrópicos sobre a composição taxonômica, funcional e filogenética de anuros (adultos) em 33 poças. Verificamos que os preditores espaciais foram os principais responsáveis pelos padrões de estrutura taxonômica e funcional, enquanto a estrutura filogenética foi mais associada aos preditores ambientais e pelo uso da terra (único preditor antropogênico). Este manuscrito está em preparação para submissão a um periódico na área de ecologia a ser escolhido.

CAPÍTULO I

WHAT AND WHEN LOCAL PREDICTORS DRIVE TADPOLE DIVERSITY IN SUBTROPICAL TEMPORARY PONDS?

SUBMETIDO À
HYDROBIOLOGIA

CAPÍTULO 1

What and when local predictors drive tadpole diversity in subtropical temporary ponds?

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Abstract

1. We evaluated seasonal variation in taxonomic, functional and phylogenetic diversity and redundancy of tadpoles present in 401 points of 10 ponds in southern Brazil. We predicted i) congruent patterns between all components of diversity and environmental descriptors; ii) higher effects of descriptors in the three components in seasons with high hydric stress; iii) all components would be influenced by different sets of environmental descriptors in each season. Predictions were tested using Linear Mixed Models.

2. Taxonomic, functional but mainly the phylogenetic diversity, responded similarly to water depth during the low hydric stress period. This also was observed for functional redundancy. This influence was positive for all components of diversity. Phylogenetic redundancy was not explained by any of environmental descriptors. In the period of higher hydric stress components of diversity were not significantly affected by environmental descriptors.

3. Environmental filtering seems to strongly influence tadpole community structure in temporary ponds, at least during the winter. Water depth gradients create a variety of micro-habitat conditions allowing diverse sets of species to settle and co-occur in ponds. These sets are then filtered according to their swimming and foraging abilities along the depth gradient, where intermediate depths should contain the greatest tadpole diversity.

KEYWORDS

Amphibians, community assembly, depth gradients, environmental filtering, seasonality, functional and phylogenetic diversity.

Introduction

Aquatic communities are influenced by different environmental factors, suggesting that biological communities do not exclusively result from events of dispersion and stochasticity (Petchey et al., 2007; Villéger et al., 2010, Mason et al., 2011; de Bello et al., 2013) but are also the result of environmental filtering. In this process, environmental factors act mainly as a filter, selecting the species of the regional pool, so that the local community composition results from the direct relation between the ecological characteristics of the species and the biotic and abiotic environment (Poff, 1997; Leibold et al., 2004; Hubbel, 2001). Thus, communities under equivalent environmental conditions should contain species with similar ecological requirements and should be more similar to each other than expected at random (Parris, 2004; Heino et al., 2015).

Recent studies support the idea that research of community structure should not focus solely on taxonomic diversity, but rather on a set of metrics that contemplate different aspects of diversity and that are complementary to each other (Díaz et al., 2007; Mouchet et al., 2010; Cavender-Bares et al., 2009). By evaluating functional and phylogenetic diversity (diversity of traits and diversity of evolutionary lineages, respectively) a more accurate evaluation of functional attributes associated with the environmental descriptors and the cumulative evolutionary history in each community is achievable (Villéger et al., 2012; de Bello et al., 2013; Corbelli et al., 2015). These aspects are crucial, as they tend to reflect the resilience of a system to environmental changes (Petchey & Gaston, 2006; Mouchet et al., 2010; Meynard et al., 2011). Incorporating information on the evolutionary history of species through phylogenetic diversity allows evaluating the contribution of historical processes (e.g. extinction and speciation events) towards the assembly of present-day communities, even when these processes act at larger spatial scales (Faith, 2016). Frequently patterns in the three components of diversity tend to be consistent (Erös et al., 2009; Meynard et al., 2011; Arnan et al., 2017), but these relationships between the components vary according to the taxonomic group and the degree of niche conservatism of the traits (Cavender-Bares et al., 2009; Arnan et al., 2015; Sobral & Cianciaruso, 2016). Thus, there are cases in which the metrics may vary differently along the same environmental gradients (Devictor et al., 2010; Safi et al., 2011; Corbelli et al., 2015).

Temporary ponds are part of the great diversity of freshwater environments (Williams et al., 2004). The effect of environmental filtering on the community structure in these ponds is dependent on the seasonal changes of the hydroperiod – period during which the pond retains water – and other local environmental conditions (Williams, 2006; Mendez et al., 2012; Ruhi et al., 2013). This effect is generally accentuated under a scenario of high hydric stress - when the effect of some kind of unfavorable environmental variable induces local changes or adaptations (e.g. temperature and evapotranspiration rates)- when changes in internal pond conditions tend to constrain local species compositions more severely (Peltzer & Lajmanovich, 2004; Williams, 2006; Hamerlik et al., 2014). Hydroperiod tends to define community composition, with evolutionarily convergent and more functionally redundant species co-occurring in conditions with high hydric stress (clustering pattern). On the other hand, functional and phylogenetically more divergent species co-occur in seasons with low hydric stress when water is abundant and temperature, dissolved oxygen and pH are not extreme (Schriever & Lytle, 2016; Ruhi et al., 2014; Martins et al., 2015; Strauβ et al., 2016).

Tadpoles select specific micro-habitats along environmental gradients (Altig & Johnston, 1989). This behavior seems to reflect the morphology and the evolutionary history of each species (Marques & Nomura, 2015) and can be influenced by several environmental descriptors (Haramuda, 2007). In fact, aquatic vegetation and depth were considered the main predictors of species richness and functional and phylogenetic diversity of tadpoles in ponds and streams (Both et al., 2011b; Queiroz, da Silva & Rossa-Feres, 2015; Melo et al., 2017; Escoriza & Ben Hassine, 2017). The presence and structuring of aquatic vegetation promotes micro-spatial heterogeneity and provides excellent locations for foraging and protection against predators (Eterovick & Fernandes, 2001; Alford et al., 1999; Hero et al., 2001; Kopp, Wachlevski & Eterovick, 2006), while depth gradients allow the differential exploration of the water column and the maintenance of species with different periods of larval development (Wellborn, Skelly & Werner, 1996; Both et al., 2011a; Escoriza & Ben Hassine, 2017). Water chemistry (dissolved oxygen, pH) and temperature may also influence tadpole diversity, as they induce physiological and behavioral responses that are determinant in relationships with predators and competitors (Warner, Dunson & Travis, 1991). The pH levels are generally higher when the pools are drying due to the high concentration of ions and CO_2 (Rowe, Sadinski & Dunson, 1992; Angélibert et al., 2004). Thus, tadpole survival rates should be expected to be different along the gradients of water chemistry (Moore & Towsend, 1998).

Few studies on tadpole community structuring have explored the influence of environmental filtering on the three components of diversity (Strauβ et al., 2016; Escoriza & Ben Hassine, 2017). Here, we aim to evaluate the relationships between local environmental descriptors and the diversity metrics (taxonomic, functional and phylogenetic diversity) of tadpole communities in temporary ponds located in the southernmost of Brazil. We evaluate if: i) local environmental descriptors act as predictors of tadpole diversity; ii) different components of diversity respond to the same descriptors; iii) the influence of descriptors on the diversity metrics changes seasonally. We expect congruent patterns between the three components of diversity and significant relationships with local environmental descriptors (Ribeiro et al., 2017;

Escoriza & Ben Hassine, 2017). However, the patterns of diversity should be contrasting between seasons as a consequence of the reproductive phenology of the adults of some species that present seasonal peaks of activity which are related to some environmental conditions (e.g photoperiod (day light length) and temperature; Both et al., 2008a). In the seasons with low hydric stress (Austral Spring and Winter) we expect a positive influence of aquatic vegetation, temperature and depth on the three components of diversity (Both et al., 2011a; Pujol-Buxó et al., 2017; Melo et al., 2017). The gradual increase of the levels of these descriptors favors the co-occurrence of benthic and nectonic species, which have different morphologies for the exploitation of resources (Michel, 2011, Queiroz, da Silva & Rossa-Feres, 2015, Escoriza & Ben Hassine, 2017). In the seasons with high hydric stress (Austral Summer and Autumn) we expect the latter to drastically alter pond environmental conditions, resulting in lower levels of diversity and higher levels of functional redundancy (Ruhi et al., 2014; Strauβ et al., 2016; Nunes et al. 2016). Diversities should be influenced by the descriptors that affect the survival of tadpoles (Strauβ et al., 2016), and they should be positively associated with dissolved oxygen levels and negatively associated with extreme temperature and pH levels (Warner, Dunson & Travis, 1991).

Material and Methods

Study Area

The study was developed in the southern remnants of Atlantic Forest Biome at the Reserva Biológica do Lami José Lutzemberger (30 ° 14'10.3 "S, 51 ° 05'51.7" W), an area with 204.04 hectares located on the banks of Guaíba Lake, Porto Alegre, Rio Grande do Sul, Brazil (Figure 1). The area is a conservation area characterized by a low sandy plain landscape, formed by Quaternary sediments, and by a flat relief, which may present sandy elevations interspersed with depressions (Borges-Martins et al., 2013). Local vegetation composes the ecotone containing plant formations of the Semi-deciduous Seasonal Forest and the Dense Ombrophylous Forest (Brack et al., 1998). The typical climate is of the Cfa type (Wrege et al., 2011), characterized by average temperatures of the warmer month exceeding 33ºC and the coldest month varying between 10 and 23ºC (see the Table S1 of supplementary material). The rainfall is well distributed throughout the year, with slightly higher rainfall volumes between July (Austral Winter) and December (Austral Spring-Summer), a period of low water stress, while low levels of precipitation can occur more frequently between March (Austral Autumn-Summer) and May (Austral Autumn), a period of higher water stress, although there is no well-defined dry season. Annual average rainfall is 1500 mm (Wrege et al., 2011; Radin et al., 2017; Table S1 of supplementary material).

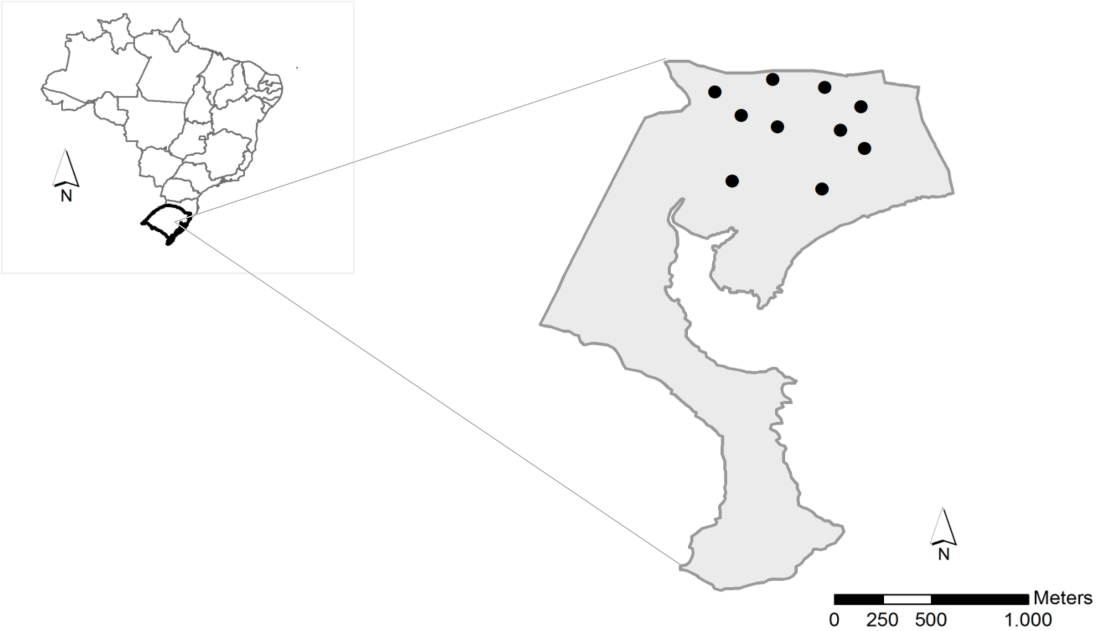


Figure 1: Location of the study area at Reserva Biológica do Lami in Porto Alegre municipality, Rio Grande do Sul, Brazil. Dots indicate the 10 ponds sampled.

Data Collection

The study was conducted in a group of small temporary ponds used as breeding sites by anurans. At the study site there are numerous water bodies (ponds) with average deep of 50 centimeters and surrounded by native vegetation cover composed of grasslands associated with shrubs and eventually a tree layer with a predominance of Asteraceae e Poaceae families. The hidroperiods of ponds have two well-defined scenarios: one with low and the other with high hydric stress, distributed in a non-predictive way throughout the year. We selected 10 ponds for sampling collection according to i) area accessibility and ii) those distance to ther ponds of at least 250 meters. Data collection took place monthly during anuran breeding season, between September 2013 and August 2014. Samples were collected in each pond from survey points at least three meters apart from each other (Prado et al., 2009). Delimitation of collection points and sampling methods of tadpoles followed Alford and Crump (1982), marking each point to be sampled with a metal cylinder (70 centimeters long and 32 centimeters in diameter), open in both ends. Points were sampled in transects and the individuals confined to the metal cylinder were collected with a wire mesh of 3 millimeters for a period of three minutes (see the sampling scheme in the supplementary material – Figure S2). Specimens collected were stored in separate flasks for each collection point. Tadpoles were identified in the laboratory to the species level, and were deposited in the Scientific Collection of the Zoology Department of the Federal University of Rio Grande do Sul.

The hydroperiod characterization of each pond was performed monthly by recording their individual total area and average depth . The surveyed ponds differed in relation to the environmental structure and the number of months they retained water (Table 1), as well as to the number of surveyed points (see Supplementary Material Table S3).

The following local descriptors were evaluated for each collection point: percentage of vegetation cover in the internal area of the cylinder, categorized in: 1)(none), 2)(1-25%), 3) (26 - 50%), 4) (51-75%), 5) (> 76%); distance from the sampling point to the margin (centimeters); depth of the sampling point (cm); pH; dissolved oxygen; water temperature (ºC); month in which it was sampled. pH, temperature and dissolved oxygen of water were measured with specific equipment. Water column depth was measured with a ruler positioned in the center of the cylinder area. Lastly, we divided the area of the cylinder into four parts, each representing 25% of the covered area, to measure the percentage of aquatic vegetation. The variation of each environmental descriptor between the seasons is presented in supplementary material (S4).

Table 1 - Characterization of ponds (P1 – P10) sampled in the Reserva Biológica do Lami in relation to distribution of tadpoles in the period between September/2013 and August / 2014. Seasons: Spring (1); Summer (2); Autumn (3); Winter (4); Type of vegetation of the margin: Shrub (Sh.); underbrush (und.).

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Total area (m^2)	50	205	20	810	85	54	15	64	112	84
Average depth (cm)	30	50	12	55	30	20	35	40	38	45
Seasons of the year in which it retained water	1; 4	1;2;3; 4	1; 4	1;2;3; 4	1;2;3; 4	1;2;4	1.	1;2;3; 4	1; 4	1; 4
Number of months of the year in which it	6	12	4	12	10	6	7	7	6	6

retained water										
Aquatic vegetation(%)	>50%	>50%	<50%	>50%	>50%	>50%	>50%	>50%	50%	>50%
Types of margin vegetation	Sh.;Und.	Sh.;Und.	Und.	Sh.;Und.	Sh.;Und.	Sh.;Und.	Sh.;Und.	Sh.;Und.	Sh.;Und.	Und.

Ethics Statement

Collection permits were provided by the Brazilian government (ICMBio) (authorization 40180-2). Field studies did not involve endangered or protected species. Manipulation of animals in the field was restricted to a minimum since we limited sampling to specimens collected in the points delimited by the cylinder (see the section above). The collected specimens were immediately anesthetized with xylocaine and fixed in 10% formaldehyde. At the beginning of the field sampling planning, in 2013, this study was approved by the animal ethics committee in our graduation program. All sampling procedures were reviewed and specifically approved as part of the process of obtaining the field permits from ICMBio (see above).

Construction of Data Matrices

We began by constructing two matrices – a presence/absence matrix and an environmental descriptor matrix – containing species data collected at the collection points of each of the sampled ponds during the two seasons: season with low hydric stress, which included September and October/2013 and May-August/2014, and season with high hydric stress, which included November and December/2013 and

January-April/2014 (see Supplementary Material Table S1 for details). The values of the environmental descriptors were standardized by subtracting the average from each value of the descriptor and dividing the result by the standard deviation.

Phylogenetic relationship trees were built on the basis of the information contained in the presence/absence matrix. The phylogeny was created by pruning the dated amphibian tree proposed in the work of Jetz and Pyron (2018) to include only the species found in the communities using the function *prune.sample* of the R package picante (Kembel et al., 2010). Then we built a matrix of phylogenetic distances composed of all the species occurring in the ponds throughout the seasons.

For the functional matrix, we measured 12 different traits (see Table S5 of the supplementary material) from a minimum of 5 tadpoles of each species collected during the study period in all ponds. The tadpoles were previously classified according to development stages (sensu Gosner, 1960), and only those between stages 33 and 39 were measured (Queiroz, da Silva & Rossa-Feres, 2015; Jordani et al., 2019). The restriction to this range of development reduces the influence of intraspecific variation, thus excluding possible allometric differences related to ontogenetic development (Grosjean, 2005). The functional traits used in this study were selected given their well-known relations with feeding and swimming behavior, habitat use, or tadpole life history (Inger et al., 1987; Altig & Johnston, 1989; Rossa- Feres, Jim, & Fonseca, 2004; Lajmanovich, 2000; Eterovick & Barros, 2003; Strauβ et al., 2010).

We used Variance Inflation Factor Analysis (VIF, Lin, Foster, & Ungar, 2011) to assess the multicollinearity among the descriptors of the environmental matrix and among the traits of the functional matrix. The value of VIF for an explanatory variable is obtained using the R^2 value of the regression of this variable against all other explanatory variables. We considered variables with VIF values above five as correlated. Results did not indicate a significant correlation between any of the traits

(Supplementary Material Table S6) or between any of environmental descriptors (Supplementary Material Table S7).

Statistical Analysis

The diversity present at each of the sampling points was evaluated using Rao's Quadratic Entropy Index (Rao, 1982). This index is based on the proportion of species present in a community and some measure of dissimilarity, ranging from 0 to 1. One of the advantages of this method is that it allows biodiversity to be divided into alpha, beta and gamma components (Pavoine, Dufour, & Chessel, 2004), providing a flexible framework that can be adapted to quantify and compare different components of diversity such as taxonomic, functional, and phylogenetic diversity of the communities (de Bello et al., 2009, Meynard et al., 2011, Bernard-Verdier, Flores, Navas & Garnier, 2013; Arnan, Cerdá & Retana, 2014; 2017). The taxonomic distances between species within each sampled point k were obtained from the presence/absence matrix through the formula:

$$Rao\ (k) = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij}$$

$d_{ij} = 1$, where d_{ij} is the distance between species i and j. The phylogenetic distances between the species present in the phylogenetic tree were measured using the co-phenetic distances of the phylogenetic matrix. We used the functional matrix to calculate the Euclidean distances between species based on the Gower distance. Finally, we evaluated the functional and phylogenetic redundancies that measure the resilience of a community to ensure the provision of ecosystem processes against any type of disturbance (Pillar et al., 2013). This maintenance is ensured by the presence of functional and phylogenetically similar species, which differ in their responses to these disturbances. The respective redundancies were obtained through the difference between the species diversity and the Rao quadratic entropy based on their functional and phylogenetic dissimilarity, respectively (de Bello et al., 2006). All Rao's quadratic entropy calculations were performed using the 'SYNCSA' package in the R (R Development Core Team, 2013) environment.

We used Linear Mixed-Effect Models (LMM) with Gaussian distribution to model the relation between diversity indexes (taxonomic, functional and phylogenetic diversity and functional and phylogenetic redundancies) and local environmental descriptors. This approach explicitly models the relation within the data set using random effects or latent random variables (Breslow & Clayton, 1993; Zhang et al., 2012). We built several models with different sets of environmental descriptors, so that all possible combinations could be evaluated. Pond was included as random effect. Model selection was done using the Akaike Information Criteria correcting (AICc) to select the model containing the most information among all candidate hypotheses (Buham & Anderson, 2002). We also took into account the AICc weights (w) which are indicative of the empirical support for each model relative to others in the candidate set. Finally, we applied a threshold of AICc 2 units to define model support (in other words, we considered models with ΔAIC<2 as equivalent; Zuur et al., 2009). LMMs were built using the 'nlme', 'MuMIn' and 'lme4' packages in the R (R Development Core Team, 2013).

Results

We collected a total of 2,390 tadpoles from 18 species of three families: Hylidae (7), Leptodactilydae (10) and Odontoprhynidae (1) (Table 2). The seasons with low hydric stress (Austral Spring and Winter) presented the highest richness and abundance of tadpoles.

Table 2 – Abundance of tadpoles collected per species at the Reserve Biológica do Lami, southern Brazil, between September/2013 and August/2014. Seasons with low hydrical stress (Spring and Winter); Seasons with high hydrical stress (Summer and Autumn).

Specie	Spring	Summer	Autumn	Winter
Dendropsophus minutus	10	8	38	4
Boana faber	12	219	76	64
Boana pulchella	15	0	0	11
Leptodactylus fuscus	5	2	0	0
Leptodactylus gracilis	8	0	0	1
Leptodactylus latrans	98	0	0	0
Leptodactylus mystacinus	6	0	0	0
Odontophrynus americanus	22	0	0	0
Physalaemus biligonigerus	7	0	0	2
Physalaemus cuvieri	4	32	2	0
Physalaemus gracilis	142	12	0	3
Physalaemus henselii	188	0	0	191
Physalaemus lisei	36	0	0	1
Pseudopaludicola falcipes	2	0	0	0
Ololygon berthae	155	2	7	89
Scinax granulatus	446	23	2	6
Scinax squalirostris	363	39	0	31
Julianus uruguayus	6	0	0	0
Abundance	1525	337	125	403
Richness	18	8	5	11

LMM showed that the three components of diversity generally responded to the same set of local environmental descriptors (Tables 3 and 4). However, the relationship with the environmental descriptors varied throughout the seasons. In the

Austral Winter (season with low hydric stress) water depth positively affected the components of diversity. Phylogenetic redundancy was not explained by any of the local environmental descriptors measured for the seasons with low hydric stress.

Table 3 - Summary of the best-adjusted models resulting from the GLMM for each of the diversity components analyzed for tadpole communities. R^2m (fixed effects); R^2C (fixed + random effects).

	Season	Model	AICc	ΔAICc	Weight	R^2m	R^2C
Functional Diversity	Winter	Null	-32.61	0	0.54	0.09	0.10
		Depth	-30.79	1.82	0.23		
	Spring	Null	-123.27	0	0.91	<0.01	0.21
	Summer	Null	-0.93	0	0.70	0.21	0.21
	Autumn	Null	-18.12	0	0.73	0.22	0.82
Functional Redundancy	Winter	Null	-96.06	0	0.51	0.11	0.14
		Depth	-94.72	1.33	0.26		
	Spring	Null	-247.69	0	0.92	0.02	0.13
	Summer	Null	-32.86	0	0.76	0.25	0.25
	Autumn	Null	-50.14	0	0.88	0.25	0.87
Phylogenetic Diversity	Winter	Depth	22.04	0	0.35	0.11	0.16
		Null	22.30	0.25	0.29		
	Spring	Null	26.09	0	0.89	<0.01	0.21
	Summer	Null	17.15	0	0.57	0.24	0.24
	Autumn	Null	-10.05	0	0.74	0.21	0.80
Phylogenetic Redundancy	High Hydrical Stress	Null	-38.90	0	0.71	0.12	0.29
	Low Hydrical Stress	Null	-90.44	0	0.87	0.03	0.08
Taxonomic Diversity	Winter	Depth	40.12	0	0.32	0.10	0.12
		Null	40.17	0.05	0.31		
	Spring	Null	92.11	0	0.87	<0.01	0.17

	Summer	Null	23.76	0	0.55	0.23	0.23
	Autumn	Null	1.33	0	0.71	0.24	0.89

Table 4: Results of ANOVA tests showing the effects of water depth on tadpole diversity components

Diversity Components	**Effect**	**F**	**p**
Functional diversity	0.05	6.95	0.01
Functional redundancy	0.04	9.06	0.003
Phylogenetic diversity	0.08	8.55	0.004
Phylogenetic redundancy	NS	NS	NS
Taxonomic diversity	0.09	8.08	0.006

In relation to the distribution of tadpoles along the water depth gradient in the winter, intermediary (16-45 centimeters) and deep (46-70 centimeters) micro-habitats showed the highest richness and diversity (Figures 2 and 3 a-d), while shallow depth micro-habitats (0-15 cm) presented the lowest values. During Austral Summer and Autumn, periods of high hydric stress, the null hypothesis was not rejected for any of the components of diversity. The table including all the models and possible combinations of local descriptors and diversity metrics is presented as Supplementary Material (Tables S8-S27).

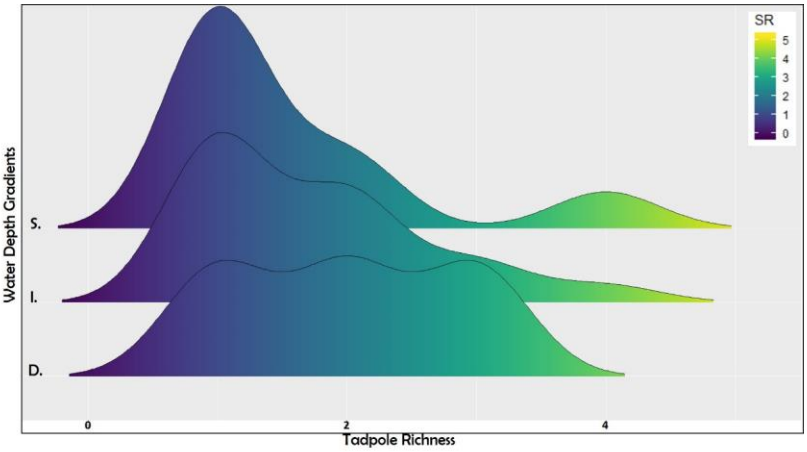
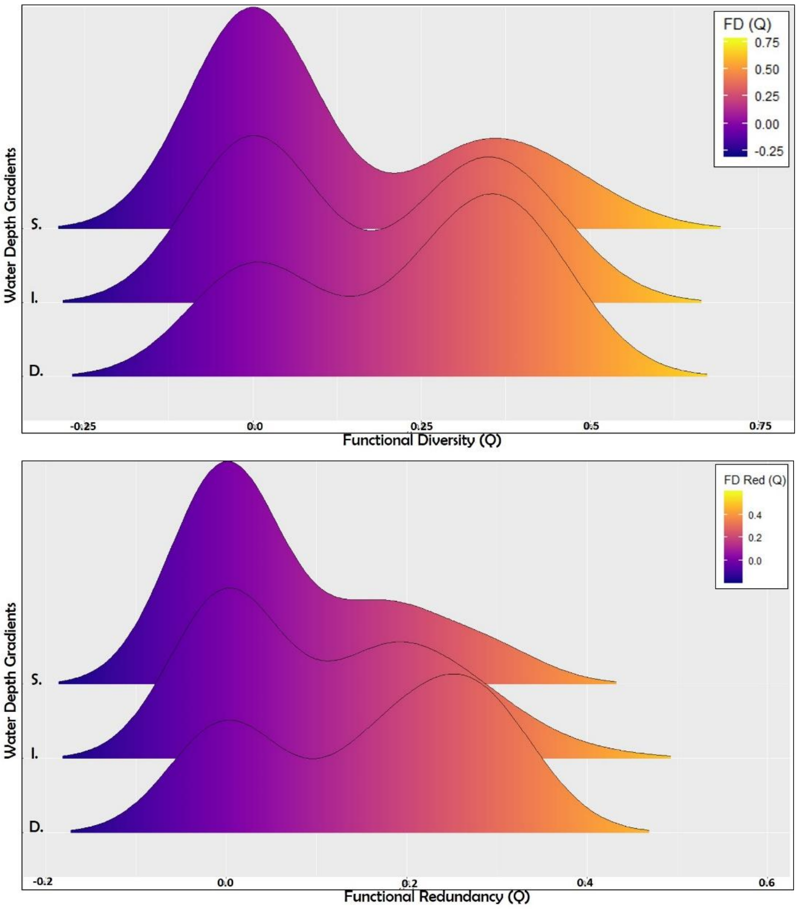


Figure 2: Tadpole richness distribution in microhabitats along the depth gradient during the winter. S: shallow (0-15 cm); I: intermediary (16-45 cm); D: deep (46-70 cm).



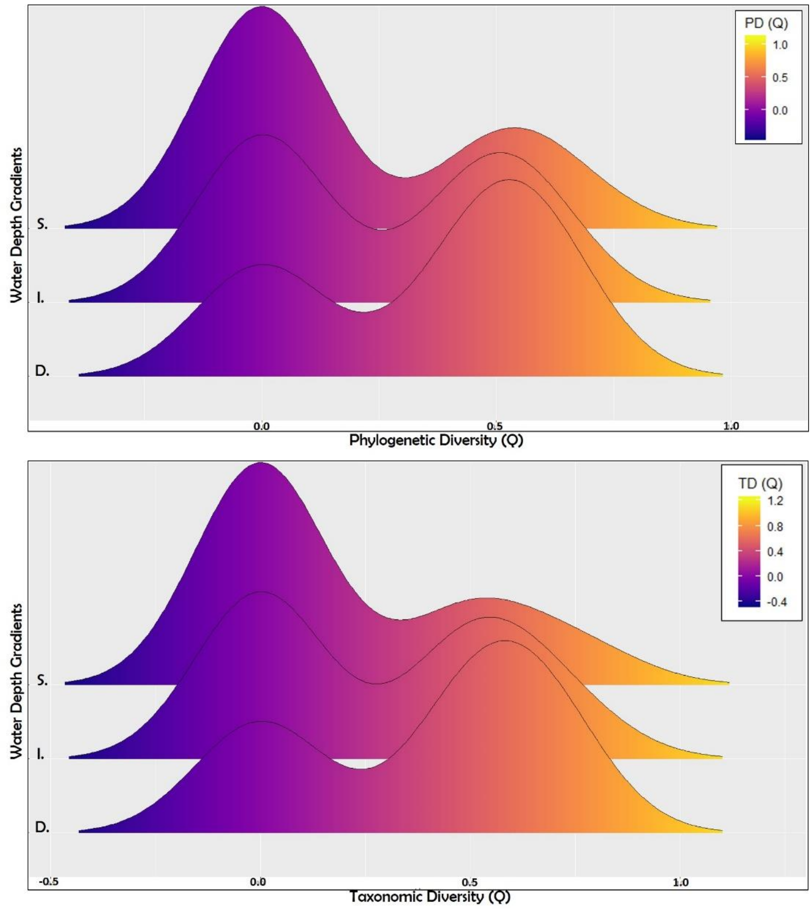


Figure 3: Tadpole diversity distribution in microhabitats along the depth gradient during the winter. S.: shallow (0-15 cm); I.: intermediary (16-45 cm); D.: deep (46-70 cm).

Discussion

Tadpole community assembly is not completely random

Our results revealed that local environmental descriptors influence the diversity of tadpoles in ponds. Although the null model was frequently among the best set of models, all diversity metrics evaluated here were associated with water depth in the season with low hydric stress. So, environmental descriptors drive, at least in the winter, the diversity of tadpoles in lentic systems, and are also in agreement with other studies that found non-random patterns of organization in tadpole communities (Both et al., 2011b, Strauβ et al., 2016; Knauth, Moreira & Maltchik, 2018).

Still, environmental filtering does not seem to be the only mechanism driving tadpole assembly in our study system. Recent studies have reported that tadpole diversity patterns in ponds are the result of a complex balance between environmental and spatial factors, the latter of which seem to hold the largest fraction of total variance observed in communities (Leão-Pires, Luiz & Sawaya, 2018; Marques et al., 2018). Moreover, other niche-based processes (e.g. predation and competition) have been identified as the main agents in the modification of the structure of aquatic communities, to the extent of modifying the relation between environmental and spatial factors and the components of diversity (Livingston et al., 2017).

The multifaceted approach used in this study made it possible to bring to the foreground the role of local environmental descriptors as predictors of diversity in communities of tadpoles in temporary ponds. Although some studies have suggested that the relation between taxonomic, functional and phylogenetic diversity is conditioned by the environment and that they can covariate in different ways along environmental gradients (Devictor et al., 2010, Safi et al., 2011; Bernard-Verdier, Flores, Navas & Garnier et al., 2013), our results revealed congruent responses of the three components of diversity to the environmental descriptors, corroborating our initial prediction and patterns described for other anuran communities (Ribeiro et al., 2017, Escoriza & Ben Hassein, 2017).

The relation between environmental descriptors and diversity changes seasonally

Our results are consistent with the theory that environmental filtering is an important agent driving the assembly of communities in seasonal systems, as evidenced by several groups of aquatic organisms (e.g. Poff, 1997; Datry et al., 2014; Florencio et al., 2014), including anurans (Escoriza & Ben Hassine, 2017; Couto et al., 2017; Knauth, Moreira & Maltchik, 2018). The effect of local environmental descriptors on components of diversity was discrepant between seasons and significantly higher during periods of low hydric stress. These results did not confirm our initial prediction and are discrepant with the findings of previous studies where there was evidence of environmental filtering in seasons with high hydric stress in the same system type (e.g. Chase, 2007; Ruhi et al., 2013).

The richness and abundance of tadpoles was highest in the end of the season with low hydric stress and declined gradually towards periods of high hydric stress, following the general pattern found in tropical and subtropical regions (e.g. Kopp, Wachlevski, & Eterovick, 2006, Both et al., 2008b; Both et al. 2011b; Strauβ et al., 2016). This period coincides with the peak of reproductive activity for most of the recorded species (see Supplementary Material Table S28). Indeed, reproductive activity is closely related to the seasonal variation of some abiotic components, such as photoperiod (day length), precipitation and air humidity (Both et al., 2008a; Canavero, Arim, & Brazeiro, 2009; Ximenez & Tozetti, 2015; Schalk & Saenz, 2016). The winter in the southern region of Brazil is considered harsh and might cause restrictions in the metabolic rates of several species that, consequently, limit their activities to the final months of the wet season (Ximenez & Tozetti, 2015). However, during this period the ponds are full of water, and the gradual increase of photoperiod and air temperature may serve as stimulus for the beginning of reproduction of several species; this may even occur by the end of winter (Both et al., 2008a). This relation was already reported for anuran communities of the Brazilian Atlantic Forest and Pantanal, where environmental seasonality strongly influences anuran reproductive phenology and seems to affect functional and phylogenetic diversities (Da Silva et al., 2012; Martins et al., 2015). Therefore, it is not surprising that anuran community assembly, and specifically species spatial and temporal distribution, is closely related to the reproductive activity of the adults (Resetaritis & Wilbur, 1991; Alford, 1999).

In our study area the increase in the volume of water in the ponds resulting from both the intensification of precipitation and the decrease of evaporation in the season with low hydric stress seems to create milder environmental conditions for the species present (Lake, 2003), which seems to provide greater diversity and availability of foraging and roosting resources (e.g. food and micro-habitats). Different micro-habitats combining for a wide array of environmental conditions are necessary for the co-occurrence of a larger set of species (Eterovick & Barata, 2006; Both et al., 2011b). Environmental heterogeneity (e.g. depth, temperature and vegetation) usually presents a linear relation with the diversity of tadpoles in ponds, as it maximizes the occupancy of the functional space and, consequently, should add phylogenetic diversity (Escoriza & Ben Hassine, 2017).

Periods of high hydric stress were characterized by the reduction of tadpole richness and abundance. In fact, most tadpoles probably completed larval development and left the ponds before their complete drought (Strauβ et al., 2016). During these periods, water depth may reach extremely low levels and this is a limiting factor for the occurrence of some groups of species that have limited swimming capacities at shallow depths (e.g. genus *Scinax*; Queiroz, Silva & Rossa-Feres, 2015). In accordance, the remaining sets of species were composed, for the most part, of species that present flat bodies, low fins and ventral oral discs (e.g. genus *Physalaemus*). These functional traits are shared by species belonging to different lineages and are adaptations for the exploration the pond bottom, and may also be important for resisting extreme temperature and dissolved oxygen conditions at low depths (Babbitt & Tarner, 2000; Martins et al., 2015; Queiroz, Silva & Rossa-Feres, 2015; Strauβ et al., 2016). In these conditions the influence of local predictors may be irrelevant, and stochastic events may prevail in structuring the community (Chase, 2007; Delatorre et al., 2015).

Tadpole diversity responds to water depth

Taxonomic, functional and phylogenetic tadpole diversity in periods of low hydric stress were influenced by water depth levels, corroborating our initial prediction. Many studies reported the strong influence of water depth in the community assembly of aquatic organisms, including functional and phylogenetic alpha and beta diversities (e.g., corals: Doxa et al., 2016; fishes: Langer et al., 2017; anurans: Werner et al., 2007; Both et al., 2011a; Semlitsch et al., 2015; Péntek et al., 2016) and also recolonization of ponds that undergo some type of environmental stress (Lesbarrères et al., 2009). Water depth is closely related to the variation in water volume of the ponds and can be used as proxy for the hydroperiod (Vanschoenwinkel et al., 2009). In turn, the tadpoles present direct responses to the variation in the water volumes of the pools, especially in extreme situations (Wellborn, Skelly & Werner, 1996; Werner et al., 2007) . The tendency is that peaks of richness, density and diversity are reached in intermediate depths and hydroperiods (Wellborn, Skelly & Werner, 1996; Snodgrass, Bryan Jr. & Burger, 2000; Semlitsch et al., 2015), and our results are consistent with this pattern. For tadpoles this relationship became even more evident when trait information was used to explain the patterns of functional dissimilarity between pond communities (Queiroz, da Silva & Rossa-Feres, 2015). Species are filtered according to their swimming and foraging capacities (Escoriza & Ben Hassine, 2017), and depth extremes will consist mainly of tadpoles of the Leptodactylidae and Hylidae (shallow and deep gradients, respectively), while intermediate depths should present functionally and phylogenetically diverse clusters (Queiroz, da Silva & Rossa-Feres, 2015).

Water depth can exert numerous effects on tadpoles. The diversity of aquatic vegetation and the proliferation of algae in ponds, which serve as food resources for tadpoles, the area covered by ponds, the availability of organic matter and pond productivity are all influenced by depth (Altig, 2007; Shulse et al., 2010, 2012; Langer et al., 2017). Foraging and shelter resources decline in extreme ranges and are less variable in seasons when water persists for longer times in ponds (Wetzel, 2001; Anusa, Ndagurwa & Magadza, 2012; Doxa et al., 2016; Langer et al., 2017). Under conditions of low hydric stress, the availability of distinct ecological niches increases, and then species will adapt their occurrences according to their phenotypic plasticity, local adaptation rates and also competitive abilities along the depth gradients (Koprivnikar, Paull & Johnson, 2014). So, the availability and variation of these resources should drive diversity patterns and promote dissimilarities at the local scale (Levin et al., 2001; Lins et al., 2017).

Depth also underlies the variation in temperature and solar radiation affecting tadpoles in ponds (Knapp et al., 2016; Johnson et al., 2017). Although tadpoles can exploit a wide range of temperature and radiation to adjust ontogenic development and physiological and activity levels (Johnson et al., 2017), a positive relation has been demonstrated between constant exposure to high levels of solar radiation and increased susceptibility to parasitic epidemics (e.g. virulent amphibian chytrid; Hite et al., 2016, Knapp et al., 2016, Johnson et al., 2017). The direct and indirect effects of ultraviolet radiation (UVR) may involve both increased fungal infection rates and the eradication of parasitic zooplankton, especially at great depths (Hite et al., 2016), leading to the decline or extinction of hundreds of amphibian species and threatening hundreds of others (Crawford, Lips & Bermingham, 2010; Knapp et al., 2016).

Conclusions

Tadpole components of diversity respond to environmental factors. However, in our study system this relation was only significant during times of low hydric stress, when environmental conditions are milder and allow the coexistence of phylogenetically and functionally diverse taxa. In this period, diversity metrics were significantly associated with water depth. Also, the diversity metrics used here were consistent in their response to local environmental descriptors, demonstrating that the results produced for one metric can be extended to the others. Our results reinforce the impact of environmental descriptors on anuran life cycle and the notion that tadpole community assembly is not random. Other ecological factors (e.g. similarity limitation and predation) may act concomitantly and change the organization of communities at different spatial and temporal scales. Our results contribute to the understanding of the ecology of the larval phase of the anurans, an unexplored stage of the life of a group of organisms that participates in the most diverse ecosystem functions.

Acknowledgments

We thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial support to DAD, MJRP and TGS, and Reserva Biológica do Lami for all the support during the field activities. This study was done under ICMBIO license number 40180. We also thank all colleagues who helped during field and lab work and Eduardo Ferreira (CESAM/DBUA – UVS), Márcio Borges Martins (UFRGS) and Vinícius Bastazini (CNRS) for their comments on previous versions of the manuscript.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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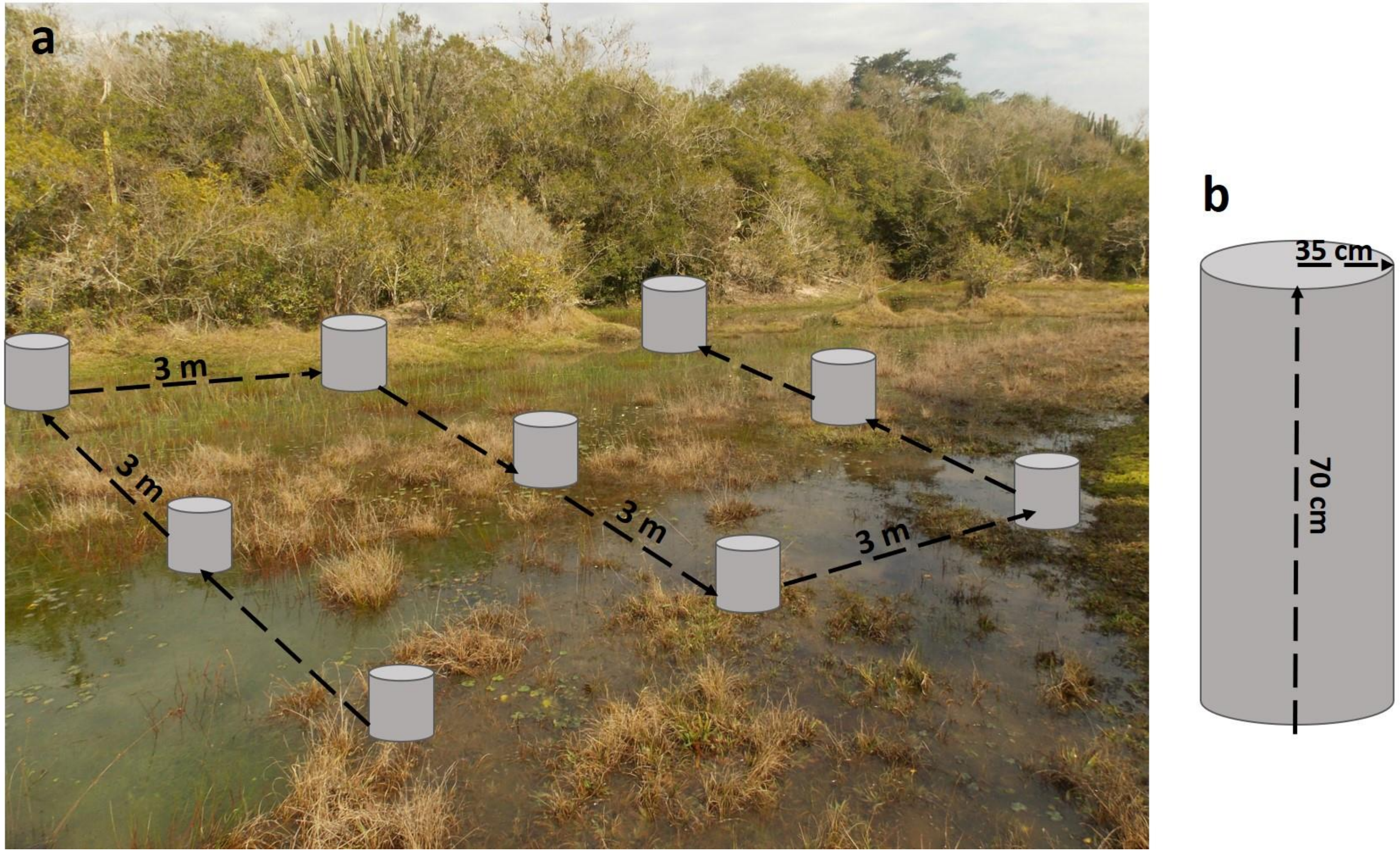
Supplementary Material relating to the material and methods section

S1 - Monthly average of the climate descriptors recorded for the city of Porto Alegre, Rio Grande do Sul, Brazil, in the period between September 2013 and August 2014.

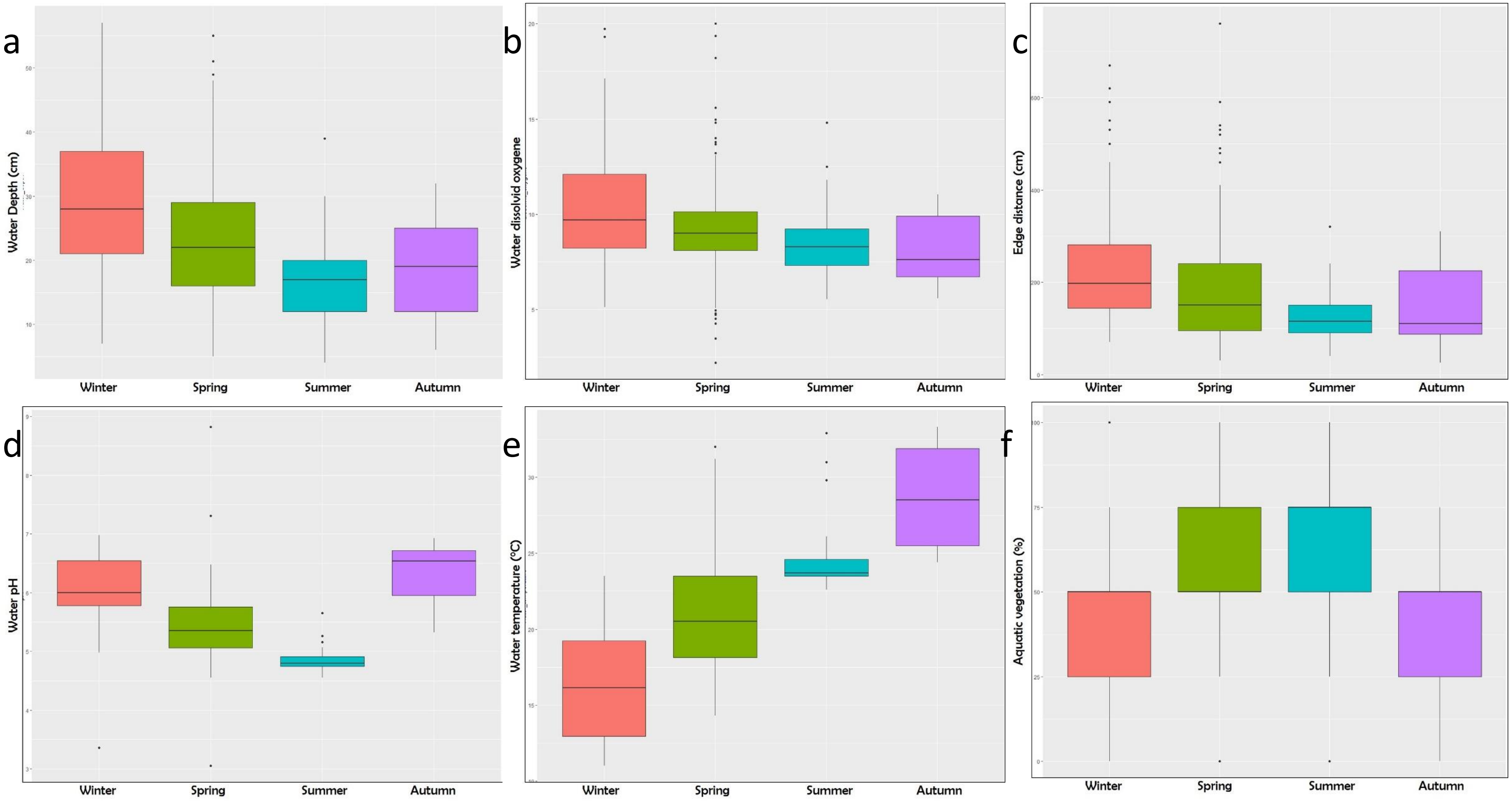
Month	Season	Photoperiod/day length (hours)	Total Precipitation (cm^3)	Maximum Temperature (°C)	Minimum Temperature (°C)	Air humidity (average)	Evaporation (average)
September/2013	Wet	137,7	135,3	21,2	13,6	78,3	55,9
October/2013	Wet	207,8	131,8	22,9	15	74,7	75,3
November/2013	Dry	258,1	184,6	26,5	17,47	71,1	107,1
December/2013	Dry	282,8	76,6	33,1	20,28	70,9	123,9
January/2014	Dry	244,9	76,8	33,8	21,9	71,2	106,7
February/2014	Dry	222,3	147,7	32,4	21,8	74,3	130,5
March/2014	Dry	191,3	126,4	29,8	19,41	77,7	106,9
April/2014	Dry	181,4	83,5	27,4	17,4	76,9	78,8
May/2014	Wet	134,7	71	21,6	13,67	83,8	47,1
June/2014	Wet	102,8	228,6	19,8	12,11	87,1	36,1
July/2014	Wet	154	253,5	21,16	11,29	82,8	38,3
August/2014	Wet	164,3	129,1	22,8	10,5	78,1	43,6



S2 – Scheme showing (a) the sampling procedure in transects and (b) the metal cylinder that was used to delimit the collection points and confine the tadpoles.

S3 – Number of points sampled in each pond across seasons

Pond	Spring	Summer	Autumn	Winter
Pond 1	12	0	0	3
Pond 2	49	17	9	17
Pond 3	10	0	0	6
Pond 4	41	7	16	9
Pond 5	45	8	5	21
Pond 6	23	4	0	7
Pond 7	6	0	0	0
Pond 8	29	6	3	14
Pond 9	9	0	0	6
Pond 10	11	0	0	8
Total	235	42	33	91


a
Water Depth (cm)
10
20
30
40
50
Winter
Spring
Summer
Autumn
b
Water dissolvid oxygene
5
10
15
20
Winter
Spring
Summer
Autumn
c
Edge distance (cm)
0
200
400
600
Winter
Spring
Summer
Autumn
d
Water pH
3
4
5
6
7
8
9
Winter
Spring
Summer
Autumn
e
Water temperature (°C)
15
20
25
30
Winter
Spring
Summer
Autumn
f
Aquatic vegetation (%)
0
25
50
75
100
Winter
Spring
Summer
Autumn

S4 – Boxplots showing the total variation in micro-habitats within each season of: a) water depth; b) dissolved oxygen; c) of distance from micro-habitats to the ponds' edge; d) pH of water; e) temperature of water; f) % aquatic vegetation.

S5 - Functional traits measured from different functional characteristics of tadpoles present in the studied ponds.

Functional trait	Characteristics measured	Variable
Body Height	body height/total length	Continuous
Body length	Body length/total length	Continuous
Body Width	Body Width/Total Length	Continuous
Caudal muscles width	maximum width of the caudal musculature/body length	Continuous
Dorsal fin height	maximum height of dorsal fin/ maximum height of the caudal musculature	Continuous
Ventral fin height	maximum height of ventral fin/ maximum height of the caudal musculature	Continuous
Number of teeth rows	Sum of number of forward and back rows	Continuous
Eye size	eye diameter / body length	Continuous
Oral disc position	Anteroventral; ventral	Categorical
Position in the water column	Benthic; nectonic	Categorical
Protection of eggs and early stages of life	protected in a foam nest; protected in natural or constructed basins; none/absent	Categorical
Presence of scourge	Present or absent	Binary

S6 – Variation Inflation Factor Analysis of tadpole traits.

Functional traits	VIF value
Body length	1.62
Body width	2.06
Body height	1.93

Width of caudal muscles	1.45
Dorsal fin height	1.52
Ventral fin height	1.22
Nostril size	1.03
Nostril position	2.06
Eye size	1.49
Spiracle length	1.34
Opening position of the spiracle	1.29
Presence of flagellum	1.17
Number of teeth rows	1.05
Oral disc position	2.76
Eye position	1.47
Eggs	1.21

S7 – Variation Inflation Factor Analysis of Environmental descriptors of micro-habitats.

Environmental descriptors	**VIF value**
Aquatic Vegetation	1.08
Depth	1.32
Dissolved Oxygen	1.02
Edge Distance	1.13
pH	1.10
Temperature	1.21

Supplementary Material relating to Results section

S8: Summary of adjusted models produced by GLMM analysis relating local descriptors and phylogenetic diversity in tadpole communities in ponds at Winter season (season with low hydric stress). Local descriptors: Depth (water column depth); Diss. ox. (dissolved oxygen); edge. dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	delta	weight
depth	4	-6,74016	22,04369	0	0,35449
null	3	-7,98018	22,2937	0,250001	0,295186
depth+temp.	5	-7,18605	25,22924	3,185548	0,068022
depth+diss.ox.	5	-7,37819	25,61352	3,569828	0,056131
pH	4	-8,89937	26,36212	4,318427	0,038605
diss.ox.	4	-8,9824	26,52817	4,48448	0,03553
temp.	4	-9,05298	26,66935	4,625651	0,033108
depth+pH	5	-7,97526	26,80766	4,763965	0,030896
edge.dist.	4	-9,85045	28,26428	6,220586	0,014914
depth+veget.	5	-8,81608	28,4893	6,445604	0,013327
veget.	4	-10,0666	28,69663	6,652935	0,012015
depth+diss.ox.+temp.	6	-7,87405	28,9655	6,921801	0,010503
depth+edge.dist.	5	-9,07621	29,00956	6,965864	0,010275
depth+pH+temp.	6	-8,21646	29,65032	7,606622	0,007458
pH+temp.	5	-9,63686	30,13087	8,087172	0,005865
depth+temp.+veget.	6	-8,94224	31,10187	9,058172	0,003609
diss.ox.+temp.	5	-10,2649	31,38695	9,34326	0,00313
depth+diss.ox.+pH	6	-9,09331	31,40401	9,36032	0,003103
diss.ox.+pH	5	-10,282	31,42105	9,377356	0,003077

depth+edge.dist.+temp.	6	-9,43735	32,0921	10,0484	0,0022
edge.dist.+temp.	5	-10,7146	32,28634	10,24264	0,001996
temp.+veget.	5	-10,8442	32,54556	10,50186	0,001754
depth+diss.ox.+veget.	6	-9,82216	32,86171	10,81802	0,001497
edge.dist.+pH	5	-11,0462	32,94959	10,90589	0,001433
depth+diss.ox.+edge.dist.	6	-9,95775	33,13289	11,08919	0,001307
diss.ox.+edge.dist.	5	-11,1649	33,18698	11,14328	0,001272
pH+veget.	5	-11,2013	33,25967	11,21597	0,001227
diss.ox.+veget.	5	-11,3332	33,52361	11,47992	0,001075
depth+pH+veget.	6	-10,2282	33,6737	11,63	0,000998
depth+diss.ox.+pH+temp.	7	-9,07951	33,80608	11,76239	0,000934
depth+edge.dist.+pH	6	-10,4453	34,10796	12,06427	0,000803
edge.dist.+veget.	5	-11,8157	34,48854	12,44485	0,000664
diss.ox.+pH+temp.	6	-10,9782	35,17377	13,13007	0,000471
depth+edge.dist.+veget.	6	-11,0419	35,30119	13,2575	0,000442
depthdiss.ox.+temp.+veget.	7	-9,87786	35,40278	13,35909	0,00042
depth+pH+temp.+veget.	7	-10,2959	36,23878	14,19509	0,000277
depth+diss.ox.+edge.dist.+temp.	7	-10,3276	36,3022	14,25851	0,000268
pH+temp.+veget.	6	-11,7541	36,72551	14,68182	0,000217
edge.dist.+pH+temp.	6	-11,7747	36,76671	14,72301	0,000212
depth+edge.dist.+pH+temp.	7	-10,7011	37,04922	15,00553	0,000184
diss.ox.+edge.dist.+temp.	6	-12,1957	37,60887	15,56517	0,000139
diss.ox.+temp.+veget.	6	-12,2191	37,65558	15,61188	0,000136
depth+edge.dist.+temp.+veget.	7	-11,1227	37,89242	15,84872	0,000121
edge.dist.+temp.+veget.	6	-12,4233	38,06396	16,02027	0,000111
diss.ox.+edge.dist.+pH	6	-12,6123	38,44197	16,39827	9,19E-05
diss.ox.+pH+veget.	6	-12,6893	38,59597	16,55228	8,51E-05
depth+diss.ox.+pH+veget.	7	-11,5066	38,66019	16,61649	8,24E-05
depth+diss.ox.+edge.dist.+pH	7	-11,6922	39,03145	16,98776	6,85E-05
edge.dist.+pH+veget.	6	-13,2478	39,71306	17,66936	4,87E-05
diss.ox.+edge.dist.+veget.	6	-13,4342	40,0857	18,04201	4,04E-05
depth+diss.ox.+edge.dist.+veget.	7	-12,3223	40,29165	18,24796	3,65E-05
depth+diss.ox.+pH+temp.+veget.	8	-11,3531	40,85542	18,81173	2,75E-05
depth+edge.dist.+pH+veget.	7	-12,6145	40,87604	18,83235	2,72E-05
depth+diss.ox.+edge.dist.+pH+temp.	8	-11,6586	41,46653	19,42284	2,03E-05
diss.ox.+edge.dist.+pH+temp.	7	-13,2099	42,06694	20,02325	1,50E-05
diss.ox.+pH+temp.+veget.	7	-13,2376	42,12222	20,07852	1,46E-05
depth+diss.ox.+edge.dist.+temp.+veget.	8	-12,2946	42,73852	20,69482	1,07E-05

edge.dist.+pH+temp.+veget.	7	-13,8135	43,27403	21,23033	8,21E-06
depth+edge.dist.+pH+temp.+veget.	8	-12,7142	43,5777	21,53401	7,05E-06
diss.ox.+edge.dist.+temp.+veget.	7	-14,0989	43,84478	21,80108	6,17E-06
diss.ox.+edge.dist.+pH+veget.	7	-14,9669	45,5809	23,53721	2,59E-06
depth+diss.ox.+edge.dist.+pH+veget.	8	-14,0591	46,26745	24,22376	1,84E-06
depth+diss.ox.+edge.dist.+pH+temp.+ veget.	9	-13,896	48,51932	26,47563	5,96E-07
diss.ox.+edge.dist.+pH+temp.+veget.	8	-15,4205	48,99025	26,94656	4,71E-07

S9: Summary of adjusted models produced by GLMM analysis relating local descriptors and phylogenetic diversity in tadpole communities in ponds in the Spring (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	delta	weight
null	3	-9,99194	26,09982	0	0,891468
temp.	4	-12,6134	33,42099	7,321165	0,022926
depth	4	-12,7333	33,66068	7,560853	0,020337
pH	4	-12,9769	34,14792	8,048093	0,01594
diss.ox.	4	-12,9907	34,17562	8,075797	0,015721
veget.	4	-13,0593	34,31276	8,212933	0,014679
edge.dist.	4	-13,1135	34,42117	8,321348	0,013904
depth+temp.	5	-15,4158	41,12438	15,02456	0,000487
pH+temp.	5	-15,5723	41,43735	15,33753	0,000416
diss.ox.+temp.	5	-15,6198	41,53238	15,43255	0,000397
temp.+veget.	5	-15,6914	41,67549	15,57567	0,00037
depth+pH	5	-15,6931	41,67892	15,57909	0,000369
depth+diss.ox.	5	-15,7423	41,77736	15,67754	0,000351
edge.dist.+temp.	5	-15,7442	41,78102	15,68119	0,000351
depth+veget.	5	-15,8167	41,92609	15,82626	0,000326
depth+edge.dist.	5	-15,8416	41,9759	15,87607	0,000318
diss.ox.+pH	5	-15,9747	42,24207	16,14225	0,000279
pH+veget.	5	-16,0411	42,37491	16,27508	0,000261
diss.ox.+veget.	5	-16,0566	42,40585	16,30603	0,000257
edge.dist.+pH	5	-16,0883	42,46932	16,36949	0,000249
diss.ox.+edge.dist.	5	-16,1066	42,50589	16,40606	0,000244
edge.dist.+veget.	5	-16,1804	42,65346	16,55364	0,000227
depth+pH+temp.	6	-18,3543	49,12035	23,02052	8,94E-06
depth+diss.ox.+temp.	6	-18,423	49,25771	23,15789	8,35E-06
depth+temp.+veget.	6	-18,5014	49,41456	23,31474	7,72E-06
depth+edge.dist.+temp.	6	-18,5227	49,45723	23,35741	7,55E-06
diss.ox.+pH+temp.	6	-18,5771	49,56601	23,46618	7,15E-06
pH+temp.+veget.	6	-18,6477	49,70725	23,60742	6,67E-06
edge.dist.+pH+temp.	6	-18,6908	49,79337	23,69354	6,38E-06

diss.ox.+temp.+veget.	6	-18,6952	49,80223	23,70241	6,36E-06
depth+diss.ox.+pH	6	-18,7017	49,81509	23,71527	6,32E-06
diss.ox.+edge.dist.+temp.	6	-18,7447	49,90116	23,80133	6,05E-06
depth+pH+veget.	6	-18,7745	49,96069	23,86087	5,87E-06
depth+edge.dist.+pH	6	-18,7745	49,96071	23,86088	5,87E-06
edge.dist.+temp.+veget.	6	-18,8207	50,05314	23,95331	5,61E-06
depth+diss.ox.+veget.	6	-18,8233	50,0584	23,95857	5,59E-06
depth+diss.ox.+edge.dist.	6	-18,8456	50,10295	24,00313	5,47E-06
depth+edge.dist.+veget.	6	-18,9221	50,25602	24,15619	5,07E-06
diss.ox.+pH+veget.	6	-19,0375	50,48668	24,38686	4,51E-06
diss.ox.+edge.dist.+pH	6	-19,0802	50,57226	24,47244	4,32E-06
edge.dist.+pH+veget.	6	-19,152	50,71567	24,61584	4,03E-06
diss.ox.+edge.dist.+veget.	6	-19,1721	50,75592	24,65609	3,95E-06
depth+diss.ox.+pH+temp.	7	-21,3598	57,27125	31,17142	1,52E-07
depth+edge.dist.+pH+temp.	7	-21,431	57,41364	31,31381	1,41E-07
depth+pH+temp.+veget.	7	-21,438	57,42771	31,32789	1,40E-07
depth+diss.ox.+pH+temp.	7	-21,5058	57,56334	31,46351	1,31E-07
depth+diss.ox.+edge.dist.+temp.	7	-21,5246	57,60091	31,50108	1,29E-07
depth+edge.dist.+temp.+veget.	7	-21,6054	57,76254	31,66272	1,19E-07
diss.ox.+pH+temp.+veget.	7	-21,6499	57,85162	31,7518	1,14E-07
diss.ox.+edge.dist.+pH+temp.	7	-21,6892	57,93019	31,83037	1,09E-07
edge.dist.+pH+temp.+veget.	7	-21,7645	58,0807	31,98088	1,01E-07
depth+diss.ox.+edge.dist.+pH	7	-21,7782	58,10805	32,00823	9,99E-08
depth+diss.ox.+pH+veget.	7	-21,7805	58,11277	32,01295	9,97E-08
diss.ox.+edge.dist.+temp.+veget.	7	-21,8186	58,18897	32,08915	9,59E-08
depth+edge.dist.+pH+veget.	7	-21,8532	58,25807	32,15824	9,27E-08
depth+diss.ox.+edge.dist.+veget.	7	-21,9235	58,39881	32,29899	8,64E-08
diss.ox.+edge.dist.+pH+veget.	7	-22,1425	58,83672	32,7369	6,94E-08
depth+diss.ox.+edge.dist.+pH+temp.	8	-24,4306	65,57417	39,47434	2,39E-09
depth+diss.ox.+pH+temp.+veget.	8	-24,4408	65,5944	39,49457	2,37E-09
depth+edge.dist.+pH+temp.+veget.	8	-24,5121	65,73709	39,63727	2,20E-09
depth+diss.ox.+edge.dist.+temp.+veget.	8	-24,6045	65,92179	39,82197	2,01E-09
diss.ox.+edge.dist.+pH+temp.+veget.	8	-24,7604	66,23362	40,1338	1,72E-09
depth+diss.ox.+edge.dist.+pH+veget.	8	-24,8543	66,42141	40,32159	1,56E-09
depth+diss.ox.+edge.dist.+pH+temp.+ veget.	9	-27,509	73,91355	47,81373	3,69E-11

S15: Summary of adjusted models produced by GLMM analysis relating local descriptors and phylogenetic diversity in tadpole communities in ponds in the Summer (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	delta	weight
null	3	-5,09569	17,15138	0	0,568755

temp.	4	-5,49076	20,64819	3,496806	0,098993
pH	4	-5,90338	21,47342	4,322036	0,065525
diss.ox.	4	-6,05522	21,7771	4,625716	0,056294
edge.dist.	4	-6,26452	22,19571	5,044331	0,045663
depth	4	-6,3351	22,33687	5,185492	0,042551
veget.	4	-6,79761	23,26188	6,1105	0,026795
pH+temp.	5	-5,99517	24,59903	7,447645	0,013731
edge.dist.+pH	5	-6,01013	24,62895	7,477567	0,013527
depth+pH	5	-6,66672	25,94214	8,790755	0,007015
edge.dist.+temp.	5	-6,73785	26,0844	8,933021	0,006533
diss.ox.+pH	5	-6,82715	26,263	9,111621	0,005975
temp.+veget.	5	-6,84112	26,29094	9,13956	0,005892
diss.ox.+temp.	5	-7,01365	26,63599	9,484606	0,004959
depth+temp.	5	-7,02605	26,66079	9,509408	0,004898
diss.ox.+edge.dist.	5	-7,20413	27,01696	9,865582	0,004099
depth+veget.	5	-7,24182	27,09233	9,940948	0,003947
depth+edge.dist.	5	-7,41542	27,43953	10,28815	0,003318
edge.dist.+veget.	5	-7,42857	27,46584	10,31445	0,003275
depth+diss.ox.	5	-7,57915	27,767	10,61561	0,002817
pH+veget.	5	-7,60341	27,81551	10,66413	0,002749
diss.ox.+veget.	5	-7,75303	28,11475	10,96337	0,002367
edge.dist.+pH+temp.	6	-6,71967	29,25752	12,10614	0,001337
diss.ox.+edge.dist.+pH	6	-7,00198	29,82215	12,67076	0,001008
depth+edge.dist.+pH	6	-7,27169	30,36156	13,21018	0,00077
edge.dist.+pH+veget.	6	-7,28464	30,38746	13,23608	0,00076
depth+pH+temp.	6	-7,30324	30,42467	13,27328	0,000746
pH+temp.+veget.	6	-7,46604	30,75027	13,59889	0,000634
diss.ox.+pH+temp.	6	-7,55762	30,93341	13,78203	0,000578
depth+pH+veget.	6	-7,62512	31,06841	13,91703	0,000541
edge.dist.+temp.+veget.	6	-7,94845	31,71509	14,5637	0,000391
depth+temp.+veget.	6	-7,96896	31,7561	14,60472	0,000383
depth+diss.ox.+pH	6	-8,0164	31,85098	14,6996	0,000366
depth+edge.dist.+temp.	6	-8,0826	31,98337	14,83199	0,000342
depth+edge.dist.+veget.	6	-8,20224	32,22266	15,07128	0,000304
diss.ox.+edge.dist.+temp.	6	-8,25327	32,32472	15,17334	0,000288
diss.ox.+temp.+veget.	6	-8,42297	32,66412	15,51274	0,000243
diss.ox.+edge.dist.+veget.	6	-8,42722	32,67262	15,52123	0,000242
diss.ox.+pH+veget.	6	-8,53349	32,88516	15,73378	0,000218
depth+diss.ox.+temp.	6	-8,53977	32,89771	15,74633	0,000217
depth+diss.ox.+edge.dist.	6	-8,66237	33,14292	15,99154	0,000192
depth+diss.ox.+veget.	6	-8,66376	33,1457	15,99431	0,000191
edge.dist.+pH+temp.+veget.	7	-7,65447	34,64226	17,49088	9,05E-05
depth+edge.dist.+pH+veget.	7	-7,90556	35,14446	17,99308	7,04E-05
diss.ox.+edge.dist.+pH+temp.	7	-8,04307	35,41947	18,26809	6,14E-05
depth+edge.dist.+pH+temp.	7	-8,0967	35,52673	18,37534	5,82E-05
depth+pH+temp.+veget.	7	-8,30445	35,94223	18,79085	4,73E-05
depth+diss.ox.+edge.dist.+pH	7	-8,418	36,16934	19,01795	4,22E-05
diss.ox.+edge.dist.+pH+veget.	7	-8,48033	36,294	19,14262	3,96E-05

depth+diss.ox.+pH+temp.	7	-8,8904	37,11414	19,96276	2,63E-05
diss.ox.+pH+temp.+veget.	7	-9,05577	37,44487	20,29349	2,23E-05
depth+edge.dist.+temp.+veget.	7	-9,06178	37,45689	20,3055	2,22E-05
depth+diss.ox.+pH+veget.	7	-9,10512	37,54358	20,39219	2,12E-05
diss.ox.+edge.dist.+temp.+veget.	7	-9,41288	38,1591	21,00772	1,56E-05
depth+diss.ox.+edge.dist.+veget.	7	-9,52832	38,38997	21,23858	1,39E-05
depth+diss.ox.+temp.+veget.	7	-9,56646	38,46625	21,31487	1,34E-05
depth+diss.ox.+edge.dist.+temp.	7	-9,62528	38,58389	21,43251	1,26E-05
depth+edge.dist.+pH+temp.+veget.	8	-8,67516	40,55032	23,39893	4,72E-06
diss.ox.+edge.dist.+pH+veget.+temp.	8	-9,20356	41,60711	24,45573	2,78E-06
depth+diss.ox.+edge.dist.+pH+veget.	8	-9,42122	42,04244	24,89106	2,24E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	-9,43232	42,06465	24,91327	2,21E-06
depth+diss.ox.+pH+temp.+veget.	8	-9,91925	43,03849	25,88711	1,36E-06
depth+diss.ox.+edge.dist.+temp.+veget.	8	-10,5586	44,31727	27,16589	7,18E-07
depth+diss.ox.+edge.dist.+pH+temp.+ veget.	9	-10,2583	47,99025	30,83886	1,14E-07

S10: Summary of adjusted models produced by GLMM analysis relating local descriptors and phylogenetic diversity in tadpole communities in ponds in the Autumn (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	8,546509	-10,0495	0	0,739697
veget.	4	7,275804	-4,73343	5,316112	0,051841
temp.	4	7,249725	-4,68127	5,368272	0,050507
edge.dist.	4	7,188721	-4,55926	5,490279	0,047518
pH	4	6,896197	-3,97421	6,075326	0,035466
depth	4	6,52309	-3,228	6,821541	0,024422
diss.ox.	4	6,381929	-2,94568	7,103862	0,021207
pH+temp.	5	5,928931	0,99928	11,04882	0,00295
temp.+veget.	5	5,823815	1,209512	11,25905	0,002656
edge.dist.+veget.	5	5,75536	1,346424	11,39596	0,00248
edge.dist.+pH	5	5,722968	1,411207	11,46075	0,002401
edge.dist.+temp.	5	5,71512	1,426902	11,47644	0,002382
pH+veget.	5	5,683607	1,489929	11,53947	0,002308
depth+diss.ox.	5	5,618333	1,620476	11,67002	0,002162
diss.ox.+temp.	5	5,323733	2,209678	12,25922	0,001611
depth+temp.	5	5,300832	2,25548	12,30502	0,001574
depth+edge.dist.	5	5,12443	2,608282	12,65782	0,00132
diss.ox.+veget.	5	5,101567	2,654009	12,70355	0,00129
depth+veget.	5	5,027298	2,802546	12,85208	0,001197
diss.ox.+edge.dist.	5	5,00792	2,841303	12,89084	0,001174
depth+pH	5	4,98243	2,892283	12,94182	0,001145
diss.ox.+pH	5	4,748799	3,359545	13,40908	0,000906
edge.dist.+pH+temp.	6	4,57107	7,057859	17,1074	0,000143
pH+temp.+veget.	6	4,458644	7,282711	17,33225	0,000127

depth+diss.ox.+temp.	6	4,354273	7,491454	17,54099	0,000115
edge.dist.+pH+veget.	6	4,34385	7,5123	17,56184	0,000114
depth+diss.ox.+pH	6	4,338109	7,523781	17,57332	0,000113
edge.dist.+temp.+veget.	6	4,219934	7,760132	17,80967	0,0001
depth+diss.ox.+edge.dist.	6	4,219208	7,761584	17,81112	0,0001
diss.ox.+pH+temp.	6	4,208257	7,783485	17,83302	9,92E-05
diss.ox.+temp.+veget.	6	4,188031	7,823937	17,87348	9,72E-05
depth+diss.ox.+veget.	6	4,12261	7,95478	18,00432	9,11E-05
depth+pH+temp.	6	4,052262	8,095476	18,14501	8,49E-05
depth+temp.+veget.	6	3,951511	8,296978	18,34652	7,68E-05
depth+edge.dist.+temp.	6	3,929132	8,341737	18,39128	7,51E-05
depth+pH+edge.dist.	6	3,849742	8,500516	18,55005	6,93E-05
diss.ox.+edge.dist.+temp.	6	3,769659	8,660682	18,71022	6,40E-05
diss.ox.+edge.dist.+veget.	6	3,581692	9,036616	19,08616	5,30E-05
diss.ox.+edge.dist.+pH	6	3,55109	9,09782	19,14736	5,14E-05
depth+pH+veget.	6	3,52484	9,15032	19,19986	5,01E-05
diss.ox.+pH+veget.	6	3,519755	9,16049	19,21003	4,98E-05
depth+edge.dist.+veget.	6	3,502226	9,195548	19,24509	4,90E-05
depth+diss.ox.+pH+temp.	7	3,420189	13,05436	23,1039	7,11E-06
depth+diss.ox.+edge.dist.+pH	7	3,416418	13,0619	23,11144	7,09E-06
edge.dist.+pH+temp.+veget.	7	3,015814	13,86311	23,91265	4,75E-06
depth+diss.ox.+pH+temp.	7	3,014516	13,8657	23,91524	4,74E-06
depth+diss.ox.+edge.dist.+temp.	7	3,0055	13,88374	23,93328	4,70E-06
diss.ox.+pH+temp.+veget.	7	2,98355	13,92764	23,97718	4,60E-06
depth+edge.dist.+pH+temp.	7	2,917975	14,05879	24,10833	4,31E-06
depth+diss.ox.+pH+veget.	7	2,887188	14,12036	24,1699	4,17E-06
diss.ox.+edge.dist.+pH+temp.	7	2,780689	14,33336	24,3829	3,75E-06
depth+pH+temp.+veget.	7	2,630889	14,63296	24,6825	3,23E-06
depth+diss.ox.+edge.dist.+veget.	7	2,601655	14,69143	24,74097	3,14E-06
diss.ox.+edge.dist.+temp.+veget.	7	2,473433	14,94787	24,99741	2,76E-06
depth+edge.dist.+temp.+veget.	7	2,396155	15,10243	25,15197	2,55E-06
depth+edge.dist.+temp.+veget.	7	2,216456	15,46182	25,51136	2,13E-06
diss.ox.+edge.dist.+pH+veget.	7	2,160943	15,57285	25,62239	2,02E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	2,529287	18,94143	28,99096	3,75E-07
depth+diss.ox.+pH+temp.+veget.	8	1,98694	20,02612	30,07566	2,18E-07
depth+diss.ox.+edge.dist.+pH+veget.	8	1,770675	20,45865	30,50819	1,76E-07
depth+diss.ox.+edge.dist.+temp.+veget.	8	1,478071	21,04386	31,0934	1,31E-07
diss.ox.+edge.dist.+pH+temp.+veget.	8	1,390355	21,21929	31,26883	1,20E-07
depth+edge.dist.+pH+temp.+veget.	8	1,296098	21,4078	31,45734	1,09E-07
depth+diss.ox.+edge.dist.+pH+temp.+ veget.	9	0,889692	26,80885	36,85839	7,33E-09

S11: Summary of adjusted models produced by GLMM analysis relating local descriptors and phylogenetic redundancy in tadpole communities in ponds in the Winter (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	9	-1137,94	2296,598	0	0,999988
depth+diss.ox.+edge.dist.+pH+temp.+ veget.	8	-1151,79	2321,725	25,12764	3,50E-06
depth+diss.ox.+pH+temp.+veget.	8	-1151,82	2321,789	25,19087	3,39E-06
depth+diss.ox.+edge.dist.+temp.+veget.	8	-1151,95	2322,049	25,45131	2,97E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	-1152,65	2323,449	26,85073	1,48E-06
diss.ox.+edge.dist.+pH+temp.+veget.	8	-1153,52	2325,193	28,59477	6,18E-07
depth+edge.dist.+pH+temp.+veget.	8	-1156,32	2330,791	34,19341	3,76E-08
depth+diss.ox.+edge.dist.+pH+veget.	7	-1165,68	2347,016	50,41842	1,13E-11
depth+diss.ox.+temp.+veget.	7	-1165,8	2347,244	50,64595	1,01E-11
depth+diss.ox.+edge.dist.+temp.	7	-1165,9	2347,438	50,84069	9,12E-12
depth+diss.ox.+pH+temp.	7	-1166,36	2348,36	51,76227	5,75E-12
diss.ox.+pH+temp.+veget.	7	-1166,54	2348,724	52,12617	4,80E-12
diss.ox.+edge.dist.+temp.+veget.	7	-1166,63	2348,911	52,31293	4,37E-12
diss.ox.+edge.dist.+pH+temp.	7	-1167,25	2350,148	53,55027	2,35E-12
depth+pH+temp.+veget.	7	-1167,43	2350,497	53,89961	1,98E-12
depth+edge.dist.+temp.+veget.	7	-1167,78	2351,209	54,61116	1,38E-12
depth+edge.dist.+pH+temp.	7	-1168,02	2351,692	55,09424	1,09E-12
edge.dist.+pH+temp.+veget.	7	-1170,12	2355,894	59,29589	1,33E-13
depth+diss.ox.+pH+veget.	7	-1170,25	2356,143	59,54534	1,17E-13
depth+diss.ox.+edge.dist.+veget.	7	-1170,36	2356,376	59,77868	1,05E-13
depth+diss.ox.+edge.dist.+pH	7	-1170,74	2357,133	60,53482	7,16E-14
diss.ox.+edge.dist.+pH+veget.	7	-1171,63	2358,898	62,30019	2,96E-14
depth+edge.dist.+temp.+veget.	6	-1179,73	2372,685	76,08765	3,00E-17
depth+diss.ox.+temp.	6	-1180,23	2373,677	77,07952	1,83E-17
diss.ox.+temp.+veget.	6	-1180,42	2374,062	77,46412	1,51E-17
diss.ox.+pH+temp.	6	-1180,51	2374,246	77,64868	1,38E-17
diss.ox.+edge.dist.+temp.	6	-1181,15	2375,509	78,91092	7,32E-18
depth+temp.+veget.	6	-1181,59	2376,39	79,79265	4,71E-18
depth+pH+temp.	6	-1181,65	2376,52	79,92255	4,42E-18
pH+temp.+veget.	6	-1181,68	2376,586	79,98785	4,27E-18
depth+edge.dist.+temp.	6	-1181,93	2377,084	80,48637	3,33E-18
edge.dist.+temp.+veget.	6	-1182,25	2377,713	81,11551	2,43E-18
edge.dist.+pH+temp.	6	-1184,03	2381,286	84,68791	4,08E-19
depth+diss.ox.+veget.	6	-1184,24	2381,695	85,0971	3,32E-19
depth+diss.ox.+pH	6	-1184,27	2381,764	85,16662	3,21E-19
depth+diss.ox.+edge.dist.	6	-1184,42	2382,065	85,46723	2,76E-19
diss.ox.+pH+veget.	6	-1184,68	2382,569	85,97156	2,15E-19
diss.ox.+edge.dist.+veget.	6	-1184,77	2382,748	86,15072	1,96E-19
diss.ox.+edge.dist.+pH	6	-1185,33	2383,875	87,27713	1,12E-19
depth+pH+veget.	6	-1185,58	2384,368	87,77031	8,73E-20
depth+edge.dist.+veget.	6	-1185,85	2384,924	88,32609	6,61E-20
depth+edge.dist.+pH	6	-1185,89	2385,002	88,40443	6,36E-20
edge.dist.+pH+veget.	5	-1194,27	2399,389	102,7908	4,78E-23
diss.ox.+temp.	5	-1195,45	2401,766	105,1682	1,46E-23
depth+temp.	5	-1195,54	2401,935	105,3369	1,34E-23
temp.+veget.	5	-1195,94	2402,73	106,1322	8,99E-24

pH+temp.	5	-1196,19	2403,233	106,635	6,99E-24
edge.dist.+temp.	5	-1198,13	2407,122	110,5241	1,00E-24
depth+diss.ox.	5	-1198,34	2407,527	110,9297	8,16E-25
diss.ox.+veget.	5	-1198,5	2407,849	111,2509	6,95E-25
diss.ox.+pH	5	-1198,68	2408,218	111,6199	5,78E-25
diss.ox.+edge.dist.	5	-1199,25	2409,364	112,766	3,26E-25
depth+veget.	5	-1199,52	2409,894	113,2963	2,50E-25
pH+veget.	5	-1199,62	2410,103	113,5049	2,25E-25
depth+pH	5	-1199,81	2410,479	113,8807	1,87E-25
depth+edge.dist.	5	-1199,85	2410,555	113,9575	1,80E-25
edge.dist.+veget.	5	-1200,09	2411,036	114,4387	1,41E-25
edge.dist.+pH	4	-1209,83	2428,214	131,6161	2,63E-29
temp.	4	-1212,39	2433,346	136,748	2,02E-30
diss.ox.	4	-1213,45	2435,462	138,8638	7,02E-31
veget.	4	-1213,55	2435,666	139,068	6,34E-31
depth	4	-1213,76	2436,081	139,4828	5,15E-31
pH	4	-1214,06	2436,675	140,0769	3,83E-31
edge.dist.	3	-1227,7	2461,726	165,1277	1,39E-36

S12: Summary of adjusted models produced by GLMM analysis relating local descriptors and phylogenetic redundancy in tadpole communities in ponds in the Spring (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	9	-3317,32	6653,532	0	0,999975
depth+diss.ox.+edge.dist.+pH+temp.+veget.	8	-3330,42	6677,549	24,01641	6,09E-06
depth+edge.dist.+pH+temp.+veget.	8	-3330,61	6677,938	24,40516	5,02E-06
depth+diss.ox.+pH+temp.+veget.	8	-3330,81	6678,342	24,81008	4,10E-06
depth+diss.ox.+edge.dist.+pH+veget.	8	-3330,85	6678,405	24,87251	3,97E-06
depth+diss.ox.+edge.dist.+temp.+veget.	8	-3330,88	6678,481	24,94844	3,82E-06
diss.ox.+edge.dist.+pH+temp.+veget.	8	-3331,52	6679,755	26,22215	2,02E-06
depth+diss.ox.+edge.dist.+pH+temp.	7	-3343,71	6701,974	48,4421	3,03E-11
depth+pH+temp.+veget.	7	-3343,9	6702,347	48,81488	2,51E-11

depth+edge.dist.+pH+veget.	7	-3343,94	6702,441	48,90878	2,40E-11
depth+edge.dist.+temp.+veget.	7	-3343,99	6702,529	48,99692	2,29E-11
edge.dist.+pH+temp.+veget.	7	-3344,07	6702,696	49,16357	2,11E-11
depth+diss.ox.+pH+veget.	7	-3344,27	6703,084	49,55195	1,74E-11
diss.ox.+edge.dist.+temp.+veget.	7	-3344,28	6703,114	49,58141	1,71E-11
depth+diss.ox.+temp.+veget.	7	-3344,31	6703,162	49,62995	1,67E-11
diss.ox.+edge.dist.+pH+veget.	7	-3344,41	6703,366	49,8339	1,51E-11
depth+diss.ox.+edge.dist.+veget.	7	-3344,42	6703,394	49,86141	1,49E-11
diss.ox.+pH+temp.+veget.	7	-3344,63	6703,812	50,27984	1,21E-11
depth+edge.dist.+pH+temp.	7	-3344,83	6704,204	50,67168	9,93E-12
depth+diss.ox.+pH+temp.	7	-3344,99	6704,539	51,00673	8,39E-12
depth+diss.ox.+edge.dist.+temp.	7	-3345,03	6704,618	51,08536	8,07E-12
diss.ox.+edge.dist.+pH+temp.	7	-3345,05	6704,652	51,11997	7,93E-12
depth+diss.ox.+edge.dist.+pH	6	-3357,16	6726,732	73,19955	1,27E-16
depth+pH+veget.	6	-3357,36	6727,138	73,60566	1,04E-16
edge.dist.+pH+veget.	6	-3357,37	6727,156	73,62323	1,03E-16
edge.dist.+temp.+veget.	6	-3357,38	6727,17	73,63719	1,02E-16
depth+temp.+veget.	6	-3357,49	6727,388	73,8558	9,17E-17
depth+edge.dist.+veget.	6	-3357,52	6727,457	73,9242	8,86E-17
pH+temp.+veget.	6	-3357,74	6727,896	74,36325	7,12E-17
diss.ox.+edge.dist.+veget.	6	-3357,77	6727,946	74,41364	6,94E-17
diss.ox.+pH+veget.	6	-3357,8	6728,019	74,48689	6,69E-17
depth+diss.ox.+veget.	6	-3357,94	6728,286	74,7539	5,85E-17
depth+pH+temp.	6	-3357,94	6728,289	74,75631	5,85E-17
diss.ox.+temp.+veget.	6	-3358,1	6728,611	75,07815	4,98E-17
depth+edge.dist.+temp.	6	-3358,14	6728,687	75,15455	4,79E-17
edge.dist.+pH+temp.	6	-3358,15	6728,714	75,18142	4,73E-17
depth+edge.dist.+pH	6	-3358,32	6729,047	75,51427	4,00E-17
depth+diss.ox.+pH	6	-3358,38	6729,176	75,64349	3,75E-17
diss.ox.+edge.dist.+temp.	6	-3358,43	6729,275	75,74257	3,57E-17
depth+diss.ox.+temp.	6	-3358,48	6729,374	75,84146	3,40E-17

diss.ox.+edge.dist.+pH	6	-3358,55	6729,518	75,98611	3,16E-17
diss.ox.+pH+temp.	6	-3358,59	6729,583	76,05024	3,06E-17
depth+diss.ox.+edge.dist.	5	-3370,8	6751,892	98,35993	4,38E-22
edge.dist.+veget.	5	-3370,82	6751,942	98,40985	4,27E-22
pH+veget.	5	-3370,89	6752,077	98,54483	3,99E-22
depth+veget.	5	-3371,04	6752,375	98,8427	3,44E-22
temp.+veget.	5	-3371,33	6752,958	99,42592	2,57E-22
diss.ox.+veget.	5	-3371,43	6753,143	99,61106	2,34E-22
depth+pH	5	-3371,49	6753,266	99,73386	2,20E-22
edge.dist.+temp.	5	-3371,54	6753,368	99,836	2,09E-22
depth+temp.	5	-3371,55	6753,4	99,86732	2,06E-22
edge.dist.+pH	5	-3371,66	6753,603	100,0705	1,86E-22
pH+temp.	5	-3371,68	6753,651	100,119	1,82E-22
depth+edge.dist.	5	-3371,88	6754,056	100,5241	1,48E-22
diss.ox.+edge.dist.	5	-3371,92	6754,142	100,6099	1,42E-22
diss.ox.+pH	5	-3371,99	6754,263	100,7309	1,34E-22
depth+diss.ox.	5	-3372,02	6754,342	100,8093	1,29E-22
diss.ox.+temp.	4	-3384,39	6776,975	123,4427	1,57E-27
veget.	4	-3384,95	6778,101	124,5685	8,92E-28
edge.dist.	4	-3385	6778,187	124,6548	8,54E-28
pH	4	-3385,09	6778,37	124,8374	7,80E-28
depth	4	-3385,13	6778,447	124,9148	7,50E-28
temp.	4	-3385,44	6779,078	125,5452	5,47E-28
diss.ox.	3	-3398,51	6803,141	149,6089	3,26E-33

S13: Summary of adjusted models produced by GLMM analysis relating local descriptors and phylogenetic redundancy in tadpole communities in ponds in the Summer (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	9	-362,788	753,0503	0	0,999987
depth+diss.ox.+edge.dist.+pH+temp.+veget.	8	-377,298	777,796	24,74568	4,23E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	-377,646	778,4924	25,44215	2,99E-06

depth+edge.dist.+pH+temp.+veget.	8	-378,08	779,3607	26,31036	1,94E-06
depth+diss.ox.+edge.dist.+temp.+veget.	8	-378,213	779,6264	26,57614	1,69E-06
diss.ox.+edge.dist.+pH+temp.+veget.	8	-378,332	779,8633	26,81301	1,51E-06
depth+diss.ox.+edge.dist.+pH+veget.	8	-380,036	783,2716	30,22132	2,74E-07
depth+diss.ox.+pH+temp.+veget.	7	-391,927	803,1869	50,13666	1,30E-11
depth+edge.dist.+pH+temp.+	7	-392,573	804,4787	51,42841	6,80E-12
depth+diss.ox.+edge.dist.+temp.	7	-392,733	804,7998	51,74949	5,79E-12
depth+diss.ox.+edge.dist.+pH	7	-392,797	804,9279	51,87762	5,43E-12
depth+edge.dist.+pH+veget.	7	-392,932	805,1966	52,14635	4,75E-12
depth+edge.dist.+temp.+veget.	7	-393,166	805,6645	52,61417	3,76E-12
diss.ox.+edge.dist.+pH+temp.	7	-393,48	806,2939	53,24361	2,74E-12
diss.ox.+edge.dist.+pH+veget.	7	-393,486	806,3058	53,25549	2,73E-12
edge.dist.+pH+temp.+veget.	7	-393,518	806,3696	53,31935	2,64E-12
diss.ox.+edge.dist.+temp.+veget.	7	-393,632	806,5979	53,54759	2,36E-12
depth+diss.ox.+edge.dist.+veget.	7	-394,689	808,7114	55,66114	8,19E-13
depth+pH+temp.+veget.	7	-394,689	808,7121	55,66185	8,19E-13
depth+diss.ox.+pH+temp.	7	-394,846	809,0251	55,97481	7,00E-13
diss.ox.+pH+temp.+veget.	7	-395,359	810,0513	57,00104	4,19E-13
depth+diss.ox.+pH+veget.	7	-395,688	810,71	57,65968	3,02E-13
depth+diss.ox.+temp.+veget.	6	-407,067	829,9524	76,90215	2,00E-17
depth+edge.dist.+pH	6	-407,164	830,1459	77,09558	1,82E-17
depth+edge.dist.+temp.	6	-408,002	831,8225	78,77219	7,85E-18
depth+diss.ox.+edge.dist.	6	-408,019	831,8554	78,80512	7,72E-18
edge.dist.+pH+temp.	6	-408,094	832,006	78,95568	7,16E-18
depth+edge.dist.+veget.	6	-408,127	832,0713	79,02104	6,93E-18
diss.ox.+edge.dist.+pH	6	-408,252	832,3229	79,27259	6,11E-18
edge.dist.+pH+veget.	6	-408,508	832,8334	79,78312	4,73E-18
diss.ox.+edge.dist.+temp.	6	-408,746	833,3102	80,25993	3,73E-18
diss.ox.+edge.dist.+veget.	6	-408,784	833,3869	80,33664	3,59E-18
edge.dist.+temp.+veget.	6	-409,114	834,0469	80,99665	2,58E-18
depth+pH+temp.	6	-409,568	834,9533	81,90299	1,64E-18
pH+temp.+veget.	6	-409,605	835,0275	81,97721	1,58E-18
diss.ox.+pH+temp.	6	-409,792	835,403	82,3527	1,31E-18
depth+pH+veget.	6	-409,885	835,5885	82,53825	1,19E-18
depth+diss.ox.+pH	6	-410,104	836,0266	82,97634	9,59E-19
diss.ox.+pH+veget.	6	-410,302	836,4224	83,37209	7,87E-19
depth+diss.ox.+temp.	6	-410,382	836,5827	83,53245	7,26E-19
diss.ox.+temp.+veget.	6	-410,456	836,7299	83,67956	6,75E-19
depth+temp.+veget.	6	-411,147	838,1128	85,06247	3,38E-19
depth+diss.ox.+veget.	5	-422,317	857,2437	104,1934	2,37E-23
depth+edge.dist.	5	-422,731	858,0701	105,0198	1,57E-23
edge.dist.+pH	5	-423,272	859,1517	106,1014	9,13E-24
edge.dist.+temp.	5	-423,376	859,3617	106,3114	8,22E-24
diss.ox.+edge.dist.	5	-423,529	859,6658	106,6155	7,06E-24
edge.dist.+veget.	5	-424,093	860,7942	107,7439	4,02E-24
pH+temp.	5	-424,189	860,9864	107,9361	3,65E-24
depth+pH	5	-424,454	861,5165	108,4662	2,80E-24

pH+veget.	5	-424,613	861,8349	108,7846	2,39E-24
diss.ox.+pH	5	-424,8	862,2088	109,1585	1,98E-24
depth+temp.	5	-424,979	862,5669	109,5166	1,65E-24
diss.ox.+temp.	5	-425,182	862,9733	109,923	1,35E-24
temp.+veget.	5	-425,622	863,8529	110,8026	8,70E-25
depth+diss.ox.	5	-425,633	863,8753	110,825	8,60E-25
depth+veget.	5	-425,804	864,2162	111,1659	7,25E-25
diss.ox.+veget.	4	-437,947	885,5602	132,5099	1,68E-29
edge.dist.	4	-438,887	887,4411	134,3908	6,57E-30
pH	4	-439,524	888,7141	135,6639	3,48E-30
temp.	4	-439,952	889,5704	136,5201	2,26E-30
veget.	4	-440,079	889,8256	136,7753	1,99E-30
diss.ox.	4	-440,156	889,9782	136,928	1,85E-30
veget.	3	-454,369	915,6979	162,6476	4,80E-36

S14: Summary of adjusted models produced by GLMM analysis relating local descriptors and phylogenetic redundancy in tadpole communities in ponds in the Autumn (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	9	-319,557	667,7015	0	0,999976
depth+diss.ox.+edge.dist.+pH+temp.+ veget.	8	-334,026	692,0525	24,35106	5,15E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	-334,137	692,2743	24,57287	4,61E-06
depth+diss.ox.+edge.dist.+temp.+veget.	8	-334,192	692,3835	24,68209	4,37E-06
diss.ox.+edge.dist.+pH+temp.+veget.	8	-334,329	692,6579	24,95649	3,81E-06
depth+edge.dist.+pH+temp.+veget.	8	-334,345	692,6906	24,98917	3,75E-06
depth+diss.ox.+edge.dist.+pH+veget.	8	-334,726	693,451	25,74955	2,56E-06
depth+diss.ox.+pH+temp.+veget.	7	-348,424	716,7418	49,04038	2,24E-11
depth+diss.ox.+edge.dist.+veget.	7	-348,475	716,845	49,14353	2,13E-11
edge.dist.+pH+temp.+veget.	7	-348,603	717,1016	49,40019	1,87E-11
depth+diss.ox.+edge.dist.+temp.	7	-348,657	717,2078	49,50633	1,78E-11
diss.ox.+edge.dist.+pH+temp.	7	-348,744	717,3836	49,68216	1,63E-11
diss.ox.+edge.dist.+temp.+veget.	7	-348,79	717,4743	49,77281	1,56E-11
depth+edge.dist.+pH+temp.	7	-348,836	717,5665	49,86503	1,49E-11
depth+edge.dist.+temp.+veget.	7	-348,918	717,7317	50,0302	1,37E-11
depth+diss.ox.+edge.dist.+pH	7	-348,936	717,767	50,06558	1,34E-11
diss.ox.+edge.dist.+pH+veget.	7	-349,08	718,0551	50,35367	1,16E-11
depth+edge.dist.+pH+veget.	7	-349,358	718,6109	50,90942	8,81E-12
depth+diss.ox.+temp.+veget.	7	-349,423	718,74	51,03854	8,26E-12
diss.ox.+pH+temp.+veget.	7	-349,509	718,9118	51,21033	7,58E-12
depth+diss.ox.+temp.+veget.	7	-349,527	718,9494	51,24795	7,44E-12
depth+diss.ox.+pH+temp.	7	-349,564	719,0218	51,32036	7,18E-12
depth+pH+temp.+veget.	6	-362,888	741,9768	74,27532	7,44E-17
diss.ox.+edge.dist.+veget.	6	-362,93	742,0591	74,35769	7,14E-17
edge.dist.+temp.+veget.	6	-362,947	742,0931	74,39159	7,02E-17
edge.dist.+pH+veget.	6	-363,114	742,4278	74,72636	5,93E-17

depth+edge.dist.+veget.	6	-363,21	742,6206	74,91912	5,39E-17
diss.ox.+edge.dist.+temp.	6	-363,301	742,8024	75,10099	4,92E-17
edge.dist.+pH+temp.	6	-363,311	742,8216	75,12017	4,87E-17
depth+diss.ox.+edge.dist.	6	-363,316	742,8311	75,12961	4,85E-17
depth+edge.dist.+temp.	6	-363,494	743,1884	75,48698	4,06E-17
diss.ox.+edge.dist.+pH	6	-363,633	743,4653	75,76382	3,53E-17
depth+diss.ox.+veget.	6	-363,633	743,4664	75,76491	3,53E-17
depth+edge.dist.+pH	6	-363,657	743,5145	75,81308	3,45E-17
pH+temp.+veget.	6	-364,028	744,2551	76,55361	2,38E-17
diss.ox.+veget.+temp.	6	-364,108	744,4154	76,71391	2,20E-17
depth+temp.+veget.	6	-364,15	744,4998	76,79834	2,11E-17
depth+diss.ox.+temp.	6	-364,162	744,523	76,82157	2,08E-17
diss.ox.+pH+veget.	6	-364,179	744,5588	76,85731	2,04E-17
diss.ox.+pH+temp.	6	-364,321	744,8418	77,14034	1,77E-17
depth+pH+veget.	6	-364,366	744,9322	77,23077	1,70E-17
depth+pH+temp.	6	-364,379	744,9571	77,2556	1,68E-17
depth+diss.ox.+pH	5	-376,839	766,5358	98,83439	3,45E-22
edge.dist.+veget.	5	-377,809	768,4754	100,7739	1,31E-22
edge.dist.+pH	5	-377,831	768,5193	100,8178	1,28E-22
diss.ox.+edge.dist.	5	-377,935	768,727	101,0255	1,15E-22
edge.dist.+temp.	5	-378,108	769,073	101,3715	9,72E-23
diss.ox.+veget.	5	-378,124	769,1049	101,4035	9,56E-23
temp.+veget.	5	-378,145	769,1463	101,4449	9,37E-23
depth+edge.dist.	5	-378,178	769,2129	101,5114	9,06E-23
pH+veget.	5	-378,327	769,5113	101,8099	7,80E-23
depth+veget.	5	-378,435	769,727	102,0255	7,01E-23
depth+diss.ox.	5	-378,766	770,389	102,6875	5,03E-23
pH+temp.	5	-378,78	770,4162	102,7147	4,96E-23
diss.ox.+temp.	5	-378,927	770,7111	103,0096	4,28E-23
depth+temp.	5	-378,989	770,836	103,1345	4,02E-23
diss.ox.+pH	5	-379,171	771,1996	103,4982	3,35E-23
depth+pH	4	-392,058	793,9341	126,2326	3,88E-28
edge.dist.	4	-392,129	794,0763	126,3748	3,61E-28
veget.	4	-392,956	795,7309	128,0294	1,58E-28
diss.ox.	4	-393,267	796,3519	128,6505	1,16E-28
depth	4	-393,339	796,4972	128,7957	1,08E-28
pH	4	-393,346	796,5108	128,8093	1,07E-28
temp.	3	-407,251	821,5445	153,843	3,92E-34

S15: Summary of adjusted models produced by GLMM analysis relating local descriptors and functional diversity in tadpole communities in ponds in the Winter (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	19,47235	-32,6114	0	0,540167
depth	4	19,67615	-30,7889	1,822444	0,230381
pH	4	18,03736	-27,5113	5,100023	0,042801

temp.	4	17,81358	-27,0638	5,54759	0,034219
diss.ox.	4	17,78358	-27,0038	5,60759	0,033208
depth+temp.	5	18,5956	-26,3341	6,27731	0,023758
depth+diss.ox.	5	18,3008	-25,7445	6,866907	0,017692
veget.	4	17,11535	-25,6673	6,944041	0,017023
edge.dist.	4	17,07823	-25,5931	7,018286	0,016403
depth+pH	5	17,91449	-24,9718	7,639518	0,012023
depth+veget.	5	17,33034	-23,8035	8,807818	0,006704
depth+edge.dist.	5	16,90686	-22,9566	9,654784	0,004389
pH+temp.	5	16,86829	-22,8794	9,731919	0,004223
depth+pH+temp.	6	17,23906	-21,2607	11,35062	0,00188
diss.ox.+pH	5	16,03882	-21,2205	11,39087	0,001843
diss.ox.+temp.	5	16,01317	-21,1692	11,44216	0,001796
depth+diss.ox.+temp.	6	17,17021	-21,123	11,48834	0,001755
temp.+veget.	5	15,93205	-21,007	11,6044	0,001656
edge.dist.+temp.	5	15,66839	-20,4796	12,13173	0,001272
depth+temp.+veget.	6	16,75658	-20,2958	12,3156	0,00116
pH+veget.	5	15,42347	-19,9898	12,62157	0,000996
edge.dist.+pH	5	15,42343	-19,9897	12,62165	0,000996
diss.ox.+edge.dist.	5	15,22067	-19,5842	13,02717	0,000813
diss.ox.+veget.	5	15,18125	-19,5054	13,106	0,000782
depth+diss.ox.+pH	6	16,12662	-19,0358	13,57552	0,000618
edge.dist.+veget.	5	14,87267	-18,8882	13,72317	0,000574
depth+edge.dist.+temp.	6	15,951	-18,6846	13,92675	0,000519
depth+diss.ox.+veget.	6	15,58109	-17,9448	14,66657	0,000358
depth+pH+veget.	6	15,38777	-17,5581	15,05321	0,000295
depth+diss.ox.+edge.dist.	6	15,3811	-17,5448	15,06655	0,000293
depth+edge.dist.+pH	6	15,05095	-16,8845	15,72684	0,000211
diss.ox.+pH+temp.	6	14,79322	-16,3691	16,24231	0,000163
depth+edge.dist.+veget.	6	14,70132	-16,1852	16,42612	0,000149
pH+temp.+veget.	6	14,52758	-15,8378	16,77359	0,000125
edge.dist.+pH+temp.	6	14,31518	-15,413	17,19839	0,000101
depth+diss.ox.+pH+temp.	7	15,50482	-15,3626	17,24878	9,85E-05
diss.ox.+temp.+veget.	6	13,88112	-14,5448	18,06651	6,54E-05
edge.dist.+temp.+veget.	6	13,85969	-14,502	18,10938	6,40E-05
depth+diss.ox.+temp.+veget.	7	15,00503	-14,363	18,24836	5,97E-05
depth+pH+temp.+veget.	7	14,95643	-14,2658	18,34556	5,69E-05
diss.ox.+edge.dist.+temp.	6	13,64041	-14,0634	18,54793	5,14E-05
diss.ox.+edge.dist.+pH	6	13,29169	-13,366	19,24537	3,63E-05
diss.ox.+pH+veget.	6	13,28852	-13,3597	19,25171	3,62E-05
depth+edge.dist.+pH+temp.	7	14,38047	-13,1139	19,49747	3,20E-05
depth+diss.ox.+edge.dist.+temp.	7	14,37055	-13,094	19,51733	3,17E-05
depth+edge.dist.+temp.+veget.	7	14,17706	-12,7071	19,9043	2,61E-05
edge.dist.+pH+veget.	6	12,94	-12,6626	19,94874	2,55E-05
diss.ox.+edge.dist.+veget.	6	12,63961	-12,0618	20,54952	1,89E-05
depth+diss.ox.+pH+veget.	7	13,38355	-11,12	21,49132	1,18E-05
depth+diss.ox.+edge.dist.+pH	7	13,15523	-10,6634	21,94795	9,40E-06
depth+diss.ox.+edge.dist.+veget.	7	12,7026	-9,75814	22,85322	5,98E-06

depth+edge.dist.+pH+veget.	7	12,63028	-9,61351	22,99785	5,56E-06
diss.ox.+pH+temp.+veget.	7	12,30073	-8,9544	23,65696	4,00E-06
diss.ox.+edge.dist.+pH+temp.	7	12,18229	-8,71752	23,89384	3,55E-06
edge.dist.+pH+temp.+veget.	7	12,05135	-8,45565	24,15571	3,12E-06
depth+diss.ox.+pH+temp.+veget.	8	13,02451	-7,89976	24,7116	2,36E-06
diss.ox.+edge.dist.+temp.+veget.	7	11,5723	-7,49754	25,11382	1,93E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	12,58544	-7,02162	25,58974	1,52E-06
depth+diss.ox.+edge.dist.+temp.+veget.	8	12,24789	-6,34653	26,26483	1,09E-06
depth+edge.dist.+pH+temp.+veget.	8	12,15362	-6,15799	26,45337	9,88E-07
diss.ox.+edge.dist.+pH+veget.	7	10,60374	-5,56043	27,05093	7,33E-07
depth+diss.ox.+edge.dist.+pH+veget.	8	10,47944	-2,80963	29,80173	1,85E-07
diss.ox.+edge.dist.+pH+temp.+veget.	8	9,754287	-1,35932	31,25204	8,97E-08
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	10,15102	0,425225	33,03659	3,67E-08

S16: Summary of adjusted models produced by GLMM analysis relating local descriptors and functional diversity in tadpole communities in ponds in the Spring (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	64,6937	-123,271	0	0,913888
depth	4	61,83114	-115,468	7,803368	0,018468
temp.	4	61,70451	-115,215	8,056619	0,016271
edge.dist.	4	61,57236	-114,951	8,320916	0,014257
diss.ox.	4	61,39148	-114,589	8,682675	0,011898
pH	4	61,38814	-114,582	8,689372	0,011858
veget.	4	61,24663	-114,299	8,972391	0,010294
depth+temp.	5	58,75363	-107,215	16,05689	0,000298
depth+pH	5	58,5701	-106,848	16,42396	0,000248
depth+edge.dist.	5	58,55884	-106,825	16,44648	0,000245
edge.dist.+temp.	5	58,5357	-106,779	16,49275	0,00024
depth+diss.ox.	5	58,50362	-106,715	16,55691	0,000232
pH+temp.	5	58,43383	-106,575	16,69649	0,000216
diss.ox.+temp.	5	58,37583	-106,459	16,81248	0,000204
depth+veget.	5	58,37188	-106,451	16,8204	0,000203
diss.ox.+edge.dist.	5	58,28601	-106,279	16,99214	0,000187
temp.+veget.	5	58,25123	-106,21	17,06169	0,00018
edge.dist.+pH	5	58,24209	-106,192	17,07996	0,000179
edge.dist.+veget.	5	58,12161	-105,951	17,32092	0,000158
diss.ox.+pH	5	58,08418	-105,876	17,39579	0,000153
diss.ox.+veget.	5	57,94573	-105,599	17,6727	0,000133
pH+veget.	5	57,94426	-105,596	17,67563	0,000133
depth+pH+temp.	6	55,51897	-98,6262	24,64529	4,07E-06
depth+edge.dist.+temp.	6	55,47095	-98,5301	24,74134	3,88E-06
depth+diss.ox.+temp.	6	55,41852	-98,4253	24,84619	3,68E-06
depth+temp.+veget.	6	55,29564	-98,1795	25,09196	3,25E-06
depth+pH+temp.	6	55,2759	-98,14	25,13143	3,19E-06

depth+diss.ox.+edge.dist.	6	55,24933	-98,0869	25,18456	3,11E-06
depth+diss.ox.+pH	6	55,23947	-98,0672	25,20429	3,08E-06
edge.dist.+pH+temp.	6	55,23209	-98,0524	25,21906	3,05E-06
diss.ox.+edge.dist.+temp.	6	55,22527	-98,0388	25,2327	3,03E-06
depth+pH+veget.	6	55,11278	-97,8138	25,45767	2,71E-06
depth+edge.dist.+veget.	6	55,10263	-97,7935	25,47797	2,68E-06
diss.ox.+pH+temp.	6	55,1025	-97,7932	25,47824	2,68E-06
edge.dist.+temp.+veget.	6	55,08099	-97,7502	25,52126	2,62E-06
depth+diss.ox.+veget.	6	55,0466	-97,6814	25,59003	2,54E-06
pH+temp.+veget.	6	54,98301	-97,5543	25,71721	2,38E-06
diss.ox.+edge.dist.+pH	6	54,95542	-97,4991	25,7724	2,31E-06
diss.ox.+temp.+veget.	6	54,92526	-97,4388	25,8327	2,25E-06
diss.ox.+edge.dist.+veget.	6	54,83646	-97,2611	26,01032	2,06E-06
edge.dist.+pH+veget.	6	54,79444	-97,1771	26,09434	1,97E-06
diss.ox.+pH+veget.	6	54,64162	-96,8715	26,4	1,69E-06
depth+edge.dist.+pH+temp.	7	52,21089	-89,87	33,40142	5,10E-08
depth+diss.ox.+pH+temp.	7	52,1805	-89,8093	33,46219	4,95E-08
depth+diss.ox.+edge.dist.+temp.	7	52,15247	-89,7532	33,51825	4,81E-08
depth+pH+temp.+veget.	7	52,06277	-89,5738	33,69765	4,40E-08
depth+edge.dist.+temp.+veget.	7	52,01586	-89,48	33,79147	4,20E-08
depth+diss.ox.+edge.dist.+pH	7	51,96365	-89,3756	33,89588	3,99E-08
depth+diss.ox.+temp.+veget.	7	51,96307	-89,3744	33,89706	3,98E-08
diss.ox.+edge.dist.+pH+temp.	7	51,92053	-89,2893	33,98213	3,82E-08
depth+edge.dist.+pH+veget.	7	51,82177	-89,0918	34,17966	3,46E-08
depth+diss.ox.+edge.dist.+veget.	7	51,79541	-89,0391	34,23238	3,37E-08
depth+diss.ox.+pH+veget.	7	51,78443	-89,0171	34,25433	3,33E-08
edge.dist.+pH+temp.+veget.	7	51,78007	-89,0084	34,26305	3,32E-08
diss.ox.+edge.dist.+temp.+veget.	7	51,77318	-88,9946	34,27683	3,29E-08
diss.ox.+pH+temp.+veget.	7	51,65437	-88,757	34,51445	2,93E-08
diss.ox.+edge.dist.+pH+veget.	7	51,50893	-88,4661	34,80533	2,53E-08
depth+diss.ox.+edge.dist.+pH+temp.	8	48,8896	-81,0663	42,20514	6,25E-10
depth+edge.dist.+pH+temp.+veget.	8	48,75777	-80,8027	42,46879	5,48E-10
depth+diss.ox.+pH+temp.+veget.	8	48,72687	-80,7409	42,5306	5,31E-10
depth+diss.ox.+edge.dist.+temp.+veget.	8	48,70004	-80,6872	42,58426	5,17E-10
depth+diss.ox.+edge.dist.+pH+veget.	8	48,51184	-80,3108	42,96065	4,29E-10
diss.ox.+edge.dist.+pH+temp.+veget.	8	48,47112	-80,2294	43,0421	4,12E-10
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	45,43918	-71,9828	51,28863	6,66E-12

S17: Summary of adjusted models produced by GLMM analysis relating local descriptors and functional diversity in tadpole communities in ponds in the Summer (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	3,9439	-0,9278	0	0,6987
pH	4	2,8684	3,9298	4,8576	0,0616
temp.	4	2,7409	4,1849	5,1127	0,0542
diss.ox.	4	2,5344	4,5978	5,5256	0,0441
edge.dist.	4	2,374	4,9187	5,8465	0,0376
depth	4	2,1751	5,3164	6,2442	0,0308
veget.	4	2,0374	5,5918	6,5196	0,0268
edge.dist.+pH	5	2,1979	8,2128	9,1406	0,0072
pH+temp.	5	1,9258	8,7572	9,685	0,0055
depth+pH	5	1,5189	9,571	10,499	0,0037
diss.ox.+pH	5	1,5031	9,6025	10,53	0,0036
edge.dist.+temp.	5	1,1961	10,216	11,144	0,0027
temp.+veget.	5	1,1586	10,291	11,219	0,0026
depth+veget.	5	1,0257	10,557	11,485	0,0022
diss.ox.+temp.	5	1,0095	10,59	11,518	0,0022
diss.ox.+edge.dist.	5	0,9776	10,654	11,581	0,0021
edge.dist.+veget.	5	0,9435	10,722	11,649	0,0021
pH+veget.	5	0,9298	10,749	11,677	0,002
depth+temp.	5	0,8916	10,825	11,753	0,002
depth+edge.dist.	5	0,7936	11,022	11,949	0,0018
diss.ox.+veget.	5	0,6393	11,33	12,258	0,0015
depth+diss.ox.	5	0,6093	11,39	12,318	0,0015
edge.dist.+pH+temp.	6	0,8621	14,094	15,022	0,0004
diss.ox.+edge.dist.+pH	6	0,8075	14,203	15,131	0,0004
edge.dist.+pH+veget.	6	0,7172	14,384	15,312	0,0003
depth+edge.dist.+pH	6	0,5202	14,778	15,706	0,0003
depth+pH+veget.	6	0,3209	15,176	16,104	0,0002
depth+pH+temp.	6	0,2785	15,261	16,189	0,0002
pH+temp.+veget.	6	0,2152	15,388	16,316	0,0002
diss.ox.+pH+temp.	6	0,146	15,526	16,454	0,0002
depth+diss.ox.+pH	6	-0,1471	16,112	17,04	0,0001
edge.dist.+temp.+veget.	6	-0,2567	16,332	17,259	0,0001
depth+edge.dist.+veget.	6	-0,2846	16,387	17,315	0,0001
depth+temp.+veget.	6	-0,285	16,388	17,316	0,0001
diss.ox.+pH+veget.	6	-0,4389	16,696	17,624	0,0001
depth+edge.dist.+temp.	6	-0,4633	16,745	17,673	0,0001
diss.ox.+edge.dist.+veget.	6	-0,4788	16,776	17,704	0,0001
diss.ox.+edge.dist.+temp.	6	-0,5403	16,899	17,827	9,40E-05
diss.ox.+temp.+veget.	6	-0,6563	17,131	18,059	8,37E-05
depth+diss.ox.+veget.	6	-0,7258	17,27	18,198	7,81E-05
depth+diss.ox.+edge.dist.	6	-0,8045	17,427	18,355	7,22E-05
depth+diss.ox.+temp.	6	-0,8294	17,477	18,405	7,04E-05
edge.dist.+pH+temp.+veget.	7	-0,3495	20,032	20,96	1,96E-05
depth+edge.dist.+pH+veget.	7	-0,3837	20,101	21,029	1,90E-05
diss.ox.+edge.dist.+pH+temp.	7	-0,6897	20,713	21,64	1,40E-05
depth+edge.dist.+pH+temp.	7	-0,828	20,989	21,917	1,22E-05

diss.ox.+edge.dist.+pH+veget.	7	-0,8847	21,103	22,031	1,15E-05
depth+pH+temp.+veget.	7	-0,9541	21,242	22,169	1,07E-05
depth+diss.ox.+edge.dist.+pH	7	-0,9588	21,251	22,179	1,07E-05
depth+diss.ox.+pH+veget.	7	-1,4872	22,308	23,236	6,29E-06
depth+diss.ox.+pH+temp.	7	-1,53	22,393	23,321	6,03E-06
diss.ox.+pH+temp.+veget.	7	-1,6137	22,561	23,489	5,54E-06
depth+edge.dist.+temp.+veget.	7	-1,6812	22,696	23,623	5,18E-06
diss.ox.+edge.dist.+temp.+veget.	7	-1,9218	23,177	24,105	4,07E-06
depth+diss.ox.+edge.dist.+veget.	7	-1,9593	23,252	24,18	3,92E-06
depth+diss.ox.+temp.+veget.	7	-2,1269	23,587	24,515	3,32E-06
depth+diss.ox.+edge.dist.+temp.	7	-2,2294	23,792	24,72	3,00E-06
depth+edge.dist.+pH+temp.+veget.	8	-1,7001	26,6	27,528	7,36E-07
diss.ox.+edge.dist.+pH+temp.+veget.	8	-2,1648	27,53	28,457	4,62E-07
depth+diss.ox.+edge.dist.+pH+veget.	8	-2,2309	27,662	28,59	4,33E-07
depth+diss.ox.+edge.dist.+pH+temp.	8	-2,3903	27,981	28,908	3,69E-07
depth+diss.ox.+pH+temp.+veget.	8	-2,8304	28,861	29,789	2,38E-07
depth+diss.ox.+edge.dist.+temp.+veget.	8	-3,3944	29,989	30,917	1,35E-07
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	-3,5618	34,597	35,525	1,35E-08

S18: Summary of adjusted models produced by GLMM analysis relating local descriptors and functional diversity in tadpole communities in ponds in the Autumn (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	12,581	-18,119	0	0,7739
veget.	4	11,086	-12,353	5,766	0,0433
edge.dist.	4	11,085	-12,351	5,7676	0,0433
temp.	4	11,055	-12,291	5,828	0,042
pH	4	10,932	-12,045	6,0739	0,0371
depth	4	10,27	-10,723	7,3961	0,0192
diss.ox.	4	10,243	-10,668	7,451	0,0187
pH+temp.	5	9,7912	-6,7252	11,394	0,0026
edge.dist.+pH	5	9,7727	-6,6883	11,431	0,0026
pH+veget.	5	9,5371	-6,217	11,902	0,002
edge.dist.+veget.	5	9,4292	-6,0013	12,118	0,0018
temp.+veget.	5	9,4275	-5,9979	12,121	0,0018
edge.dist.+temp.	5	9,4108	-5,9645	12,154	0,0018
depth+diss.ox.	5	9,0416	-5,2261	12,893	0,0012
diss.ox.+temp.	5	9,0034	-5,1496	12,969	0,0012
depth+temp.	5	8,9394	-5,0216	13,097	0,0011
diss.ox.+veget.	5	8,7776	-4,698	13,421	0,0009
depth+pH	5	8,7712	-4,6853	13,434	0,0009
depth+edge.dist.	5	8,7408	-4,6245	13,494	0,0009

diss.ox.+edge.dist.	5	8,7335	-4,6099	13,509	0,0009
depth+veget.	5	8,6387	-4,4203	13,699	0,0008
diss.ox.+pH	5	8,6027	-4,3483	13,771	0,0008
edge.dist.+pH+temp.	6	8,423	-0,646	17,473	0,0001
edge.dist.+pH+veget.	6	8,2002	-0,2003	17,919	9,95E-05
pH+temp.+veget.	6	8,1276	-0,0551	18,064	9,25E-05
diss.ox.+pH+temp.	6	7,9795	0,241	18,36	7,98E-05
depth+diss.ox.+pH	6	7,855	0,49	18,609	7,04E-05
depth+pH+temp.	6	7,758	0,684	18,803	6,39E-05
edge.dist.+temp.+veget.	6	7,7172	0,7656	18,885	6,14E-05
depth+diss.ox.+temp.	6	7,6822	0,8356	18,955	5,93E-05
diss.ox.+temp.+veget.	6	7,652	0,8959	19,015	5,75E-05
depth+edge.dist.+pH	6	7,6446	0,9108	19,03	5,71E-05
depth+diss.ox.+edge.dist.	6	7,5093	1,1814	19,3	4,99E-05
depth+temp.+veget.	6	7,4567	1,2866	19,405	4,73E-05
diss.ox.+edge.dist.+pH	6	7,4113	1,3775	19,496	4,52E-05
depth+edge.dist.+temp.	6	7,4044	1,3911	19,51	4,49E-05
depth+diss.ox.+veget.	6	7,3999	1,4003	19,519	4,47E-05
diss.ox.+edge.dist.+temp.	6	7,3278	1,5445	19,663	4,16E-05
diss.ox.+pH+veget.	6	7,2126	1,7748	19,894	3,71E-05
depth+pH+veget.	6	7,1717	1,8566	19,975	3,56E-05
diss.ox.+edge.dist.+veget.	6	7,1221	1,9558	20,075	3,38E-05
depth+edge.dist.+veget.	6	6,9788	2,2424	20,361	2,93E-05
depth+diss.ox.+edge.dist.+pH	7	6,9366	6,0215	24,14	4,43E-06
depth+diss.ox.+pH+temp.	7	6,8493	6,1962	24,315	4,06E-06
edge.dist.+pH+temp.+veget.	7	6,681	6,5327	24,652	3,43E-06
depth+edge.dist.+pH+temp.	7	6,5718	6,7511	24,87	3,08E-06
diss.ox.+pH+temp.+veget.	7	6,5413	6,8121	24,931	2,99E-06
diss.ox.+edge.dist.+pH+temp.	7	6,5	6,8947	25,014	2,86E-06
depth+diss.ox.+pH+veget.	7	6,2596	7,3755	25,494	2,25E-06
depth+diss.ox.+temp.+veget.	7	6,199	7,4968	25,616	2,12E-06
depth+pH+temp.+veget.	7	6,1814	7,5319	25,651	2,08E-06
depth+diss.ox.+edge.dist.+temp.	7	6,1594	7,576	25,695	2,04E-06
depth+edge.dist.+pH+veget.	7	5,8528	8,1891	26,308	1,50E-06
diss.ox.+edge.dist.+pH+veget.	7	5,8474	8,1999	26,319	1,49E-06

diss.ox.+edge.dist.+temp.+veget.	7	5,8207	8,2534	26,372	1,45E-06
depth+diss.ox.+edge.dist.+veget.	7	5,7428	8,4091	26,528	1,34E-06
depth+edge.dist.+temp.+veget.	7	5,7349	8,4249	26,544	1,33E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	5,8964	12,207	30,326	2,01E-07
depth+diss.ox.+pH+temp.+veget.	8	5,2602	13,48	31,598	1,06E-07
depth+diss.ox.+edge.dist.+pH+veget.	8	5,1328	13,734	31,853	9,37E-08
diss.ox.+edge.dist.+pH+temp.+veget.	8	4,9029	14,194	32,313	7,45E-08
depth+edge.dist.+pH+temp.+veget.	8	4,7905	14,419	32,538	6,66E-08
depth+diss.ox.+edge.dist.+temp.+veget.	8	4,4886	15,023	33,142	4,92E-08
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	4,0975	20,393	38,512	3,36E-09

S19: Summary of adjusted models produced by GLMM analysis relating local descriptors and functional redundancy in tadpole communities in ponds in the Winter (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	51,198	-96,062	0	0,5129
depth	4	51,645	-94,727	1,3351	0,2631
pH	4	50,584	-92,605	3,4572	0,0911
depth+pH	5	50,615	-90,373	5,6887	0,0298
edge.dist.	4	49,005	-89,447	6,6153	0,0188
diss.ox.	4	48,962	-89,36	6,7017	0,018
depth+diss.ox.	5	50,074	-89,291	6,7705	0,0174
temp.	4	48,546	-88,529	7,5331	0,0119
veget.	4	48,168	-87,772	8,2895	0,0081
depth+temp.	5	49,048	-87,24	8,8221	0,0062
depth+edge.dist.	5	48,804	-86,751	9,3114	0,0049
depth+veget.	5	48,58	-86,303	9,7586	0,0039
diss.ox.+pH	5	48,228	-85,599	10,463	0,0027
edge.dist.+pH	5	47,866	-84,875	11,187	0,0019
pH+temp.	5	47,842	-84,826	11,236	0,0019
depth+diss.ox.+pH	6	48,686	-84,154	11,908	0,0013
pH+veget.	5	47,389	-83,921	12,141	0,0012
depth+pH+temp.	6	48,067	-82,916	13,146	0,0007
diss.ox.+edge.dist.	5	46,563	-82,27	13,792	0,0005
edge.dist.+temp.	5	46,434	-82,011	14,051	0,0005
depth+edge.dist.+pH	6	47,472	-81,726	14,336	0,0004
depth+pH+veget.	6	47,379	-81,54	14,522	0,0004
diss.ox.+temp.	5	46,126	-81,394	14,668	0,0003
edge.dist.+veget.	5	45,995	-81,133	14,929	0,0003
depth+diss.ox.+temp.	6	47,174	-81,131	14,931	0,0003
diss.ox.+veget.	5	45,88	-80,903	15,159	0,0003
depth+diss.ox.+edge.dist.	6	47,053	-80,889	15,173	0,0003
depth+diss.ox.+veget.	6	46,882	-80,546	15,516	0,0002
temp.+veget.	5	45,533	-80,21	15,852	0,0002

depth+edge.dist.+temp.	6	46,283	-79,349	16,713	0,0001
depth+temp.+veget.	6	46,048	-78,879	17,183	9,52E-05
depth+edge.dist.+veget.	6	45,754	-78,29	17,772	7,10E-05
diss.ox.+pH+temp.	6	45,398	-77,578	18,484	4,97E-05
diss.ox.+edge.dist.+pH	6	45,374	-77,531	18,531	4,85E-05
edge.dist.+pH+temp.	6	45,206	-77,194	18,868	4,10E-05
diss.ox.+pH+veget.	6	45,01	-76,803	19,259	3,37E-05
depth+diss.ox.+pH+temp.	7	46,071	-76,495	19,567	2,89E-05
pH+temp.+veget.	6	44,696	-76,175	19,887	2,46E-05
edge.dist.+pH+veget.	6	44,688	-76,158	19,904	2,44E-05
depth+diss.ox.+edge.dist.+pH	7	45,439	-75,231	20,831	1,54E-05
depth+diss.ox.+pH+veget.	7	45,425	-75,203	20,859	1,52E-05
diss.ox.+edge.dist.+temp.	6	43,82	-74,423	21,639	1,03E-05
depth+edge.dist.+pH+temp.	7	44,979	-74,31	21,751	9,70E-06
depth+pH+temp.+veget.	7	44,901	-74,155	21,907	8,98E-06
diss.ox.+edge.dist.+veget.	6	43,478	-73,739	22,323	7,29E-06
edge.dist.+temp.+veget.	6	43,463	-73,709	22,353	7,18E-06
diss.ox.+temp.+veget.	6	43,074	-72,931	23,131	4,87E-06
depth+edge.dist.+pH+veget.	7	44,25	-72,854	23,208	4,68E-06
depth+diss.ox.+edge.dist.+temp.	7	44,22	-72,794	23,268	4,54E-06
depth+diss.ox.+temp.+veget.	7	44,142	-72,636	23,426	4,20E-06
depth+diss.ox.+edge.dist.+veget.	7	43,865	-72,083	23,979	3,19E-06
depth+edge.dist.+temp.+veget.	7	43,321	-70,995	25,067	1,85E-06
diss.ox.+edge.dist.+pH+temp.	7	42,614	-69,582	26,48	9,12E-07
diss.ox.+pH+temp.+veget.	7	42,226	-68,804	27,258	6,18E-07
diss.ox.+edge.dist.+pH+veget.	7	42,154	-68,66	27,402	5,75E-07
edge.dist.+pH+temp.+veget.	7	42,083	-68,519	27,543	5,36E-07
depth+diss.ox.+edge.dist.+pH+temp.	8	42,886	-67,623	28,439	3,42E-07
depth+diss.ox.+pH+temp.+veget.	8	42,853	-67,556	28,505	3,31E-07
depth+diss.ox.+edge.dist.+pH+veget.	8	42,179	-66,209	29,853	1,69E-07
diss.ox.+edge.dist.+temp.+veget.	7	40,795	-65,944	30,118	1,48E-07
depth+edge.dist.+pH+temp.+veget.	8	41,839	-65,53	30,532	1,20E-07
depth+diss.ox.+edge.dist.+temp.+veget.	8	41,218	-64,287	31,775	6,46E-08
diss.ox.+pH+edge.dist.+temp.+veget.	8	39,456	-60,764	35,298	1,11E-08
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	39,685	-58,642	37,42	3,84E-09

S20: Summary of adjusted models produced by GLMM analysis relating local descriptors and functional redundancy in tadpole communities in ponds in the Spring (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	126,91	-247,7	0	0,9205
temp.	4	124,23	-240,26	7,4385	0,0223
diss.ox.	4	124,18	-240,17	7,5283	0,0213
depth	4	123,31	-238,42	9,2721	0,0089
pH	4	123,26	-238,34	9,361	0,0085
veget.	4	123,21	-238,22	9,4762	0,0081
edge.dist.	4	123,18	-238,17	9,5293	0,0078
diss.ox.+temp.	5	121,21	-232,12	15,573	0,0004
depth+temp.	5	120,6	-230,9	16,794	0,0002
pH+temp.	5	120,58	-230,86	16,837	0,0002
depth+diss.ox.	5	120,56	-230,83	16,866	0,0002
diss.ox.+pH	5	120,55	-230,8	16,897	0,0002
temp.+veget.	5	120,5	-230,7	16,995	0,0002
diss.ox.+veget.	5	120,48	-230,66	17,032	0,0002
diss.ox.+edge.dist.	5	120,47	-230,66	17,04	0,0002
edge.dist.+temp.	5	120,46	-230,64	17,061	0,0002
depth+pH	5	119,67	-229,05	18,644	8,23E-05
depth+veget.	5	119,61	-228,92	18,776	7,71E-05
depth+edge.dist.	5	119,6	-228,91	18,784	7,68E-05
edge.dist.+pH	5	119,57	-228,85	18,844	7,45E-05
pH+veget.	5	119,57	-228,84	18,854	7,41E-05
edge.dist.+veget.	5	119,48	-228,67	19,028	6,79E-05
depth+diss.ox.+temp.	6	117,58	-222,74	24,952	3,51E-06
diss.ox.+pH+temp.	6	117,56	-222,71	24,984	3,46E-06
diss.ox.+temp.+veget.	6	117,48	-222,55	25,143	3,19E-06
diss.ox.+edge.dist.+temp.	6	117,47	-222,52	25,174	3,14E-06
depth+pH+temp.	6	116,96	-221,5	26,198	1,88E-06
depth+diss.ox.+pH	6	116,93	-221,45	26,245	1,84E-06
depth+diss.ox.+edge.dist.	6	116,88	-221,35	26,347	1,75E-06
diss.ox.+edge.dist.+pH	6	116,88	-221,35	26,348	1,75E-06
depth+temp.+veget.	6	116,88	-221,34	26,352	1,74E-06
depth+edge.dist.+temp.	6	116,88	-221,34	26,357	1,74E-06
depth+diss.ox.+veget.	6	116,86	-221,31	26,389	1,71E-06
pH+temp.+veget.	6	116,85	-221,29	26,409	1,70E-06
diss.ox.+pH+veget.	6	116,84	-221,28	26,419	1,69E-06
edge.dist.+pH+temp.	6	116,84	-221,26	26,433	1,68E-06
diss.ox.+edge.dist.+veget.	6	116,77	-221,13	26,568	1,57E-06
edge.dist.+temp.+veget.	6	116,74	-221,06	26,636	1,51E-06
depth+edge.dist.+pH	6	116,01	-219,6	28,095	7,30E-07
depth+pH+veget.	6	115,97	-219,53	28,163	7,05E-07

depth+edge.dist.+veget.	6	115,9	-219,4	28,3	6,59E-07
edge.dist.+pH+veget.	6	115,87	-219,34	28,362	6,39E-07
depth+diss.ox.+pH+temp.	7	113,94	-213,33	34,369	3,17E-08
depth+diss.ox.+edge.dist.+temp.	7	113,88	-213,21	34,489	2,98E-08
depth+diss.ox.+temp.+veget.	7	113,86	-213,17	34,522	2,94E-08
diss.ox.+edge.dist.+pH+temp.	7	113,85	-213,15	34,544	2,90E-08
diss.ox.+pH+temp.+veget.	7	113,84	-213,13	34,57	2,87E-08
diss.ox.+edge.dist.+temp.+veget.	7	113,74	-212,93	34,764	2,60E-08
depth+diss.ox.+edge.dist.+pH	7	113,3	-212,05	35,646	1,67E-08
depth+pH+temp.edge.dist.	7	113,27	-211,98	35,717	1,61E-08
depth+pH+temp.+veget.	7	113,24	-211,92	35,772	1,57E-08
depth+diss.ox.+pH+veget.	7	113,23	-211,91	35,784	1,56E-08
depth+diss.ox.+edge.dist.+veget.	7	113,18	-211,82	35,881	1,49E-08
diss.ox.+edge.dist.+pH+veget.	7	113,18	-211,8	35,896	1,48E-08
depth+edge.dist.+temp.+veget.	7	113,16	-211,77	35,928	1,45E-08
edge.dist.+pH+temp.+veget.	7	113,11	-211,67	36,025	1,38E-08
depth+edge.dist.+pH+veget.	7	112,31	-210,07	37,625	6,22E-09
depth+diss.ox.+edge.dist.+pH+temp.	8	110,28	-203,85	43,845	2,77E-10
depth+diss.ox.+pH+temp.+veget.	8	110,23	-203,74	43,955	2,63E-10
depth+diss.ox.+edge.dist.+temp.+veget.	8	110,17	-203,63	44,071	2,48E-10
diss.ox.+edge.dist.+pH+temp.+veget.	8	110,13	-203,55	44,151	2,38E-10
depth+diss.ox.+edge.dist.+pH+veget.	8	109,61	-202,5	45,195	1,41E-10
depth+edge.dist.+pH+temp.+veget.	8	109,55	-202,39	45,303	1,34E-10
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	106,58	-194,25	53,442	2,29E-12

S21: Summary of adjusted models produced by GLMM analysis relating local descriptors and functional redundancy in tadpole communities in ponds at Summer season (season with high hydrical stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	19,913	-32,865	0	0,7573
diss.ox.	4	18,997	-28,328	4,5376	0,0783
pH	4	18,437	-27,208	5,6575	0,0447
temp.	4	18,236	-26,805	6,0606	0,0366
edge.dist.	4	17,771	-25,875	6,9904	0,023
depth	4	17,642	-25,617	7,2485	0,0202
veget.	4	17,32	-24,974	7,8914	0,0146
diss.ox.+pH	5	17,545	-22,481	10,384	0,0042
edge.dist.+pH	5	17,271	-21,934	10,931	0,0032
pH+temp.	5	17,133	-21,657	11,208	0,0028
diss.ox.+edge.dist.	5	16,814	-21,02	11,846	0,002
diss.ox.+temp.	5	16,792	-20,976	11,89	0,002

depth+pH	5	16,756	-20,903	11,962	0,0019
depth+diss.ox.	5	16,44	-20,272	12,593	0,0014
diss.ox.+veget.	5	16,342	-20,075	12,79	0,0013
edge.dist.+temp.	5	16,127	-19,646	13,22	0,001
temp.+veget.	5	15,93	-19,252	13,613	0,0008
depth+temp.	5	15,825	-19,042	13,824	0,0008
pH+veget.	5	15,796	-18,983	13,882	0,0007
depth+veget.	5	15,739	-18,87	13,996	0,0007
depth+edge.dist.	5	15,707	-18,806	14,059	0,0007
edge.dist.+veget.	5	15,47	-18,331	14,534	0,0005
diss.ox.+edge.dist.+pH	6	16,169	-16,52	16,345	0,0002
edge.dist.+pH+temp.	6	15,534	-15,249	17,616	0,0001
diss.ox.+pH+temp.	6	15,49	-15,163	17,703	0,0001
depth+diss.ox.+pH	6	15,276	-14,733	18,132	8,75E-05
depth+edge.dist.+pH	6	15,152	-14,486	18,379	7,73E-05
depth+pH+temp.	6	14,998	-14,178	18,687	6,63E-05
edge.dist.+pH+veget.	6	14,949	-14,08	18,785	6,31E-05
diss.ox.+pH+veget.	6	14,835	-13,851	19,014	5,63E-05
depth+pH+veget.	6	14,754	-13,689	19,176	5,19E-05
pH+temp.+veget.	6	14,664	-13,51	19,355	4,75E-05
diss.ox.+edge.dist.+temp.	6	14,644	-13,47	19,396	4,65E-05
depth+diss.ox.+edge.dist.	6	14,417	-13,016	19,849	3,71E-05
diss.ox.+edge.dist.+veget.	6	14,369	-12,919	19,946	3,53E-05
depth+diss.ox.+temp.	6	14,349	-12,88	19,985	3,46E-05
diss.ox.+pH+temp.	6	14,286	-12,754	20,111	3,25E-05
depth+diss.ox.+veget.	6	14,159	-12,5	20,365	2,86E-05
depth+edge.dist.+temp.	6	13,926	-12,034	20,831	2,27E-05
depth+temp.+veget.	6	13,898	-11,977	20,889	2,20E-05
edge.dist.+temp.+veget.	6	13,877	-11,935	20,931	2,16E-05
depth+edge.dist.+veget.	6	13,747	-11,677	21,189	1,90E-05
diss.ox.+edge.dist.+pH+temp.	7	14,031	-8,7294	24,136	4,35E-06
depth+diss.ox.+edge.dist.+pH	7	13,799	-8,264	24,601	3,44E-06
diss.ox.+edge.dist.+pH+veget.	7	13,596	-7,8579	25,007	2,81E-06
depth+edge.dist.+pH+veget.	7	13,41	-7,4867	25,379	2,34E-06
edge.dist.+pH+temp.+veget.	7	13,397	-7,4605	25,405	2,30E-06
depth+edge.dist.+temp.+pH	7	13,309	-7,2852	25,58	2,11E-06
depth+diss.ox.+pH+temp.	7	13,223	-7,1117	25,754	1,94E-06
depth+pH+temp.+veget.	7	12,97	-6,6074	26,258	1,50E-06
depth+diss.ox.+pH+veget.	7	12,962	-6,5902	26,275	1,49E-06
diss.ox.+pH+temp.+veget.	7	12,9	-6,4669	26,398	1,40E-06
depth+diss.ox.+edge.dist.+temp.	7	12,343	-5,353	27,512	8,04E-07

diss.ox.+edge.dist.+temp.+veget.	7	12,288	-5,2428	27,623	7,60E-07
depth+diss.ox.+edge.dist.+veget.	7	12,202	-5,0709	27,795	6,98E-07
depth+diss.ox.+temp.+veget.	7	12,107	-4,8799	27,985	6,34E-07
depth+edge.dist.+temp.+veget.	7	11,902	-4,4699	28,395	5,17E-07
depth+diss.ox.+edge.dist.+pH+temp.	8	11,73	-0,2605	32,605	6,30E-08
diss.ox.+edge.dist.+pH+temp.+veget.	8	11,586	0,0284	32,894	5,45E-08
depth+diss.ox.+edge.dist.+pH+veget.	8	11,545	0,1092	32,975	5,24E-08
depth+edge.dist.+pH+temp.+veget.	8	11,534	0,1314	32,997	5,18E-08
depth+diss.ox.+pH+temp.+veget.	8	10,956	1,2889	34,154	2,90E-08
depth+diss.ox.+edge.dist.+temp.+veget.	8	10,159	2,8826	35,748	1,31E-08
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	9,5328	8,4081	41,274	8,26E-10

S22: Summary of adjusted models produced by GLMM analysis relating local descriptors and functional redundancy in tadpole communities in ponds in the Autumn (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	28,591	-50,138	0	0,8821
temp.	4	26,478	-43,138	6,9999	0,0266
depth	4	26,267	-42,715	7,4229	0,0216
pH	4	26,254	-42,689	7,4485	0,0213
veget.	4	25,937	-42,055	8,0826	0,0155
edge.dist.	4	25,748	-41,677	8,4605	0,0128
diss.ox.	4	25,659	-41,499	8,6385	0,0117
depth+diss.ox.	5	25,818	-38,779	11,359	0,003
depth+temp.	5	24,593	-36,33	13,808	0,0009
pH+temp.	5	24,222	-35,586	14,552	0,0006
depth+pH	5	23,868	-34,879	15,259	0,0004
diss.ox.+temp.	5	23,777	-34,696	15,442	0,0004
temp.+veget.	5	23,731	-34,605	15,533	0,0004
edge.dist.+temp.	5	23,674	-34,49	15,648	0,0004
pH+veget.	5	23,62	-34,383	15,755	0,0003
edge.dist.+pH	5	23,452	-34,046	16,092	0,0003
depth+edge.dist.	5	23,412	-33,967	16,171	0,0003
depth+veget.	5	23,36	-33,863	16,275	0,0003
diss.ox.+pH	5	23,335	-33,812	16,326	0,0003
edge.dist.+veget.	5	23,085	-33,312	16,826	0,0002

diss.ox.+veget.	5	22,994	-33,131	17,007	0,0002
diss.ox.+edge.dist.	5	22,835	-32,813	17,325	0,0002
depth+diss.ox.+temp.	6	24,242	-32,283	17,855	0,0001
depth+diss.ox.+pH	6	23,598	-30,996	19,142	6,15E-05
depth+diss.ox.+edge.dist.	6	22,916	-29,632	20,505	3,11E-05
depth+diss.ox.+veget.	6	22,911	-29,621	20,517	3,09E-05
depth+pH+temp.	6	22,34	-28,481	21,657	1,75E-05
depth+edge.dist.+temp.	6	21,854	-27,508	22,63	1,08E-05
depth+temp.+veget.	6	21,736	-27,272	22,866	9,56E-06
diss.ox.+pH+temp.	6	21,6	-27,001	23,137	8,34E-06
pH+temp.+veget.	6	21,516	-26,831	23,307	7,67E-06
edge.dist.+pH+temp.	6	21,448	-26,695	23,443	7,16E-06
diss.ox.+temp.+veget.	6	21,172	-26,143	23,995	5,43E-06
depth+edge.dist.+pH	6	21,057	-25,915	24,223	4,85E-06
depth+pH+veget.	6	21,014	-25,827	24,311	4,64E-06
diss.ox.+edge.dist.+temp.	6	21,001	-25,802	24,336	4,58E-06
edge.dist.+temp.+veget.	6	20,931	-25,662	24,476	4,27E-06
edge.dist.+pH+veget.	6	20,826	-25,452	24,686	3,85E-06
diss.ox.+pH+veget.	6	20,711	-25,221	24,917	3,43E-06
diss.ox.+edge.dist.+pH	6	20,553	-24,907	25,231	2,93E-06
depth+edge.dist.+veget.	6	20,513	-24,827	25,311	2,81E-06
depth+diss.ox.+pH+temp.	7	22,242	-24,59	25,548	2,50E-06
diss.ox.+pH+veget.	6	20,164	-24,128	26,01	1,98E-06
depth+diss.ox.+edge.dist.+temp.	7	21,491	-23,087	27,051	1,18E-06
depth+diss.ox.+temp.+veget.	7	21,385	-22,875	27,263	1,06E-06
depth+diss.ox.+edge.dist.+pH	7	20,752	-21,609	28,529	5,63E-07
depth+diss.ox.+pH+veget.	7	20,704	-21,513	28,625	5,37E-07
depth+diss.ox.+edge.dist.+veget.	7	20,013	-20,131	30,007	2,69E-07
depth+edge.dist.+pH+temp.	7	19,636	-19,378	30,76	1,85E-07
depth+pH+temp.+veget.	7	19,495	-19,096	31,042	1,60E-07
diss.ox.+pH+temp.+veget.	7	19,004	-18,114	32,024	9,81E-08
depth+edge.dist.+temp.+veget.	7	18,982	-18,068	32,069	9,59E-08
diss.ox.+edge.dist.+pH+temp.	7	18,852	-17,809	32,329	8,42E-08
edge.dist.+pH+temp.+veget.	7	18,757	-17,619	32,519	7,66E-08
diss.ox.+edge.dist.+temp.+veget.	7	18,422	-16,949	33,189	5,48E-08
depth+edge.dist.+pH+veget.	7	18,221	-16,547	33,59	4,48E-08
diss.ox.+edge.dist.+pH+veget.	7	17,94	-15,986	34,152	3,38E-08

depth+diss.ox.+edge.dist.+pH+temp.	8	19,674	-15,348	34,79	2,46E-08
depth+diss.ox.+pH+temp.+veget.	8	19,371	-14,742	35,396	1,82E-08
depth+diss.ox.+edge.dist.+temp.+veget.	8	18,603	-13,207	36,931	8,43E-09
depth+diss.ox.+edge.dist.+pH+veget.	8	17,855	-11,711	38,427	3,99E-09
depth+edge.dist.+pH+temp.+veget.	8	16,776	-9,5528	40,585	1,36E-09
diss.ox.+edge.dist.+pH+temp.+veget.	8	16,288	-8,5762	41,562	8,33E-10
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	16,742	-4,8964	45,241	1,32E-10

S23: Summary of adjusted models produced by GLMM analysis relating local descriptors and taxonomic diversity in tadpole communities in ponds in the Winter (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
depth	4	-15,779	40,121	0	0,3197
null	3	-16,919	40,171	0,0498	0,3119
pH	4	-17,299	43,161	3,0397	0,0699
depth+diss.ox.	5	-16,453	43,763	3,6421	0,0517
depth+pH	5	-16,615	44,087	3,9659	0,044
diss.ox.	4	-18,025	44,614	4,4929	0,0338
depth+temp.	5	-16,934	44,725	4,6036	0,032
temp.	4	-18,424	45,412	5,2905	0,0227
edge.dist.	4	-18,549	45,661	5,5399	0,02
veget.	4	-18,846	46,256	6,1348	0,0149
depth+veget.	5	-17,787	46,431	6,3092	0,0136
depth+edge.dist.	5	-17,937	46,731	6,6095	0,0117
pH+temp.	5	-18,556	47,968	7,8471	0,0063
depth+pH+temp.	6	-17,431	48,079	7,9576	0,006
diss.ox.+pH	5	-18,724	48,306	8,1842	0,0053
depth+diss.ox.+pH	6	-17,706	48,63	8,5086	0,0045
depth+diss.ox.+temp.	6	-17,777	48,772	8,6504	0,0042
edge.dist.+pH	5	-19,306	49,47	9,3485	0,003
pH+veget.	5	-19,524	49,906	9,7845	0,0024
depth+temp.+veget.	6	-18,6	50,417	10,296	0,0019
diss.ox.+temp.	5	-19,781	50,419	10,298	0,0019
edge.dist.+temp.	5	-19,857	50,571	10,449	0,0017
diss.ox.+edge.dist.	5	-19,882	50,622	10,501	0,0017
depth+diss.ox.+veget.	6	-18,706	50,63	10,509	0,0017
depth+diss.ox.+edge.dist.	6	-18,775	50,767	10,645	0,0016
depth+pH+veget.	6	-18,845	50,908	10,787	0,0015
depth+edge.dist.+pH	6	-18,948	51,113	10,992	0,0013
depth+edge.dist.+temp.	6	-18,957	51,132	11,01	0,0013
temp.+veget.	5	-20,139	51,136	11,014	0,0013
diss.ox.+veget.	5	-20,151	51,158	11,037	0,0013
edge.dist.+veget.	5	-20,423	51,703	11,581	0,001
depth+diss.ox.+pH+temp.	7	-18,542	52,731	12,61	0,0006

depth+edge.dist.+veget.	6	-19,881	52,98	12,859	0,0005
diss.ox.+pH+temp.	6	-20,049	53,316	13,194	0,0004
edge.dist.+pH+temp.	6	-20,492	54,202	14,08	0,0003
pH+temp.+veget.	6	-20,594	54,405	14,284	0,0003
depth+pH+temp.+veget.	7	-19,442	54,531	14,41	0,0002
diss.ox.+edge.dist.+pH	6	-20,862	54,942	14,82	0,0002
depth+diss.ox.+temp.+veget.	7	-19,647	54,942	14,821	0,0002
depth+edge.dist.+pH+temp.	7	-19,73	55,107	14,986	0,0002
diss.ox.+pH+veget.	6	-21,02	55,257	15,136	0,0002
depth+diss.ox.+edge.dist.+temp.	7	-19,982	55,611	15,489	0,0001
depth+diss.ox.+pH+veget.	7	-20,049	55,745	15,623	0,0001
depth+diss.ox.+edge.dist.+pH	7	-20,154	55,956	15,835	0,0001
diss.ox.+edge.dist.+temp.	6	-21,449	56,116	15,995	0,0001
edge.dist.+pH+veget.	6	-21,466	56,15	16,029	0,0001
edge.dist.+temp.+veget.	6	-21,507	56,231	16,109	0,0001
diss.ox.+temp.+veget.	6	-21,606	56,429	16,308	9,20E-05
depth+edge.dist.+temp.+veget.	7	-20,575	56,797	16,676	7,65E-05
diss.ox.+edge.dist.+veget.	6	-22,008	57,233	17,112	6,15E-05
depth+diss.ox.+edge.dist.+veget.	7	-21,022	57,69	17,569	4,89E-05
depth+edge.dist.+pH+veget.	7	-21,123	57,893	17,772	4,42E-05
depth+diss.ox.+pH+temp.+veget.	8	-20,71	59,57	19,448	1,91E-05
diss.ox.+edge.dist.+pH+temp.	7	-22,062	59,772	19,65	1,73E-05
depth+diss.ox.+edge.dist.+pH+temp.	8	-20,913	59,976	19,854	1,56E-05
diss.ox.+pH+temp.+veget.	7	-22,202	60,052	19,931	1,50E-05
edge.dist.+pH+temp.+veget.	7	-22,47	60,586	20,465	1,15E-05
depth+edge.dist.+pH+temp.+veget.	8	-21,69	61,53	21,409	7,18E-06
depth+diss.ox.+edge.dist.+temp.+veget.	8	-21,809	61,768	21,646	6,37E-06
diss.ox.+edge.dist.+pH+veget.	7	-23,147	61,94	21,819	5,85E-06
diss.ox.+edge.dist.+temp.+veget.	7	-23,242	62,13	22,009	5,32E-06
depth+diss.ox.+edge.dist.+pH+veget.	8	-22,487	63,124	23,003	3,23E-06
diss.ox.+edge.dist.+pH+temp.+veget.	8	-24,167	66,483	26,361	6,03E-07
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	-23,043	66,813	26,691	5,11E-07

S24: Summary of adjusted models produced by GLMM analysis relating local descriptors and taxonomic diversity in tadpole communities in ponds in the Spring season (season with low hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	-42,998	92,112	0	0,8671
temp.	4	-45,28	98,754	6,642	0,0313
depth	4	-45,614	99,422	7,3094	0,0224

diss.ox.	4	-45,71	99,615	7,502	0,0204
pH	4	-45,833	99,86	7,7476	0,018
veget.	4	-45,854	99,902	7,7899	0,0176
edge.dist.	4	-45,973	100,14	8,0271	0,0157
depth+temp.	5	-47,975	106,24	14,13	0,0007
diss.ox.+temp.	5	-48,061	106,42	14,303	0,0007
pH+temp.	5	-48,087	106,47	14,355	0,0007
temp.+veget.	5	-48,161	106,61	14,502	0,0006
edge.dist.+temp.	5	-48,264	106,82	14,708	0,0006
depth+diss.ox.	5	-48,347	106,99	14,875	0,0005
depth+pH	5	-48,428	107,15	15,036	0,0005
depth+veget.	5	-48,498	107,29	15,177	0,0004
diss.ox.+pH	5	-48,546	107,38	15,271	0,0004
depth+edge.dist.	5	-48,564	107,42	15,308	0,0004
diss.ox.+veget.	5	-48,566	107,43	15,313	0,0004
diss.ox.+edge.dist.	5	-48,678	107,65	15,536	0,0004
pH+veget.	5	-48,686	107,66	15,552	0,0004
edge.dist.+pH	5	-48,794	107,88	15,769	0,0003
edge.dist.+veget.	5	-48,829	107,95	15,837	0,0003
depth+diss.ox.+temp.	6	-50,759	113,93	21,817	1,59E-05
depth+pH+temp.	6	-50,765	113,94	21,829	1,58E-05
depth+temp.+veget.	6	-50,869	114,15	22,037	1,42E-05
diss.ox.+pH+temp.	6	-50,87	114,15	22,04	1,42E-05
depth+edge.dist.+temp.	6	-50,923	114,26	22,146	1,35E-05
diss.ox.+temp.+veget.	6	-50,939	114,29	22,176	1,33E-05
pH+temp.+veget.	6	-50,966	114,34	22,23	1,29E-05
diss.ox.+edge.dist.+temp.	6	-51,038	114,49	22,376	1,20E-05
edge.dist.+pH+temp.	6	-51,055	114,52	22,409	1,18E-05
edge.dist.+temp.+veget.	6	-51,143	114,7	22,586	1,08E-05
depth+diss.ox.+pH	6	-51,163	114,74	22,626	1,06E-05
depth+diss.ox.+veget.	6	-51,229	114,87	22,758	9,91E-06
depth+diss.ox.+edge.dist.	6	-51,293	115	22,886	9,30E-06
depth+pH+veget.	6	-51,31	115,03	22,92	9,14E-06
depth+pH+edge.dist.	6	-51,349	115,11	22,998	8,79E-06
diss.ox.+pH+veget.	6	-51,399	115,21	23,097	8,37E-06
depth+edge.dist.+veget.	6	-51,446	115,3	23,191	7,98E-06
diss.ox.+edge.dist.+pH	6	-51,5	115,41	23,299	7,56E-06
diss.ox.+edge.dist.+veget.	6	-51,534	115,48	23,368	7,31E-06
edge.dist.+pH+veget.	6	-51,647	115,71	23,594	6,53E-06
depth+diss.ox.+pH+temp.	7	-53,552	121,65	29,542	3,33E-07
depth+diss.ox.+temp.+veget.	7	-53,649	121,85	29,738	3,02E-07
depth+pH+temp.+veget.	7	-53,657	121,87	29,754	3,00E-07
depth+edge.dist.+pH+temp.	7	-53,68	121,91	29,799	2,93E-07

depth+diss.ox.+edge.dist.+temp.	7	-53,703	121,96	29,845	2,87E-07
diss.ox.+pH+temp.+veget.	7	-53,745	122,04	29,93	2,75E-07
depth+edge.dist.+temp.+veget.	7	-53,815	122,18	30,069	2,56E-07
diss.ox.+edge.dist.+pH+temp.	7	-53,831	122,21	30,102	2,52E-07
diss.ox.+edge.dist.+temp.+veget.	7	-53,914	122,38	30,268	2,32E-07
edge.dist.+pH+temp.+veget.	7	-53,931	122,41	30,302	2,28E-07
depth+diss.ox.+pH+veget.	7	-54,044	122,64	30,526	2,04E-07
depth+diss.ox.+edge.dist.+pH	7	-54,081	122,71	30,602	1,96E-07
depth+diss.ox.+edge.dist.+veget.	7	-54,172	122,9	30,784	1,79E-07
depth+edge.dist.+pH+veget.	7	-54,23	123,01	30,898	1,69E-07
diss.ox.+edge.dist.+pH+veget.	7	-54,353	123,26	31,146	1,50E-07
depth+diss.ox.+pH+temp.+veget.	8	-56,441	129,59	37,482	6,30E-09
depth+diss.ox.+edge.dist.+pH+temp.	8	-56,463	129,64	37,527	6,15E-09
depth+edge.dist.+pH+temp.+veget.	8	-56,571	129,85	37,742	5,53E-09
depth+diss.ox.+edge.dist.+temp.+veget.	8	-56,591	129,89	37,782	5,42E-09
diss.ox.+edge.dist.+pH+temp.+veget.	8	-56,705	130,12	38,01	4,83E-09
depth+diss.ox.+edge.dist.+pH+veget.	8	-56,959	130,63	38,518	3,75E-09
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	-59,35	137,6	45,484	1,15E-10

S25: Summary of adjusted models produced by GLMM analysis relating local descriptors and taxonomic diversity in tadpole communities in ponds in the Summer (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	-8,4017	23,763	0	0,5478
pH	4	-8,9283	27,523	3,7599	0,0836
diss.ox.	4	-9,0618	27,79	4,0268	0,0731
temp.	4	-9,0763	27,819	4,0558	0,0721
edge.dist.	4	-9,547	28,761	4,9973	0,045
depth	4	-9,6803	29,027	5,2639	0,0394
veget.	4	-9,9412	29,549	5,7856	0,0304
edge.dist.+pH	5	-9,1674	30,943	7,18	0,0151
pH+temp.	5	-9,2639	31,136	7,373	0,0137
diss.ox.+pH	5	-9,546	31,701	7,9374	0,0104
depth+pH	5	-9,6715	31,952	8,1883	0,0091
edge.dist.+temp.	5	-10,158	32,924	9,161	0,0056
diss.ox.+temp.	5	-10,168	32,945	9,182	0,0056
diss.ox.+edge.dist.	5	-10,213	33,034	9,2711	0,0053
temp.+veget.	5	-10,305	33,22	9,4561	0,0048
depth+temp.	5	-10,483	33,574	9,8105	0,0041
depth+veget.	5	-10,496	33,6	9,8368	0,004

pH+veget.	5	-10,514	33,638	9,8741	0,0039
depth+diss.ox.	5	-10,559	33,727	9,9633	0,0038
depth+edge.dist.	5	-10,576	33,76	9,9968	0,0037
diss.ox.+veget.	5	-10,613	33,835	10,072	0,0036
edge.dist.+veget.	5	-10,776	34,161	10,397	0,003
diss.ox.+edge.dist.+pH	6	-9,8528	35,524	11,76	0,0015
edge.dist.+pH+temp.	6	-9,9393	35,697	11,933	0,0014
depth+edge.dist.+pH	6	-10,318	36,454	12,69	0,001
edge.dist.+pH+veget.	6	-10,354	36,527	12,763	0,0009
depth+pH+temp.	6	-10,42	36,658	12,895	0,0009
diss.ox.+pH+temp.	6	-10,459	36,736	12,972	0,0008
depth+pH+veget.	6	-10,565	36,949	13,185	0,0008
pH+temp.+veget.	6	-10,649	37,117	13,353	0,0007
depth+diss.ox.+pH	6	-10,723	37,264	13,5	0,0006
diss.ox.+pH+veget.	6	-11,157	38,132	14,369	0,0004
diss.ox.+edge.dist.+temp.	6	-11,292	38,403	14,639	0,0004
depth+temp.+veget.	6	-11,322	38,463	14,7	0,0004
depth+edge.dist.+temp.	6	-11,341	38,501	14,737	0,0003
edge.dist.+temp.+veget.	6	-11,354	38,526	14,763	0,0003
diss.ox.+edge.dist.+veget.	6	-11,474	38,766	15,003	0,0003
depth+edge.dist.+veget.	6	-11,48	38,778	15,015	0,0003
diss.ox.+temp.+veget.	6	-11,512	38,843	15,08	0,0003
depth+diss.ox.+edge.dist.	6	-11,553	38,925	15,161	0,0003
depth+diss.ox.+temp.	6	-11,576	38,971	15,207	0,0003
depth+diss.ox.+veget.	6	-11,62	39,058	15,295	0,0003
depth+edge.dist.+pH+veget.	7	-10,894	41,121	17,358	9,32E-05
edge.dist.+pH+temp.+veget.	7	-10,905	41,143	17,38	9,22E-05
diss.ox.+edge.dist.+pH+temp.	7	-10,919	41,171	17,407	9,09E-05
depth+edge.dist.+pH+temp.	7	-11,158	41,649	17,886	7,16E-05
depth+diss.ox.+edge.dist.+pH	7	-11,172	41,677	17,913	7,06E-05
diss.ox.+edge.dist.+pH+veget.	7	-11,26	41,854	18,091	6,46E-05
depth+edge.dist.+pH+temp.	7	-11,341	42,015	18,252	5,96E-05
depth+diss.ox.+pH+temp.	7	-11,68	42,694	18,931	4,24E-05
depth+diss.ox.+pH+veget.	7	-11,807	42,947	19,184	3,74E-05
diss.ox.+pH+temp.+veget.	7	-11,908	43,15	19,387	3,38E-05
depth+edge.dist.+temp.+veget.	7	-12,309	43,951	20,188	2,26E-05
diss.ox.+edge.dist.+temp.+veget.	7	-12,479	44,292	20,528	1,91E-05
depth+diss.ox.+edge.dist.+veget.	7	-12,526	44,385	20,622	1,82E-05
depth+diss.ox.+edge.dist.+temp.+	7	-12,546	44,426	20,662	1,79E-05
depth+diss.ox.+temp.+veget.	7	-12,594	44,522	20,758	1,70E-05
depth+edge.dist.+pH+temp.+veget.	8	-11,748	46,696	22,932	5,74E-06
diss.ox.+edge.dist.+pH+temp.+veget.	8	-12,133	47,467	23,703	3,90E-06
depth+diss.ox.+edge.dist.+pH+veget.	8	-12,166	47,532	23,769	3,78E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	-12,181	47,561	23,798	3,72E-06
depth+diss.ox.+pH+temp.+veget.	8	-12,713	48,627	24,863	2,19E-06

depth+diss.ox.+edge.dist.+temp.+veget.	8	-13,526	50,251	26,488	9,70E-07
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	-13,085	53,644	29,881	1,78E-07

S26: Summary of adjusted models produced by GLMM analysis relating local descriptors and taxonomic diversity in tadpole communities in ponds in the Autumn (season with high hydric stress). Local descriptors: Depth (water column depth); Diss.ox. (dissolved oxygen); edge.dist. (edge distance); temp (water temperature); veget (percentage of aquatic vegetation cover).

Model	df	logLik	AICc	Δ	weight
null	3	2,8556	1,3323	0	0,7088
temp.	4	1,7206	6,3771	5,0448	0,0569
veget.	4	1,6662	6,4858	5,1535	0,0539
pH	4	1,4785	6,8611	5,5288	0,0447
edge.dist.	4	1,3789	7,0605	5,7281	0,0404
depth	4	1,1022	7,6138	6,2815	0,0307
diss.ox.	4	0,894	8,0301	6,6978	0,0249
depth+diss.ox.	5	0,6535	11,55	10,218	0,0043
pH+temp.	5	0,6226	11,612	10,28	0,0042
temp.+veget.	5	0,3968	12,063	10,731	0,0033
pH+veget.	5	0,3355	12,186	10,854	0,0031
edge.dist.+temp.	5	0,1534	12,55	11,218	0,0026
edge.dist.+pH	5	0,1463	12,564	11,232	0,0026
depth+temp.	5	0,1399	12,577	11,245	0,0026
edge.dist.+veget.	5	0,0626	12,732	11,4	0,0024
diss.ox.+temp.	5	0,0363	12,785	11,452	0,0023
depth+pH	5	-0,1318	13,121	11,788	0,002
diss.ox.+veget.	5	-0,2885	13,434	12,102	0,0017
depth+veget.	5	-0,3208	13,499	12,166	0,0016
depth+edge.dist.	5	-0,4008	13,659	12,326	0,0015
diss.ox.+pH	5	-0,465	13,787	12,455	0,0014
diss.ox.+edge.dist.	5	-0,5823	14,022	12,689	0,0012
depth+diss.ox.+pH	6	-0,1791	16,558	15,226	0,0004
depth+diss.ox.+temp.	6	-0,3363	16,873	15,54	0,0003
pH+temp.+veget.	6	-0,7316	17,663	16,331	0,0002
depth+diss.ox.+veget.	6	-0,753	17,706	16,374	0,0002
edge.dist.+pH+temp.	6	-0,8216	17,843	16,511	0,0002
depth+diss.ox.+edge.dist.	6	-0,8493	17,899	16,566	0,0002
depth+pH+temp.	6	-0,8859	17,972	16,64	0,0002
diss.ox.+pH+temp.	6	-0,8975	17,995	16,663	0,0002
diss.ox.+temp.+veget.	6	-1,0761	18,352	17,02	0,0001
edge.dist.+pH+veget.	6	-1,1318	18,464	17,131	0,0001
depth+temp.+veget.	6	-1,2096	18,619	17,287	0,0001
depth+edge.dist.+temp.	6	-1,2224	18,645	17,312	0,0001
edge.dist.+temp.+veget.	6	-1,2277	18,655	17,323	0,0001
depth+edge.dist.+pH	6	-1,4288	19,058	17,725	0,0001

diss.ox.+edge.dist.+temp.	6	-1,5369	19,274	17,941	9,01E-05
depth+pH+veget.	6	-1,5397	19,279	17,947	8,98E-05
diss.ox.+pH+veget.	6	-1,6119	19,424	18,091	8,36E-05
diss.ox.+edge.dist.+pH	6	-1,8036	19,807	18,475	6,90E-05
diss.ox.+edge.dist.+veget.	6	-1,8804	19,961	18,629	6,39E-05
depth+edge.dist.+veget.	6	-1,9171	20,034	18,702	6,16E-05
depth+diss.ox.+pH+temp.	7	-0,9285	21,752	20,419	2,61E-05
depth+diss.ox.+edge.dist.+pH	7	-1,282	22,459	21,126	1,83E-05
depth+diss.ox.+pH+veget.	7	-1,572	23,039	21,706	1,37E-05
depth+diss.ox.+temp.+veget.	7	-1,6667	23,228	21,896	1,25E-05
depth+diss.ox.+edge.dist.+temp.	7	-1,6685	23,232	21,899	1,24E-05
depth+edge.dist.+pH+temp.	7	-2,013	23,921	22,588	8,82E-06
diss.ox.+pH+temp.+veget.	7	-2,073	24,041	22,709	8,31E-06
edge.dist.+pH+temp.+veget.	7	-2,2441	24,383	23,051	7,00E-06
depth+pH+temp.+veget.	7	-2,2764	24,448	23,115	6,78E-06
depth+diss.ox.+edge.dist.+veget.	7	-2,3499	24,595	23,262	6,30E-06
diss.ox.+edge.dist.+pH+temp.	7	-2,3811	24,657	23,325	6,10E-06
depth+edge.dist.+temp.+veget.	7	-2,6924	25,28	23,947	4,47E-06
diss.ox.+edge.dist.+temp.+veget.	7	-2,7505	25,396	24,063	4,22E-06
depth+edge.dist.+pH+veget.	7	-2,9661	25,827	24,495	3,40E-06
diss.ox.+edge.dist.+pH+veget.	7	-3,0797	26,054	24,722	3,04E-06
depth+diss.ox.+edge.dist.+pH+temp.	8	-1,7455	27,491	26,159	1,48E-06
depth+diss.ox.+pH+temp.+veget.	8	-2,307	28,614	27,282	8,44E-07
depth+diss.ox.+edge.dist.+pH+veget.	8	-2,8342	29,668	28,336	4,98E-07
depth+diss.ox.+edge.dist.+temp.+veget.	8	-3,1266	30,253	28,921	3,72E-07
depth+edge.dist.+pH+temp.+veget.	8	-3,549	31,098	29,766	2,44E-07
diss.ox.+edge.dist.+pH+temp.+veget.	8	-3,666	31,332	30	2,17E-07
depth+diss.ox.+edge.dist.+pH+temp.+veget.	9	-3,2986	35,185	33,853	3,16E-08

S27 - Reproductive phenology of adults and temporal distribution of tadpoles recorded in the present study. The spiked bars represent the pattern of adult activity, and numbers represent the abundance of tadpoles in each season of the year. The (*) represent the presence of tadpoles registered in our study area.

Species	Spring	Summer	Autumn	Winter	Reference
Dendropsophus minutus	▨ *	▨ *	*	▨ *	Both et al., 2008; Santos et al., 2008
Boana faber	*	▨ *	*	*	Both et al., 2008
Boana pulchella	▨ *		▨	▨ *	Santos et al., 2008
Leptodactylus fuscus	▨ *	▨ *		▨	Santos et al., 2008
Leptodactylus gracilis	▨ *	▨		▨ *	Both et al., 2008; Santos et al., 2008
Leptodactylus latrans	*	▨			Both et al., 2008
Leptodactylus mystacinus	▨ *	▨		▨	Santos et al., 2008
Odontophrynus americanus	*		▨	▨	Santos et al., 2008
Physalaemus biligonigerus	*	▨		*	Santos et al., 2008
Physalaemus cuvieri	▨ *	▨ *	*	▨	Both et al., 2008; Santos et al., 2008
Physalaemus gracilis	▨ *	▨ *		*	Both et al., 2008
Physalaemus henselii	*	▨		*	Santos et al., 2008
Physalaemus lisei	*			*	Maneyro & Carreira, 2012

Pseudopaludicola falcipes	*				Both et al., 2008; Santos et al., 2008
Ololygon berthae	*	*	*	*	Santos et al., 2008
Scinax granulatus	*	*	*	*	Both et al., 2008; Santos et al., 2008
Scinax squalirostris	*	*	*	*	Both et al., 2008; Santos et al., 2008
Julianus urguayus	*				Maneyro & Carreira, 2012

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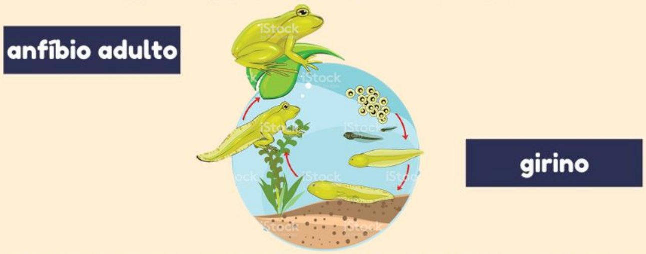
Infográfico

GIRINOS EM POÇAS

ANFÍBIOS SÃO ANIMAIS QUE TÊM DOIS CICLOS DE VIDA E QUE PASSAM POR METAMORFOSE.



Poças são pequenos corpos d'água onde vivem muitas espécies de plantas e animais, incluindo os girinos

Nós estudamos os girinos de poças para entender quais características do ambiente influenciavam a variedade de espécies.

Descobrimos que a PROFUNDIDADE DAS POÇAS influencia POSITIVAMENTE o número de espécies de anfíbios

A profundidade da água forma diversos pequenos ambientes, permitindo que espécies com histórias evolutivas diferentes se estabeleçam e habitem as mesmas poças. Então,

A PRESERVAÇÃO DOS ANFÍBIOS DEPENDE DA PRESERVAÇÃO DAS POÇAS

PARA MAIS INFORMAÇÕES:

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Comprovante de Submissão do Capítulo

Hydrobiologia

What and When local predictors drive Tadpole Diversity in Subtropical Temporary Ponds?

--Manuscript Draft--

Manuscript Number:	HYDR-D-19-00393
Full Title:	What and When local predictors drive Tadpole Diversity in Subtropical Temporary Ponds?
Article Type:	S.I. : Tropical Lakes (Ramirez et al.)
Keywords:	Amphibians; community assembly; depth gradients; environmental filtering; seasonality; functional and phylogenetic diversity
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Order of Authors Secondary Information:	
Funding Information:	Conselho Nacional de Desenvolvimento Científico e Tecnológico (163440/2015-8) — Ms Diego Anderson Dalmolin Conselho Nacional de Desenvolvimento Científico e Tecnológico (XX) — Dr. Tiago Gomes daos Santos Conselho Nacional de Desenvolvimento Científico e Tecnológico (311297/2018-8) — Dra Maria João Ramos Pereira
Abstract:	We evaluated seasonal variation in taxonomic, functional and phylogenetic diversity and redundancy of tadpoles present in 401 points of 10 ponds in southern Brazil. We predicted i) congruent patterns between all components of diversity and environmental descriptors; ii) higher effects of descriptors in the three components in seasons with high hydric stress; iii) all components would be influenced by different sets of environmental descriptors in each season. Predictions were tested using Linear Mixed Models. Taxonomic, functional but mainly the phylogenetic diversity, responded similarly to water depth during the low hydric stress period. This also was observed for functional redundancy. This influence was positive for all components of diversity. Phylogenetic redundancy was not explained by any of environmental descriptors. In the period of higher hydric stress components of diversity were not significantly affected by environmental descriptors. Environmental filtering seems to strongly influence tadpole community structure in temporary ponds, at least during the winter. Water depth gradients create a variety of micro-habitat conditions allowing diverse sets of species to settle and co-occur in ponds. These sets are then filtered according to their swimming and foraging abilities along the depth gradient, where intermediate depths should contain the greatest

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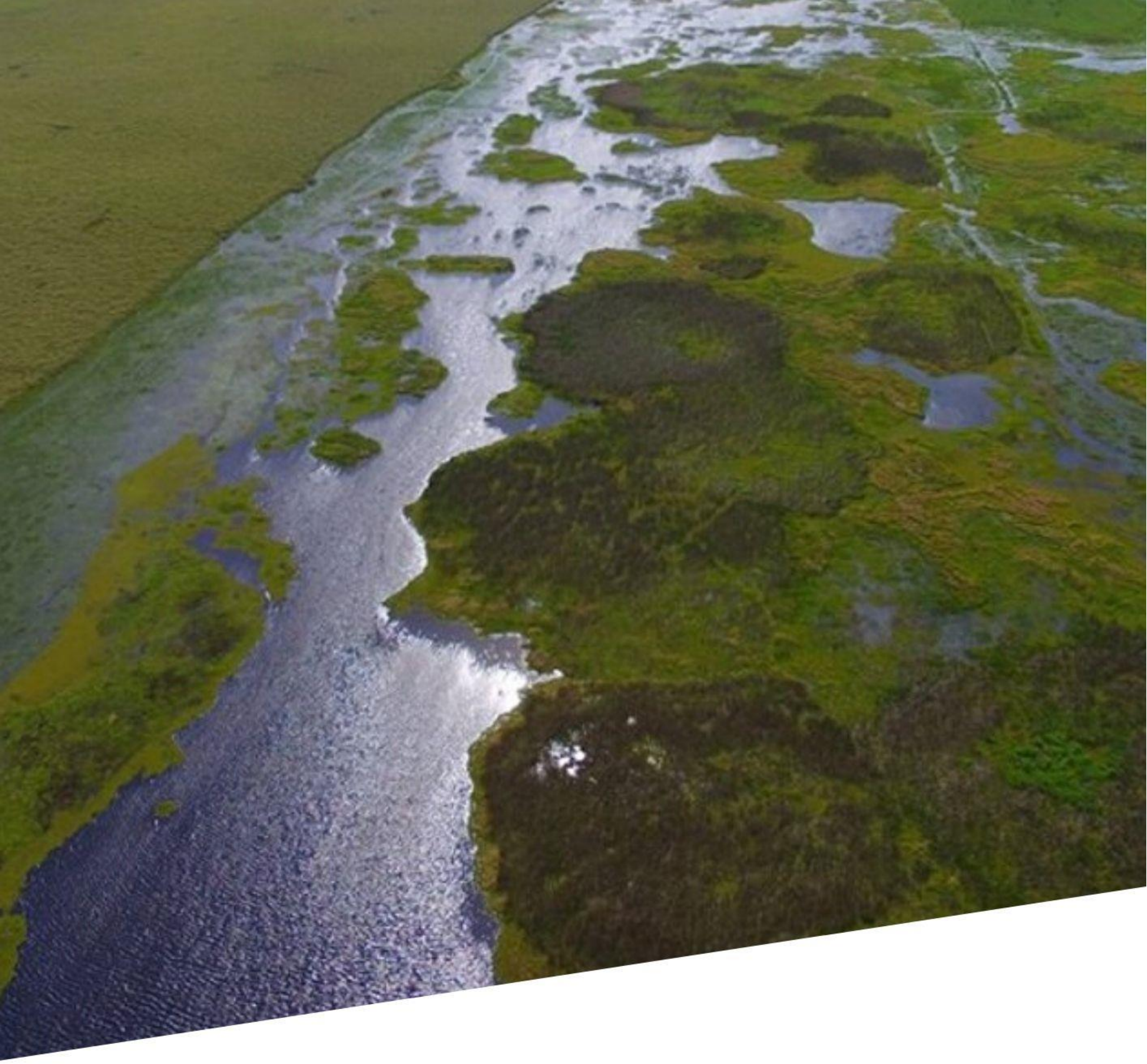

CAPÍTULO 2

TAXONOMIC AND FUNCTIONAL ANURAN BETA DIVERSITY OF A SUBTROPICAL METACOMMUNITY RESPOND DIFFERENTIALLY TO ENVIRONMENTAL AND SPATIAL PREDICTORS

ACEITO PARA PUBLICAÇÃO NA PLOS ONE

CAPÍTULO 2

Taxonomic and functional anuran beta diversity of a subtropical metacommunity respond differentially to environmental and spatial predictors

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Abstract

Anurans exhibit limited dispersion ability and have physiological and behavioural characteristics that narrow their relationships with both environmental and spatial predictors. So, the relative contributions of environmental and spatial predictors in the patterns of taxonomic and functional anuran beta diversity were examined in a metacommunity of 33 ponds along the coast of south Brazil.. We expected that neutral processes and, in particular, niche-based processes could have similar influence on the taxonomic and functional beta diversity patterns. Distance-based methods (db-RDA) with variation partitioning were conducted with abundance data to examine taxonomic and functional facets and components (total, turnover and nestedness) in relation to environmental and spatial predictors. Processes determining metacommunity structure differed between the components of beta diversity and among taxonomic and functional diversity. While taxonomic beta diversity was further accounted by both environmental and spatial predictors, functional beta diversity responded more strongly to spatial predictors. These two contrasting patterns were different to what we had predicted, suggesting that while there is a taxonomic turnover mediated by environmental filters, the spatial distance promotes the trait dissimilarity between sites. In addition, our data confirm that neutral and niche-based processes operate on anuran metacommunities even at short geographic scales. Our results reinforce the idea that studies aiming to evaluate the patterns of structure in metacommunities should include different facets of diversity so that better interpretations can be achieved.

Key words

Freshwater ponds; variation partition; niche-based process; neutral process; southern coast of Brazil

Introduction

Beta diversity connects the spatial structure of communities to a variety of ecological processes, such as neutral processes (e.g. dispersion limitation) and niche-based processes (e.g. limiting similarity and environmental filtering) [1, 2, 3, 4]. Beta diversity represents the amount of variation in species composition between a set of local communities [2, 5, 6], and can be divided into two additive components: spatial turnover and nestedness-resultant [7, 8]. Spatial turnover occurs when some species are replaced by others as a result of ecological processes (e.g. environmental filtering and dispersion limitation) that restrict their occurrence in certain places [2, 8, 9]. Nestedness, on the other hand, occurs when non-random processes of species loss result in the ordered deconstruction of assemblages, leading to the formation of local sets poorer in the number of species, and subsets of richer sites [9, 10, 11]. Despite their distinct nature, these two components are complementary and main drivers of dissimilarity patterns between communities [7].

Within the metacommunity theory, the organization of local assemblies is thought to occur at broader spatial scales [12, 13]. In metacommunities structured by neutral processes, the dispersion limitation and demographic stochasticity are the dominant factors, so that geographical distance between communities is the best predictor of beta diversity [14, 15]. In contrast, ecological interactions and environmental conditions are the most important factors in metacommunities structured by niche processes, and the environmental distance between communities should be the best predictor of beta diversity [12, 16]. However, several studies suggest that the action of these processes is not mutually exclusive, and that the structuring of biological metacommunities results from the interaction of the two processes – neutral and niche-based [13, 17]. Indeed, in aquatic metacommunities deterministic processes (especially environmental filtering) seem to be dominant, though neutral processes also contribute to the observed patterns of beta diversity [9].

Taking into account that biological communities result from a complexity of interactions between organisms, environment and space, the incorporation of functional traits (functional diversity) in community and metacommunity studies has been widely advocated (e.g. 18, 19). In fact, the use of an integrative approach where taxonomic and functional diversities are taken into account is advantageous. First, the evaluation of communities using only taxonomic identity is often difficult to interpret, since taxonomic groups may contain phylogenetic and ecological lineages in conflict between convergence and adaptive divergence [20, 21, 22]. In addition, the functional approach allows elucidating the 'true role' of each species in ecosystem processes and their resistance and resilience to environmental changes [23, 24]. Finally, several studies found congruent responses of the two metrics of diversity for the same ecosystem processes [19, 25, 26], although these relationships may vary according to the taxonomic group of interest [27, 28].

Neotropical anurans are considered excellent ecological models because they are locally abundant and sampling of most groups is relatively easy. Anurans have highly permeable skin, a complex and biphasic life cycle, limited dispersion, and geographically restricted distribution patterns [29, 30]. So, compositional variation in anuran seems to result from several factors, such as available area and hydroperiod, vegetation cover, type of surrounding matrix and geomorphology [26, 31, 32, 33, 34]. Thus, both environment and space tend to strongly contribute to the patterns of taxonomic and functional dissimilarity between anuran communities [30, 35, 36].

Although anuran beta diversity has already been addressed in several studies (e.g. 33, 36, 37), few have used an integrative approach to describe patterns of anuran beta diversity [30]. FAlthough the dominance of environmental predictors over beta diversity has been reported in several studies [e.g. 26, 29, 37], others have reported considerably greater spatial effects [38], or even a balance between both [30, 33]. These discrepancies occur because the different characteristics of anurans' life histories respond differently to ecological predictors, so that the metacommunity structure may differ between groups occurring in the same region [e.g. 39]. Thus, the concomitant evaluation of taxonomic and functional information can resolve much of the mismatch about the anuran metacommunity structure and provide important information for the conservation of species and their functions in community and ecosystem properties [40].

In this study we investigated the relationship between environmental and spatial components and the patterns of taxonomic and functional beta diversity in a metacommunity of anurans from the coastal subtropical region of southern Brazil. We expect beta diversity to be influenced by both environmental and spatial components, with a greater contribution of the environmental component to the distribution of traits and species [41]. We also expect diversity components – taxonomic and functional – to present similar responses to the sets of descriptors evaluated [30]. Through functional traits, species can shape, change and accommodate in the environment where they occur [42, 43]. Consequently, species distribution can be expected as resulting from combinations of ecologically relevant characteristics allowing them to persist in a given set of environments [44]. We thus expect functional diversity to be a better indicator of the ecological processes responsible for the structuring of the anuran metacommunity [41, 45].

Material and Methods

Ethics statement

Collection permits were provided by Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) (authorization 55409). Field studies did not involve endangered or protected species. We restricted manipulation of animals in the field to minimal as we sampled just specimens restricted in the collection units (see the section 2.3). Specimens collected were identified, measured and immediately released in the same pond where they were sampled. All sampling procedures were reviewed and specifically approved as part of obtaining the field permits by ICMBio (see above).

Study Area

This study was done in Lagoa do Peixe National Park (PNLP; 31°02'-31°48'S; 50°77'-51°15'W; figure 1), the only Ramsar site in southern Brazil [46]. With a length of 64 km and an average width of 6 km, the PNLP comprises over 34,000 hectares of protected wetlands, integrating the Coastal Plain of the State of Rio Grande do Sul, one of the regions of southern Brazil with higher concentration of wetlands [47]. The climate is subtropical humid, and temperatures range between 13 °C and 24 °C with annual average of 17.5 °C. The mean annual precipitation varies between 1200 and 1500 mm [48]. The vegetation along water bodies is typical of wetlands, with a predominance of tree and grass vegetation around water bodies and aquatic macrophytes at the edges and inland.

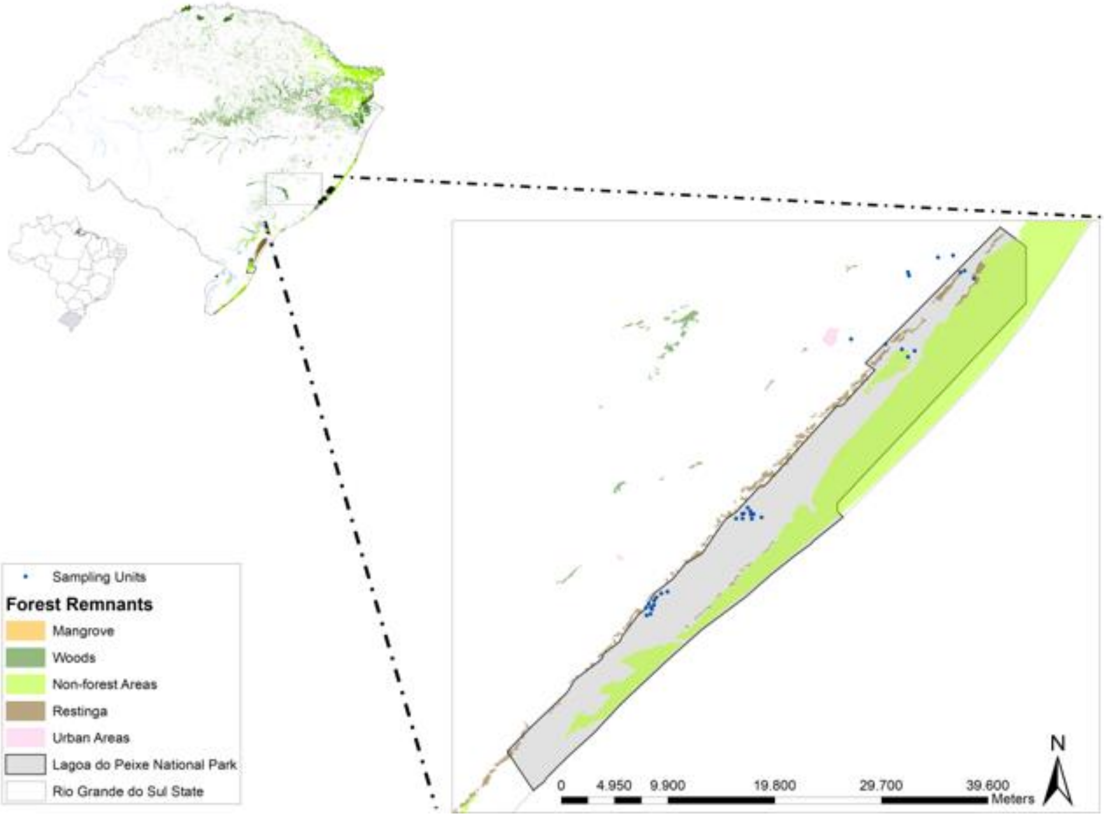


Figure 1: Study area at Lagoa do Peixe National Park, southern Brazil. Sampled ponds are represented by blue circles.

Anuran surveys and trait measurement

We sampled adult anurans in 33 water bodies throughout the study region (Fig. 1). Ponds were selected based on biotic and abiotic characteristics (see Table S1), insulation of other ponds (sample independence), accessibility and landowner permission. Distances between ponds ranged from 0.7 to 39 km. Sampling was performed monthly, from October 2016 to March 2017. The hydroperiod characterization of each pond was performed monthly by recording total area and average depth. Most of the sampled ponds showed monthly variation in water volume, but remained with over 50% of the initial volume registered (the exceptions were the ponds that showed small reductions). Thus, the ponds were characterized as semi-permanent.

We used both calling surveys and active search at breeding habitats to record the number of calling males of each species in each pond [49]. Samplings were done from 6 p.m. to 0 a.m. The total effort per pond was 1 hour per month, totalling 6 hours of sampling per pond. Sampling was performed by DAD with the help of three additional researchers. DAD was responsible for both accounting for the individuals present in each pond and for measuring the morphological traits of each individual.

We measured five morphological traits for each individual captured: head shape; eyes position; eye size; relative length of limbs; body mass (see Supplementary Material Table S2 for more information). Addittionaly, we compiled six life history traits from literature: reproductive mode; relative number of eggs; daily activity period; type of habitat; fossorial habit; reproductive season. These 11 traits were chosed based on perceived importance for determining habitat use and species resilience. All attributes were used to construct a pairwise distance matrix of species. In this procedure we used the Gower standardization for mixed variables [50].

Environmental and spatial variables

The eight environmental descriptors measured in this study and their description are presented in Table S14. Area, depth and number of vegetation types around the pond, pond vegetation (inside the pond), margin configuration and pond substrate were measured in the field through visual interpretation in an area around 5 meters from the edge of the ponds. The distance to the nearest forest fragment and distance to the nearest sampled pond were obtained from high-resolution aerial photographs of the region inspected immediately after samplings, available from Google Earth (http://earth.google.com/), combined with field inspection.

We used distance-based Moran's Eigenvector Maps (dbMEMs; 50, 51) to create spatial variables (eigenvectors) based on the Euclidean distance matrix of the geographical coordinates of the ponds. First of all, we defined the neighbourhood matrix, which describes the spatial relationships among objects [51]. In other words, we defined which ponds are neighbours and which are not. We used as spatial neighbourhood graphs 'Delaunay triangulation', 'Gabriel graph' and 'Minimum spanning trees', and as a weight measure we used the linear distances between ponds. We selected the best neighbourhood matrix based on AICc. The most parsimonious model was the one based on the 'Gabriel graph', and the truncation distance was 18.03 km (AIC = 11.22 versus 12.88 for the null model). This model also generated 23 spatial variables (eigenvectors), eight of which with positive autocorrelation.

Data Analysis

Data matrices

We built four matrix types containing the measured data of all ponds: (i) an abundance or presence/absence matrix, which contained the total species count for each pond; (ii) a trait matrix, containing average trait values for each species; (iii) an environmental matrix, containing all environmental descriptors measured in each pond; and (iv) a spatial matrix, containing all dbMEMs.

As suggested by [52], we considered the abundance of each species in a given pond as the abundance of calling males recorded in the month of highest recorded abundance. This procedure prevents underestimates of population abundance caused by calculating the mean of successive samples and prevents overestimates caused by the re-counting of individuals if successive samples are summed [52]. Abundance data were transformed using the Hellinger distance [50] to homogenize variation among species abundances. Environmental descriptors values were standardized by subtracting each value from the average of the descriptor and dividing the result by the standard deviation.

Assessing the anuran beta diversity components

We partitioned beta diversity into overall beta diversity, turnover and nestedness components following the methods proposed by [8]. This procedure was performed using the function "beta.pair" in the R package betapart [50] and the function "beta" in the R package BAT [54]. We used the Bray-Curtis dissimilarity for the abundance data. This procedure produced three dissimilarity matrices (Table 1).

Table 1: Summary of beta diversity index and their nomenclatures used in this study

	Beta diversity index	Nomenclature
Total	Overall spatial turnover	βBray
Turnover	Turnover immune to species richness variation	βBal
Nestedness	Nestedness resulting from species richness differences between sites	βGra

Community–environment relationships

We used distance-based redundancy analysis (db-RDA) on each biological dissimilarity matrix to examine community–environment relationships in more detail [55]. This method is similar to redundancy analysis, but may be based on any dissimilarity or distance matrix (in our case, Bray-Curtis dissimilarity) [50].

Initially we selected only significant environmental predictors of variation in taxonomic and functional beta diversity, which then were used for the environmental model [56]. We used forward selection with 9999 permutations to select the MEMs to run the environmental model. For this, we used the matrices containing each beta diversity component and the environmental predictors. The selection stopped either when the tested variable had a *p*-value above 0.05 or when the adjusted R^2 [56] of the full model, before any selection, was exceeded [56]. The forward selection procedure was run with the “forward.sel” function from the R package vegan [56]. The summary results of the forward selection procedure are presented in the Table S3.

Spatial predictors

We also used forward selection with 9999 permutations to select the MEMs to run the spatial model. The summary results of forward selection procedure are presented in the Tables S4 and S5.

Variation partitioning for the anuran taxonomic and functional beta Diversity

The relative contributions of the environmental descriptors and spatial variables to the taxonomic and functional beta diversity patterns were evaluated using a partial Redundancy Analysis (pRDA) with variation partitioning [51]. This analysis partitions the variance in community composition resulting from (1) each explanatory variable ([E] = environment and [S] = spatial), (2) the unique contribution of each explanatory variable ([E/S] = environment - purely environmental variables – or [S/E] = spatial – purely spatial variables) and (3) the total variance explained by the environmental and spatial variables together (spatially structured environmental variables). The variance explained by each fraction was based on the adjusted R^2 [57]. The environmental variables used in the environmental model and the spatial variables composing the spatial model were those previously selected in db-RDA and forward selection, as described above.

The significance of db-RDA axes (Tables S7 and S8) and pRDA fractions were tested through an ANOVA-like permutation test to assess the significance of the constraints, using 9999 permutations. The db-RDA and pRDA analyses were done using the functions “capscale” and “var.part”, and the permutations using the “anova.cca” function, of the R package vegan [58].

Results

Eleven species belonging to three families (Bufonidae, Hylidae and Leptodactylidae) were registered. The most frequent species were *Dendropsophus sanborni* and *Pseudis minuta*, occurring in 19 of 33 ponds evaluated. *Physalaemus biligonigerus* and *Scinax fuscovarius* were less frequent occuring, respectively, in three and four of the sampled ponds (for the complete list of species and occurrence pattern across ponds see Table S9).

Environmental predictors and anuran beta Diversity

In general, the sets of descriptors selected to compose the environmental and spatial models were different between the taxonomic and the functional beta diversities (Table 2). The greater relationship between environmental descriptors and beta diversity was observed in the total component of taxonomic beta diversity (R^2adj: 0.18; F: 1.52; p: <0.001) and for turnover (R^2adj: 0.18; F: 2.25; p: 0.02) and nestedness (R^2adj: 0.29; F: 8.40; p: <0.001) components of functional beta diversity.

Regarding taxonomic beta diversity, the environmental descriptors selected were depth, pond vegetation and pond substrate. Pond vegetation was shared for all of beta diversity components, but it was not significant for the nestedness component. Depth and pond vegetation seem to the main drivers of taxonomic beta diversity in the metacommunity, since it largely explained total beta diversity (**depth**: F=1.83, p=0.03; **pond vegetation**: F=1.42, p=0.01) and turnover (**depth**: F=2.41, p=0.02; **pond vegetation**: F=2.27, p<0.001; Table S6).

The environmental descriptors selected for the functional beta diversity were area, vegetation around the pond and types of substrate. Vegetation around the pond was the descriptor that most explained total beta diversity (F=1.84, p=0.05; Table S7) and turnover (F=3.86, p<0.001). For the nestedness, area was the descriptor that most explained total beta diversity of this component (F= 8.40; p< 0.001).

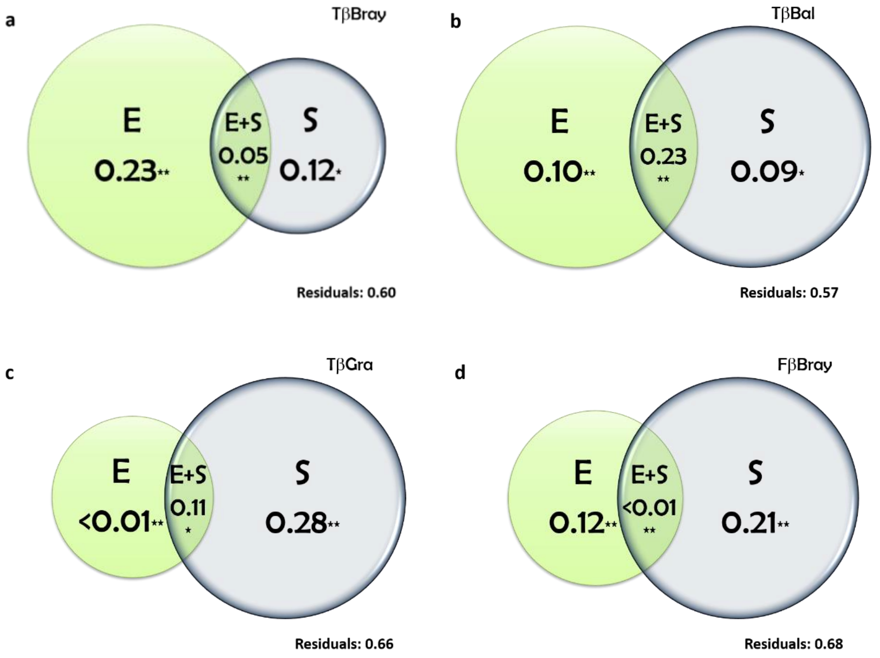
Table 2. Results of distance-based RDAs for the abundance data. Analyses were run for taxonomic and functional components based on total beta diversity, turnover and nestedness dissimilarities. Full models and marginal tests of significance for single environmental variables are shown (i.e., separate significance test for each variable in a model when all other terms are in the model).

TOTAL (βBray)			TURNOVER (βBal)			NESTEDNESS (βGra)		
Taxonomic beta diversity								
Overall test			Overall test			Overall test		
R^2adj:0.18; F:1.52; p: <0.001			R^2adj:0.08; F: 1.18; p< 0.001			R^2adj:0.001; F: 0.99; p: 0.56		
Predictor Variable	F	p	Predictor Variable	F	p	Predictor Variable	F	p
Depth	1.83	0.03	Depth	2.41	0.02	Ins.veg	0.99	0.56
Ins.veg	1.42	0.01	Ins.veg	2.27	<0.001			
Subst.	1.20	0.01	Subst.	1.67	0.05			

Functional beta diversity								
Overall test			Overall test			Overall test		
$R^2 adj$:0.05; F: 1.84; p: 0.05			$R^2 adj$:0. 18; F: 2.25; p: 0.02			$R^2 adj$:0.29; F: 8.40; p: <0.001		
Predictor Variable	*F*	*P*	Predictor Variable	*F*	*p*	Predictor Variable	*F*	*P*
Margin veg.	1.84	0.05	Margin veg.	3.86	<0.001	Area	8.40	<0.001
			Subst.	1.46	0.20			

Variation partitioning for anuran beta Diversity

Variation partitioning analyses identified significant effects of both environmental and spatial components on the anuran metacommunity structure. Both environment and space influenced the taxonomic and functional structure, but the taxonomic structure was mostly driven by environment, while functional structure was mostly determined by the spatial component (Figure 2a-2e; Table S8).



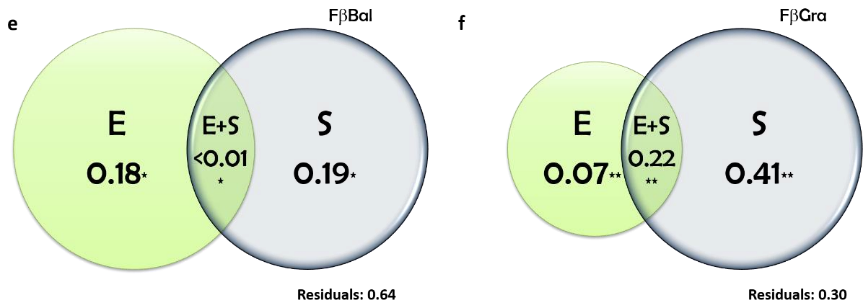


Figure 2: Variation partitioning for total taxonomic (a-c) and functional (d-ff) beta diversities of anuran communities. E = environment; S = spatial component. (*) $p < 0.05$; (**) $p < 0.001$.

Variation partitioning for taxonomic beta Diversity

The contribution of the environmental component for the total variance explained by the taxonomic beta diversity was greater than the pure spatial component (Figure 2a; Table S8). For total beta diversity, the contributions of the environmental individual fraction were 23%, while the contributions of space were 12%. The shared contribution between Environment and Space on the total variance was 5%.

The components of taxonomic beta diversity showed more complex patterns. The shared fraction between environment and space (11%), but mostly the pure spatial component (28%), explained nestedness patterns (βGra; Figure 2c)). The environmental component explained less than 1% of the variation (though it was significant; p=0.004). The opposite pattern was observed for the turnover, where the shared fraction between environment and space presented the strongest influence on the patterns (βBal= 23%; Figure 2b). The environmental fraction was slightly larger than the spatial fraction in explaining the patterns of this component (βGra= 10% and 9%, respectively)..

Variation partitioning for functional beta Diversity

Variance in functional beta diversity (βBray: 21%, Figure 2d) and its components (βBal: 19%, Figure 2e; βGra: 41%; Figure 2f)) were mostly explained by spatial processes (Table S8). However, the environmental component also contributed significantly to the explained fraction, especially towards functional turnover (βBal:18%). Finally, the largest contribution of the shared fraction between environment and space was observed solely for the functional nesting. (βGra: 22%).

Discussion

Here, we used a variation partition approach to understand how taxonomic and functional anuran beta diversity are influenced by environment and space at a regional scale in South American subtropical wetlands. Our results showed opposing patterns between taxonomic and functional beta diversity in their response to environmental and spatial predictors, contrary to what we had predicted, and has been described for metacommunities of Atlantic Forest anurans [30]. Taxonomic diversity responded to both spatial and local environmental predictors, while functional diversity was better explained by spatial predictors. We also registered opposite patterns for species turnover. While the spatially structured environment drives taxonomic turnover, the isolated fractions of space and environment were responsible for all the explanation found for functional turnover. However, it should be noted that although we found discrepancies between the taxonomic and functional structure, nestedness components for each were driven similarly by the same predictors (spatially structured environment and mostly spatial fraction).

Our findings reinforce that the structuring of beta diversity in metacommunities of organisms that depend on aquatic systems, including those of anurans, is complex [22, 30]. This allows us to infer that different processes act on the selection of species and functional attributes along metacommunities [22]. Also, the patterns and processes of diversity might differ when total beta diversity is partitioned [8]. Our results also support the assumption that beta diversity components vary across geographic space and may respond to different predictors [1, 12].

Environmental predictors and anuran beta diversity

The organization of anuran assemblages in freshwater systems exhibits patterns in response to environmental gradients [29, 34, 59]. Most of the descriptors we evaluated had some level of influence on anuran patterns of beta diversity. Indeed, different environmental factors tend to affect species differently due to differences in their physiological and behavioural characteristics [20, 35, 38]. Area and depth were the two predictors best explaining beta diversity. These two variables are associated with pond hydroperiod and promote a trade-off between the persistence of those systems and predation and competition levels, both with strong influence in anuran survival and life cycle [31, 32]. Species richness and composition will thus be affected by those descriptors, and the persistence of a species in a given community will be mediated by the presence of specific traits [31, 32]. For example, species that lay eggs in foam nests and show rapid larval development (leptodactylids as *Physalaemus biligonigerus* and *Physalaemus gracilis*) survive in ephemeral ponds but tend to present reduced rates of growth and post-metamorphic survival [60, 61]. On the other hand, the occurrence in permanent ponds is favoured by morphological and behavioural traits that facilitate the escape and co-occurrence with predators and competitors, respectively (e.g. body and fin format; refuge use; activity patterns) at the cost of time delays in development and phenotypic changes promoted by intra and interspecific interactions [62].

Substrate type and pond and margin vegetation are closely associated with species' reproductive habits (e.g. calling sites and oviposition sites). Anurans present a wide variety of reproductive modes [63, 64], and the presence of more differentiated modes requires increasing levels of environmental complexity. This is the case for most species of the Hylidae and the Leptodactylidae, which place spawning near aquatic macrophytes [64]. These variables represent resources that were also crucial for adults and juveniles in their thermoregulation and food production processes [65, 66, 67]. The significant contribution of these variables in the metacommunity structure demonstrates the importance of environmental heterogeneity towards both taxonomic and functional structures. More specifically, our results demonstrate that the presence of ponds distributed along gradients promoted by these descriptors is paramount for the maintenance of anuran populations and communities [32, 39, 68], and any change in these variables could drastically change the patterns of metacommunity organization.

Opposing patterns between taxonomic and functional beta diversity

Our results show that taxonomic beta diversity is mainly structured by niche-based processes, as the similarity in species composition decays along the environmental gradient [12]. This means that environmentally distinct ponds add different community compositions [69, 70]. However, this dissimilarity was slightly lower for the functional diversity for most cases, indicating that, although there is a taxonomic turnover mediated by environmental filters, the traits present along these gradients are often not sufficiently different for large functional dissimilarities to be observed [25, 71].

Functional beta diversity was more closely associated with spatial predictors, suggesting the dominance of neutral processes [14]. The presence of a spatial structure in beta diversity patterns of anurans has been observed to communities of Amazonia [39] and southeastern Brazil [29, 38] and appears to be common and more evident for amphibians than for other organisms (e.g. mammals, birds and invertebrates)[1]. We highlight that the combination of spatial and environmental models also contributed considerably to the explained fraction, which may suggest a certain level of spatial autocorrelation in some of the environmental variables [3]. These diversity patterns organized according to spatially structured environmental variables may be common in freshwater communities [72]. This is because the ecological variables of ponds (e.g. depth and aquatic vegetation) are not spatially independent and are often spatially structured at local and regional scales [29, 72].

The results for taxonomic and functional nestedness emphasize the pattern of dominance by spatial predictors in our study area. This may be linked to dispersal limitation (e.g. [36]); indeed, anurans relatively small body-size and physiological limitations make most species dependent on flooded or at least humid corridors for dispersal [20, 32]. In addition, the presence of natural and artificial barriers (e.g. sandy soils and roads with constant car traffic, as occurs in our study area) may prevent many species from reaching all ponds available for the whole of the metacommunity [1, 32]. As a consequence, there was a decrease in functional similarity with the increase in geographical distance, as occurs in other aquatic organisms [22, 73, 74].

Still, the association of spatial predictors with neutral dynamics and potential patterns of dispersal limitation should be interpreted cautiously. In fact, potentially important environmental variables may not have been evaluated, while contained in the spatial component [71, 75]. Also, other factors difficult to evaluate, such as predation and competition, may have a significant effect in the patterns of beta diversity and alter the importance of each predictor along the metacommunity, which was already demonstrated for microorganisms in controlled systems [76].

The processes of community assembly may act in different environmental gradients and along spatial and temporal scales, resulting in patterns of functional and phylogenetic convergence or divergence independent of the taxonomic identity [27, 77]. Such discrepancies between different metrics of diversity across spatial and temporal scales were already reported in other taxa [19, 78, 79]. Moreover, the correlation between taxonomic and functional nestedness and turnover may be higher at the alpha scale than at the beta and may be variable according to the set of the functional traits evaluated [3, 80, 81].

Conclusions

In conclusion, our results contributed to the knowledge about the relative influence of neutral and niche-based processes in determining the structure of anuran metacommunities. Along the southern coast of Brazil, the structure of beta diversity differed between the taxonomic and functional components. Despite this, we found important congruences between the components of beta diversity within each facet. The dominance of environmental and spatial predictors in the structuring of the taxonomic diversity and the spatial predictors in the structuring of the functional diversity suggest the co-existence of different processes in structuring anuran metacommunities and reinforce the importance of the inclusion of different facets of diversity in such analyses. The substantial contribution of purely spatial predictors in the patterns of both facets of diversity is similar to that found in other regions (e.g. [30]), confirming the predominance of neutral processes on the structuring of anuran metacommunities. However, the significant contribution of the shared fraction between environment and space, shows that the structure of our target metacommunity results from the interaction of both processes [17].

Acknowledgments

We thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial and logistical support and for the Diego Dalmolin' Phd scholarship and Maria João Pereira' CNPq Research Productivity scholarship. We also thank Lagoa do Peixe National Park for all the support during the field activities. This study was done under ICMBIO licence number 55409-1. Finally, we thank all those who helped during field and lab work and the Márcio Borges Martins (UFRGS) and Vinícius Bastazini (CNRS) for their contributions to previous versions of this manuscript.

Supporting information captions

Table S1 - Environmental descriptors of ponds measured between October 2016 and March 2017 at Lagoa do Peixe Nation Park, Rio Grande do Sul, Brazil. (DOCX)

Table S2– Functional traits measured (in adults). (DOCX)

Table S3 – Results for the forward selection of environmental variables to compose the spatial model of taxonomic and functional beta diversity during the pRDA analysis. (DOCX)

Table S4 – Results for the forward selection of spatial variables to compose the spatial model of taxonomic beta diversity during the pRDA analysis. (DOCX)

Table S5 – Results of forward selection of spatial variables to compose the spatial model of functional beta diversity during the pRDA analysis. (DOCX)

Table S6 – Results of anova.cca test for the two first axis of db-RDA between environmental variables selected and taxonomic beta diversity components.

Table S7– Results of anova.cca test for the two first axis of db-RDA between environmental variables selected and functional beta diversity components. (DOCX)

Table S8 – Variation partitioning for the components of anuran beta diversity based on **abundance** data. The table shows the variation explained (*R^2 adjusted*) for total taxonomic and functional beta diversity and turnover and nestedness compontens versus environment and space. E = environment; S = spatial component obtained from dbMEM; E+S = shared contribution between environment and space; E/S = the unique contribution of the environmental component; S/E = the unique contribution of the spatial component.. (DOCX)

Table S9 – Anuran species composition in each of the sampled ponds. (DOCX)

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Writing ± review & editing: Diego Anderson Dalmolin, Maria João Ramos Pereira, Alexandro Marques Tozetti.

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Supllementary Material

Table S1– Environmental descriptors of ponds measured between October 2016 and March 2017 at Lagoa do Peixe Nation Park, Rio Grande do Sul, Brazil.

Environmental descriptors	Description/levels	Ecological Relevance	Reference
Area	Total surface area of the pond (m^2)	Both are related to the occurrence and persistence of individuals in ponds, as well as the levels of competition and/or predation, and the reproductive success of each species	9, 10
Depth	Maximum depth of the pond (cm)		
Distance to the nearest forest fragment	Distance to the nearest forest fragment (m)	promote routes of dispersion and places for thermoregulation and feeding	11
Distance to the nearest sampled pond	Distance to the nearest other pond (m)	Ensure population persistence due to increased recolonization rates of ponds	12

		subject to stochastic extinctions.	
Pond vegetation	Number of vegetation types inside the pond, according to the following categories their combinations: (i) absent; (ii) macrophytes; (iii) grasses; (iv) herbs; (v) shrubs; (vi) trees.	provides a greater variety of microhabitats in both vertical and horizontal strata and thus insures that several species-specific requirements are met, promoting maintaining of a high diversity of species	11, 13
Margin configuration	(i) flat border; (ii) angular border (margins with ≥15 cm higher than the surface water).	affects microclimatic conditions and foraging and reproductive success	14
Vegetation around the pond	Number of vegetation types around the pond, according to the following categories and their combinations:(i) grasses; (ii) herbs; (iii) shrub; (iv) trees.		

Pond substrate	Number of substrate types of the pond, according to the following categories and combinations: (i) muddly; (ii) with vegetation.	influence habitat use and foraging of tadpoles	14

Table S2 - Functional traits measured (in adults).

Functional Trait	Category	Levels	Reference
Head shape	continuous	head length / head width	This study
Eyes position	continuous	Interorbital distance / head width	This study
Relative length of limbs	continuous	(Length of thigh + tibia length + tarsus length + foot length) / (arm length + forearm length + hand length)	This study
Eye size	continuous	Eye diameter / head length	This study
Body mass	continuous	grams	This study
Reproductive mode	categorical	From 1 to 40	1

Relative number of eggs	continuous	number	2, 3, 4, 5, 6, 7, 8
Daily activity period	categorical	Diurnal; nocturnal; diurnal & nocturnal	
Type of habitat	categorical	Lentic; lotic; lentic & lotic	
Fossorial habit	binary	Present; absent	
Reproductive season	categorical	Dry; rain; dry & rain	

Table S3 – Results for the forward selection of environmental variables to compose the environmental model of taxonomic and functional beta diversity during the pRDA analysis.

Type of Data	Beta Diversity Component	Predictor Variable	R^2	*adjusted* R^2 *cumulated*	*F*	*p*
Taxonomic	βBray	Depth	0.07	0.03	2.08	0.04
		Ins.veg	0.40	0.16	1.77	0.005
		Subst.	0.14	0.20	1.63	0.05
	βBal	Depth	0.07	0.03	2.28	0.03
		Ins.veg	0.44	0.20	2.13	0.005
		Subst.	0.12	0.25	1.67	0.05

	βGra	Ins.veg	0.01	0.001	1.28	0.05
Functional	βBray	Margin veg.	0.10	0.05	2.44	0.05
	βBal	Margin veg.	0.13	0.08	1.96	0.05
		Subst.	0.13	0.10	3.85	0.005
	βGra	Area	0.33	0.29	8.40	0.01

Table S4 – Results for the forward selection of spatial variables to compose the spatial model of taxonomic beta diversity during the pRDA analysis.

Type of Data	Beta Diversity Component	Predictor Variable	*R^2*	*adjusted R^2 cumulated*	*F*	*p*
Abundance	βBray	MEM 1	0.10	0.06	2.64	<0.001
		MEM 14	0.09	0.12	2.35	0.02
		MEM 3	0.08	0.17	2.39	0.02
	βBal	MEM 1	0.10	0.06	2.54	0.01
		MEM 3	0.09	0.12	2.46	0.02
		MEM 11	0.08	0.16	2.24	0.04

	MEM 12	0.07	0.21	2.20	0.03
	MEM 21	0.07	0.25	0.13	0.04
	MEM 14	0.07	0.30	2.22	0.03
	MEM 5	0.06	0.34	2.21	0.03
βGra	MEM 14	0.12	0.08	3.14	0.02
	MEM 7	0.12	0.17	3.41	0.01
	MEM 15	0.10	0.24	3.00	0.01

Table S5 – Results of forward selection of spatial variables to compose the spatial model of functional beta diversity during the pRDA analysis.

Type of Data	Beta Diversity Component	Predictor Variable	R^2	*adjusted* R^2 *cumulated*	*F*	*p*
Abundance	βBray	MEM 22	0.24	0.19	5.30	0.01
		MEM 12	0.19	0.35	5.27	0.01
		MEM 16	0.23	0.19	5.15	0.02

	βBal	MEM 1	0.13	0.29	3.40	0.04
		MEM 21	0.12	0.39	3.54	0.04
		MEM 9	0.13	0.50	4.57	0.02
		MEM 4	0.09	0.59	4.12	0.02
		MEM 12	0.09	0.70	5.42	0.006
		MEM 13	0.05	0.75	3.44	0.03
		MEM 18	0.04	0.79	3.44	0.04
	βGra	MEM 22	0.31	0.27	7.58	0.01
		MEM 12	0.23	0.48	7.75	0.007
		MEM 20	0.09	0.56	3.82	0.04
		MEM 3	0.09	0.64	4.26	0.03
		MEM 2	0.07	0.71	4.49	0.02

Table 6 – Results of anova.cca test for the two first axis of db-RDA between environmental variables selected and taxonomic beta diversity components.

Type of Data	Beta Diversity Component	db-RDA Axis	*F*	*p*
Abundance	βBray	Axis 1	3.40	0.04
		Axis 2	2.88	0.26

	βBal	Axis 1	2.15	0.05
		Axis 2	1.88	0.43
	βGra	Axis 1	1.74	0.31
		Axis 2	1.05	0.99

Table S7– Results of anova.cca test for the two first axis of db-RDA between environmental variables selected and functional beta diversity components.

Type of Data	Beta Diversity Component	db-RDA Axis	*F*	*p*
Abundance	βBray	Axis 1	1.99	0.05
	βBal	Axis 1	1.81	0.05
		Axis 2	0.94	0.95
	βGra	Axis 1	1.16	0.26
		Axis 2	0.84	0.83

Table S8: Variation partitioning for the components of anuran beta diversity based on **abundance** data. The table shows the variation explained (*R^2 adjusted*) for total taxonomic and functional beta diversity and turnover and nestedness compontens versus environment and space. E = environment; S = spatial component obtained from dbMEM; E+S = shared contribution between environment and space; E/S = the unique contribution of the environmental component; S/E = the unique contribution of the spatial component.

		TAXONOMIC			**FUNCTIONAL**		
		R^2adjusted	*F*	*p*	R^2 adjusted	*F*	*P*
TOTAL BETA DIVERSITY (βBray)	E	0.58	1.92	<0.001	0.11	1.74	0.05
	S	0.27	2.62	<0.001	0.19	3.09	0.01
	E+S	0.05	2.21	<0.001	<0.01	2.62	0.008
	E/S	0.23	1.79	<0.007	0.12	1.95	0.03
	S/E	0.12	1.92	0.04	0.21	3.19	<0.001
	Residuals	0.60	-	-	0.68	-	-

TURNOVER (βBal)	E	0.34	2.16	<0.001	0.17	2.26	0.02
	S	0.32	2.77	<0.001	0.19	1.47	0.05
	E+S	0.24	2.07	<0.001	<0.01	1.91	0.02
	E/S	0.10	1.37	0.04	0.18	1.96	0.05
	S/E	0.09	1.26	0.05	0.19	1.69	0.05
	Residuals	0.57	-	-	0.64	-	-
NESTEDNESS (βGra)	E	0.06	1.23	0.27	0.29	8.39	<0.001
	S	0.24	3.50	0.003	0.61	6.75	<0.001
	E+S	<0.01	2.26	0.004	0.22	7.69	<0.001
	E/S	0.11	1.49	0.05	0.08	4.16	0.02
	S/E	0.28	3.44	0.003	0.40	3.78	<0.001
	Residuals	0.60	-	-	0.30	-	-

Table S9 – Anuran species composition in each of the sampled ponds.

POND	*D. min.*	*D. sanb.*	*H. pul.*	*L. lat.*	*Ph. bil.*	*Ps. fal.*	*Ph. gra.*	*Pse. min.*	*R. dorb.*	*Sc. fusc.*	*Sc. squa.*
p1	0	21	0	4	0	0	0	1	0	0	0
P2	2	3	0	0	0	0	0	0	0	0	0

P3	0	0	1	2	0	0	0	0	0	1	0
p4	0	1	4	3	0	0	1	2	0	0	0
p5	9	0	0	0	0	0	0	0	0	0	0
P6	0	0	0	0	0	0	0	2	0	3	1
p7	0	20	5	0	0	0	0	0	0	0	1
p8	0	1	6	6	0	8	4	0	0	1	8
p9	0	0	1	5	0	1	4	2	0	0	0
p10	0	10	0	0	0	0	1	10	0	1	10
p11	22	12	4	6	0	0	0	0	0	0	1
p12	10	3	0	1	0	0	14	6	0	0	1
p13	0	24	7	2	0	0	34	9	1	0	2
p14	0	1	6	0	0	21	6	14	2	0	1
p16	0	23	0	1	0	0	10	1	0	0	7
p17	0	0	3	1	0	50	10	0	2	0	0
p18	0	0	0	7	0	0	0	0	1	0	0
P19	2	6	0	4	0	23	8	1	0	0	0
p20	0	0	0	0	1	0	9	0	0	0	0

p21	0	1	0	3	1	35	6	1	1	0	0
p23	0	1	0	1	0	0	2	1	0	0	0
P24	0	1	9	1	12	0	0	0	0	0	0
p25	0	7	0	2	0	1	6	0	0	0	8
p26	0	5	21	1	0	0	6	6	1	0	0
p27	0	0	4	0	0	0	0	1	0	0	0
p28	6	23	30	2	0	0	11	12	0	0	23
P29	0	0	0	0	0	14	17	53	0	0	0
p30	2	10	0	0	0	0	20	56	0	0	5
p31	0	0	0	0	0	0	0	3	0	0	0
p32	0	0	5	0	0	0	0	5	0	0	0
p33	0	0	5	0	0	0	0	0	0	0	1

Dendropsophus minutus (D. min.); *Dendropsophus sanborni* (D. sanb); *Hypsiboas pulchellus (H. pul.); Leptodactylus latrans (L. lat.); Physalaemus biligonigerus (Ph. bil.); Pseudopaludicola falcipes (Ps. fal.); Physalaemus gracilis (Ph. gra.); Pseudis minuta (Pse. min.); Rhinella dorbignyi (R. dorb.); Scinax fuscovarius (Sc. fusc.); Scinax squalirostris (Sc. squa.)*

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CAPÍTULO 3

TURNOVER OR INTRASPECIFIC TRAIT VARIATION: EXPLAINING FUNCTIONAL VARIABILITY IN A NEOTROPICAL ANURAN METACOMMUNITY

Submetido à AQUATIC SCIENCES

CAPÍTULO 3

Turnover or Intraspecific Trait Variation: explaining functional variability in a neotropical anuran metacommunity

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Abstract

Trait variation across environmental gradients results from two processes: intraspecific variation (ITV) and turnover. Tadpoles are known to exhibit phenotypic plasticity in several traits in response to the environment, resulting from intra or interspecific variation. Here we evaluate patterns of intraspecific variation in functional traits of adult anurans (head shape, eye size and position, limb length and body mass) and their relationship with environmental variables in an anuran metacommunity in southern Brazil. From anurans sampled from 33 ponds, we decomposed trait variation into ITV and turnover and modelled trait-environment relationships. We predict that the contribution of ITV and turnover to trait variation and trait-environment relationships should vary according to the preferred habitat of the species and the analysed traits. Intraspecific variation accumulated the highest rate of trait variation for arboreal species, while interspecific variation was greater for aquatic-terrestrial species and for the whole set of species. The contributions of turnover and ITV to shifts in community mean trait values were similar between traits, but differed between species sets. Depth, distance between ponds, area of *Pinus* surrounding the ponds, and types of pond vegetation and substrate strongly influenced trait variation, but their relative contribution depended on the analysed traits and species sets. The great contribution of ITV for head shape and eye size and position suggests the existence of intraspecific adaptations to microhabitats, while turnover dominance in the variation of body mass and limb length suggests differences in dispersal and trophic segregation between species.

Key-words

Amphibian adults; freshwater ponds; functional traits; local environmental conditions; opposing patterns of trait variation; trait-environment relationship.

Introduction

Functional-based approaches quickly gained prominence in community ecology. Functional traits are excellent tools for assessing the influence of ecological predictors (environmental and spatial) on community assembly patterns as well as of processes of colonization and species maintenance in different environments and geographical areas (McGill et al., 2006; Meynard et al., 2011; Tonkin et al., 2016). Ecologists now have a wide variety of functional diversity metrics - see the reviews by Villéger et al. (2010) and Mouchet et al. (2010). However, the vast majority of studies is based on assessments focusing almost entirely on mean attribute values (Luo et al., 2016). Consequently, the observed patterns of functional dissimilarity between communities were mostly attributed to interspecific trait variation, neglecting valuable information provided by intraspecific variation (McGill et al. 2006; Dahirel et al., 2017; Fajardo and Siefert, 2018).

Recent studies suggest that the quantification of intraspecific trait variation patterns (henceforth ITV) is paramount, because it allows a more accurate view of the functional organization of communities and patterns of species coexistence (Bolnick et al., 2011; Violle et al., 2012; Kraft et al., 2015). It has been demonstrated that ITV for several groups of organisms across different environmental gradients is high - e.g. trees, Jung et al. (2010), Fajardo and Siefert (2018); invertebrates, Rudolf and Rasmussen (2013) , Dahirel et al. (2017); and tadpoles, Zhao et al. (2017), Jordani et al. (2019) – strongly contributing to the increase of alpha and beta diversities (e.g. Spasojevic et al., 2016). Changes in environmental conditions lead to the expression of phenotypic plasticity in several traits (e.g. morphological, behavioural and life history) within and between populations (Mouillot et al., 2013), and, for that reason, ITV is considered the main link between mechanistic processes and community structure (Lepš et al., 2011; Siefert et al., 2015).

Community-level trait responses to niche-based processes are driven by a combination of turnover and ITV (Lepš et al., 2011). In situations where ITV is the dominant process, attribute values will vary across the environmental gradient without modification in species composition. In the opposite case, i.e., when turnover dominates, it is the species composition that varies across the gradient, with little or no change in attribute values (Lepš et al., 2011; Violle et al., 2016). Most studies published so far detected an alternation in the dominance of both processes in the ITV patterns between different types of traits along environmental gradients (e.g. Volf et al., 2016; Derroire et al., 2018; Fajardo and Siefert, 2018). Changes in the balance between those processes leading to ITV may drive the occurrence of individuals in certain environments because they facilitate or prevent the coexistence between organisms of the same species (Turcotte and Levine, 2016). Consequently, the number of individuals from each species that overlap in niche space will decrease (Cloyed and Eason, 2017).

Anurans are important components of freshwater ecosystems: they represent a substantial part of the biomass of those environments and usually occupy several positions of the trophic web (Gibbons et al., 2006; Wells, 2010; Rowland et al., 2015). The structure of anuran communities in ponds tends to respond to frequent, and often unpredictable, environmental changes - such as changes in water depth, presence and abundance of aquatic vegetation and hydroperiod (Wellborn et al., 1996; Urban, 2004; Richter-Boix et al., 2007; Werner et al., 2007). In fact, pond dynamism prompted by changes in local environmental conditions leads to different degrees of trade-offs (e.g. growth and survival) and high rates of trait diversification and specialization in resident species (e.g. body size and larval development rates; Wellborn et al., 1996; Schemske et al., 2009; Schalk et al., 2017). This pattern may be quite intense in anurans, as they have a biphasic life cycle, highly permeable skin and are highly sensitive to environmental changes during most part of their life-cycle (Niemi and McDonald, 2004). Despite the scarcity of information for adults, previous studies have shown high phenotypic plasticity in tadpoles for various attributes across different ecological gradients (Michel, 2011; Marques and Nomura, 2015; Marques et al., 2019).

In this study we used a trait-based approach to evaluate patterns of intraspecific variation and their relationship with local environmental predictors in an anuran metacommunity of 33 ponds located in the southernmost coastal region of Brazil. We test the hypothesis that species ITV and turnover processes influence trait variation patterns across environmental gradients. We expected traits related to habitat (and microhabitat) exploration and foraging – mostly those related to the trophic and functional positioning of individuals (head shape, eye position and eye size), that are promoters of the stabilization of niche differences between species – to be less variable within species in comparison to those related to physiological dispersal and control (body mass and relative limb length; Turcotte and Levine, 2016, Jordani et al., 2019) which should be more influenced by species turnover.

In addition, we evaluate the existence of possible relationships between different sets of environmental predictors and the patterns of variation of functional traits. Trait-environment relationships should be more evident between similar ecological groups, which may respond to similar environmental predictors. We expect traits related to habitat exploration/foraging to be driven by variables related to structural variation of ponds (Prado et al., 2014; Leão-Pires et al., 2018; Lima et al., 2019). We also expect traits related to dispersal and physiological control (water conservation hypothesis - Amado et al., 2019) to be associated with the geographic distance between ponds, variables reflecting hydroperiod and matrix surrounding the ponds (da Silva et al., 2012, Machado et al., 2012; Prado et al., 2014; Queiroz et al., 2015; Tavares and da Silva, 2019).

Material and Methods

Ethics statement

We obtained the collecting permits from Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) (licence 55409). Our sampling did not involve any endangered or protected species. We restricted amphibian manipulation in the field to the minimum necessary (see section 2.3); specimens collected were identified to species level, measured and immediately released after these procedures in the same pond/site where they were captured.

Study Area

This study was carried out in Lagoa do Peixe National Park (PNLP; 31°02_-31°48_S; 50°77_-51°15_W; figure 1), one of the two Ramsar sites in southern Brazil (RAMSAR, 2018). With a length of 64 km and an average width of 6 km, the PNLP comprises over 34,000 hectares of protected wetlands, integrating the Coastal Plain of the State of Rio Grande do Sul (Maltchik et al., 2003). The climate is subtropical humid, and temperatures range between 13 °C and 24 °C with annual average of 17.5 °C. The mean annual precipitation varies between 1200 and 1500 mm (Tagliani, 1995).

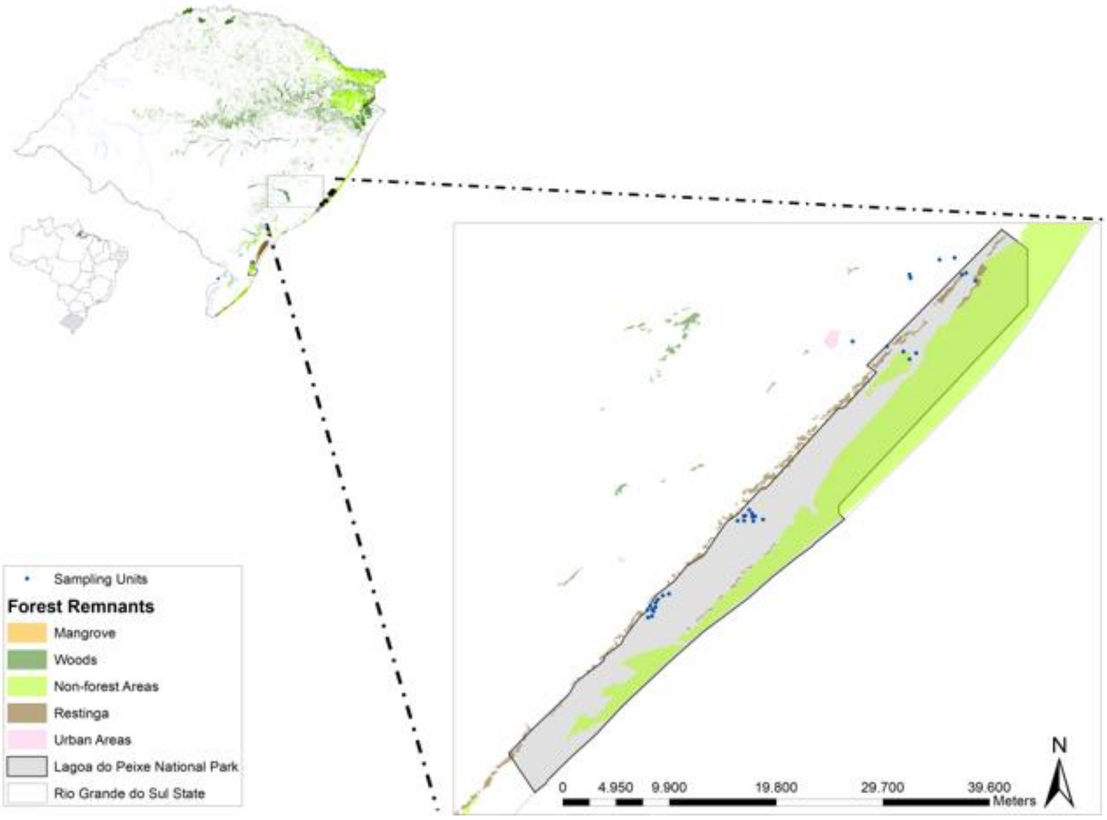

Figure 1: Study area at Lagoa do Peixe National Park, southern Brazil. Sampled ponds are represented by blue circles (N = 33).

Anuran surveys and trait measurement

We sampled adult anurans in 33 ponds throughout the study area (Fig. 1). We selected the ponds based on biotic and abiotic characteristics (see Table S1) and on the distance between ponds to guarantee spatial independence. Distance between ponds ranged from 0.7 to 39 km. Sampling was performed monthly, from October 2016 to March 2017. We used both calling surveys and active search at breeding habitats to find the individuals in each pond (Scott and Woodward, 1994). Samplings were carried out from 6 p.m. to 0 a.m; monthly effort per pond was of 1 hour, totalling 6 hours of sampling per pond.

We evaluated five functional traits in five individuals per species per pond: head shape; eye position; eye size; relative length of limbs; body mass. We chose these traits based on perceived importance for determining habitat use and species resilience, and they were characterized according to the metrics presented in Figure 2 and Table 1. To avoid reassessment of the same individual in the same sampling period, we placed all individuals captured in containers for the duration of the sampling of the respective pond and then released them at the exact same site of capture.

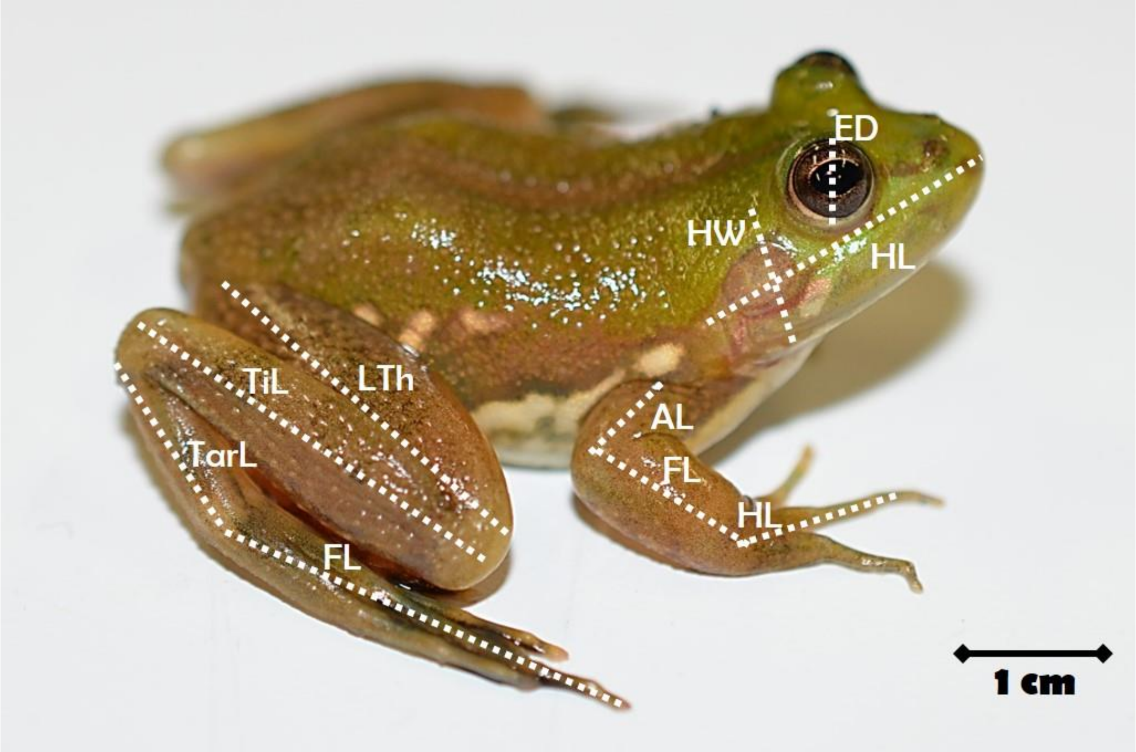

Figure 2: Metrics evaluated in adults (except body mass): length of thigh (LTh); tibia length (TiL); tarsus length (TarL); foot length (FL); arm length (AL); forearm length (FL); hand length (HL). In this picture: a male of *Pseudis minuta* (Amphibia, Hylidae) captured at the Parque Nacional da Lagoa do Peixe, Brazil.

Table 1 - Functional traits measured (in adults).

Functional Trait	**Levels**	**Ecological relevance**
Head shape (HS)	head length / head width	Varies according to foraging behaviour
Eye position (EP)	Interorbital distance / head width	Eye position and eye size are associated with the exploration of habitats and the detection of prey (foraging), reproductive partners (partner evaluation) and competitors/predators
Eye size (ES)	Eye diameter / head length	
Relative limb length (RLL)	(thigh length + tibia length + tarsus length + foot length) / (arm length + forearm length + hand length)	Associated with dispersal type or ability of the species across the habitats (locomotor performance)
Body mass (BM)	grams	Associated with accumulated biomass, habitat use and dehydration tolerance

Environmental predictors

The environmental descriptors measured in this study and their description are presented in Table S1 of supplementary material. We measured the local descriptors in the field through visual interpretation in an area around 5 meters from the edge of the ponds. We assessed area, depth and number of vegetation types around the pond and inside the pond (pond vegetation), margin configuration and type of substrate of the pond. We obtained the distance to the nearest forest fragment and the distance to the nearest sampled pond from high-resolution aerial photographs examined immediately after sampling, available from Google Earth (http://earth.google.com/), combined with field inspection.

Data analysis

Partitioning anuran intraspecific trait variation across nested scales

To quantify the extent of intraspecific vs. interspecific variation of anuran functional traits along the metacommunity, we performed a variance partitioning analysis using the function “partvar” of package cati in R software version 3.4.4 (R Core Team, 2018). This function runs a variance partitioning across nested scales using the decomposition of variance on restricted maximum likelihood (REML) method (lme function), to assess variation in traits at different taxonomic levels (i.e., within-species, species and genus) and between sites (populations; Messier et al., 2010).

Decomposing the variance in community trait composition

Following the approach proposed by Leps et al. (2011) and updated by Taudiere and Violle (2016), we decomposed the variation in community trait composition into three sources: 1) intraspecific trait variability (ITV), 2) variability due to species turnover and 3) their covariation. According to Lepš et al. (2011), trait variation will be explained by species turnover when differences in trait averages based on fixed trait values are found between habitats. On the other hand, differences in averages based on habitat specific values (e.g. ‘specific averages’) may be caused either by differences in species composition (species turnover) or intraspecific trait variation (or both). Finally, differences between specific and fixed averages may be due solely to intraspecific trait variation. These analyses were carried out using the function “decompCTRE” of the *cati* package in R software version 3.4.4 (Taudiere and Violle, 2016).

Evaluating trait-environment relationships

We used Linear Mixed-Effect Models (LMM) to model the relationship between functional traits and local environmental predictors. This approach explicitly models the relationship within the data set using random effects or latent random variables (Breslow & Clayton, 1993; Zhang et al., 2012). We built all possible models so that all combinations between environmental predictors were evaluated. We included pond as random effect. Model selection was done using the Akaike Information Criteria corrected for small samples (AICc) to select the best model containing most information among all candidate hypotheses (Buham & Anderson, 2002). We usedthe AICc weights (w) indicating the empirical support for each model relative to the others in the candidate set. Finally, we applied a threshold of 2 AICc units to define model support (in other words, we considered models with ΔAIC<2 as equivalent; Zuur et al., 2009). LMM were built using the 'nlme', 'MuMIn' and 'lme4' packages in R software version 3.4.4.

Results

We registered adults of 11 species belonging to three families (Bufonidae, Hylidae and Leptodactylidae) during our sampling. The most frequent species were *Dendropsophus sanborni* and *Pseudis minuta*, occurring in 19 of the 33 sampled ponds. *Physalaemus biligonigerus, Rhinella dorbignyi* and *Scinax fuscovarius* were rare and we were unable to capture five individuals of those species. We therefore did not include them in the subsequent analyses. In Table 2 we present all species evaluated and their groupings according to their preferred habitat.

Table 2 – Species of amphibians evaluated for intraspecific trait variation and their respective grouping based on preferred habitat.

Groups	**Species**
Aquatic-terrestrial	*Leptodactylus latrans*
	Physalaemus gracilis
	Pseudis minuta
	Pseudopaludicola falcipes
Arboreal	*Dendropsophus minutus*
	Dendropsophus sanborni
	Hypsiboas pulchellus
	Scinax squalirostris

Partitioning of anuran intraspecific trait variation across nested scales

The within-species scale accounted for most variation in head form (39%), eye size (44%) and eye position (42%) for the whole species set, while species and genus scales accounted for most variation in relative limb length (39% and 42%, respectively) and body mass (39% and 42%, respectively; Figure 3c).

We found discrepant patterns between groups. The within-species scale held 99% of variance of all traits for the arboreal species (Figure 3a), while species and genus scales accounted for the most variation of all traits for the aquatic-terrestrial species (from 75% to 95%; Figure 3b).

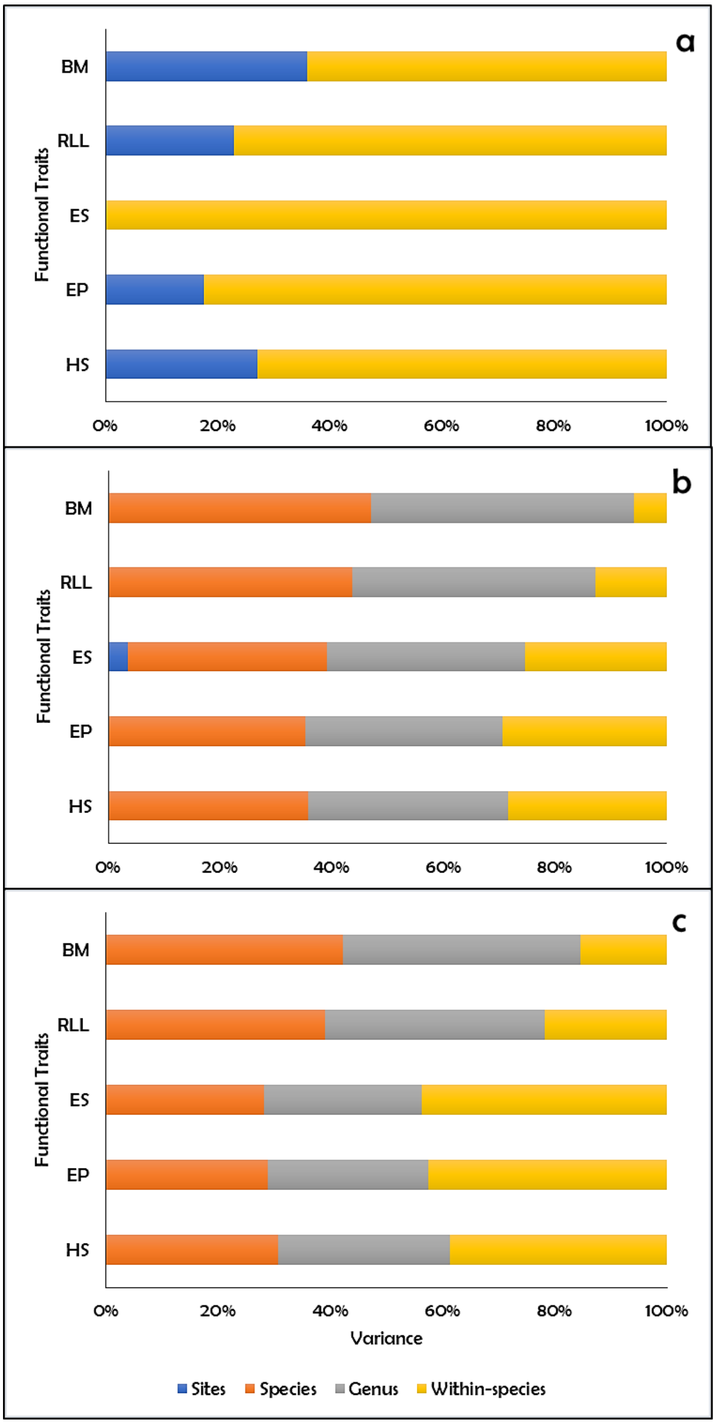

Figure 3. Variance partitioning of community traits for the sampled pond metacommunity: (a) arboreal, (b) aquatic-terrestrial, and (c) all species. Total between-plot variance in morphological trait values was partitioned into species turnover, intraspecific trait variation (ITV), and covariation between those components. Variance partitioning was conducted for

five functional traits: head shape (HS), eye position (EP), eye size (ES), relative limb length (RLL) and body mass (BM).

Relative contribution of species turnover and intraspecific trait variation

The relative contributions of species turnover and intraspecific trait variation (ITV) to shifts in community mean trait values in the anuran metacommunity was similar between traits, but differed between sets of species. For the entire species set the relative contribution of ITV ranged from 10% to 25%, while species turnover ranged from 56% to 88% (figure 4c). ITV and species turnover were positively correlated for all traits (figure 4c).

For the arboreal species set, the contribution of ITV was very similar to that of species turnover: the relative contribution of ITV ranged from 24% to 56%, while species turnover ranged from 27% to 52% (figure 4a). However, for the aquatic-terrestrial species set turnover was the main process governing the intraspecific trait variation and ranged from 69% to 116% (the lower value belonging to RLL, which presented a negative covariation between ITV and turnover), while ITV ranged from 11% to 31% (figure 4b).

ITV and species turnover were positively correlated for all traits in the arboreal species set (figure 4a), while this correlation was negative for the aquatic-terrestrial species set (figure 4a).

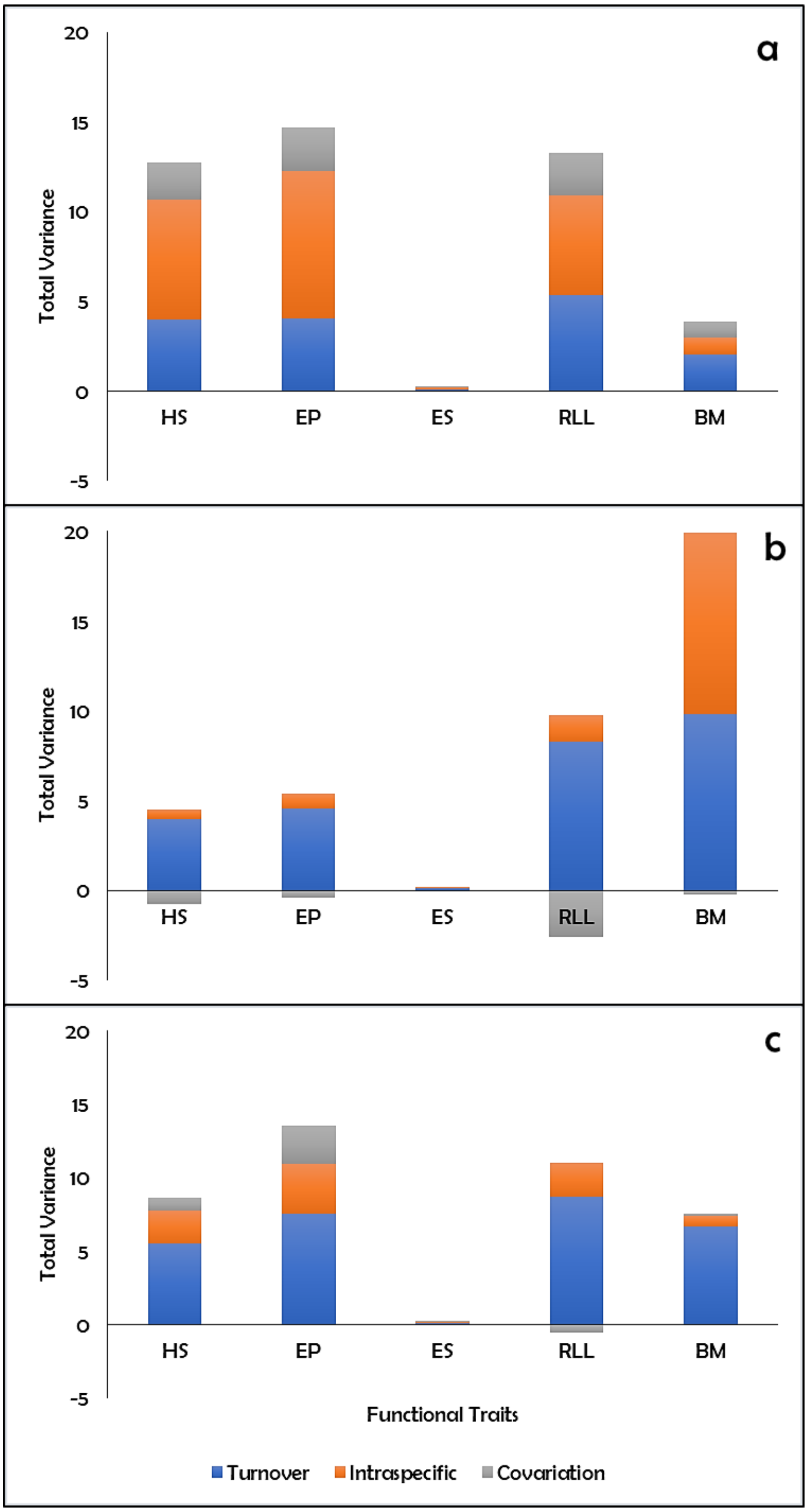
a
b
c
Total Variance
20
15
10
5
0
-5
HS
EP
ES
RLL
BM
Functional Traits
Turnover
Intraspecific
Covariation

Figure 4. Decomposition of variance of community trait for the sampled pond metacommunity: (a) arboreal, (b) aquatic-terrestrial, and (c) all species. The total between-plot variance in functional traits was partitioned into species turnover, intraspecific trait variation (ITV), and covariation between those components. Variance partitioning was carried out for five functional traits: head shape (HS), eye position (EP), eye size (ES), relative limb length (RLL) and body mass (BM).

Trait-environment relationships

The most part of total variance explained by fixed effects was found at groups levels (arboreal species; Table 2). In general, the null model was among the candidate models selected for the largest part of the functional traits in all sets of data evaluated and was, in some cases, the best fitted. For the whole species set, pine area presented positive and significant effects on the observed variation in head form (F=7.24), relative eye position (F=6.23) and relative limb length (F=3.2).

For the arboreal species set, all environmental predictors showed positive effects on the intraspecific variation of at least one of the evaluated functional traits, with the exception of margin configuration. Head form responded mostly to vegetation type (F=23.57), eye position to distance between ponds (F=12.72) and relative limb length to substrate type (F= 10.19). Finally, depth was the only variable influencing trait variation in the aquatic-terrestrial species set (EP: F= 3.49; ES: F=7.57; RLL: F=4.61; BM: F=4.96), and the relation was always negative, except for body mass. We did not find any relationship between head shape and the set of environmental predictors for this group. The summary tables of significance tests and all models tested are presented in supplementary material (respectively, Tables S2 and S3-S16).

Table 2 - Summary of the best-adjusted models resulting from the LMM for each functional trait for the sampled pond metacommunity including models for all species, arboreal species set and aquatic-terrestrial species set. R^{2}m (fixed effects); R^{2}C (fixed + random effects). (*) p< .05; (**) p< .01; (***) p< .001.

	Trait	Model	AICc	∆AICc	Weight	R^{2}m	R^{2}C
ALL SPECIES	H.S.	Pine.area(1000m^2)**	440.56	0	0.40	0.13	0.63
	E.P.	Pine.area(1000m^2)**	499.20	0	0.30	0.11	0.59
	E.S.	Null	-251.78	0	0.77	-	-
	R.L.L	Null	465.09	0	0.16		
		Pine.area (1000m^2)*	465.23	0.14	0.15	0.08	0.79
		Margin type+ Pine.area (1000m^2)*	466.91	1.82	0.06	0.11	0.80
	B.M.	Null	296.49	0	0.33	-	-
		Pine.area(1000m^2)	296.08	1.99	0.10	0.03	0.85
ARBOREAL	H.S.	Area***+depth**+ ins.veg.+subst.**+margin veg.***	226.14	0	0.06	0.51	0.57
		Depth+dist.bt.ponds***+ins.veg.+subst.***+margin veg.*	226.40	0.26	0.05	0.51	0.57
		Area***+ins.veg.+subst.**+margin veg.***	226.41	0.28	0.05	0.46	0.55
		dist.bt.ponds***+subst.*	226.73	0.59	0.05	0.31	0.53
		dist.bt.ponds***+ pine. area (1000m^2)***	227.38	1.25	0.03	0.29	0.51
		Area***+depth***+dist.bt.ponds+ins.veg.*+subst.***+margin veg.	227.54	1.39	0.03	0.53	0.56
	E.P.	dist.bt.ponds***+ subst.*	254.98	0	0.08	0.30	0.46
		Area***+depth*+ins.veg.+subst.***+margin veg.***	255.23	0.26	0.07	0.46	0.47
		Area***+ ins.veg.+subst.**+margin veg.***	255.37	0.40	0.06	0.43	0.47
		Depth***+dist.bt.ponds**+ins.veg.+subst.***+margin veg.	256.18	1.21	0.04	0.45	0.51
		Area***+depth*+dist.bt.ponds+ins.veg.+subst.***+margin veg.***	256.47	1.50	0.04	0.48	0.48
	E.S.	Null	-109.24	0	0.89	-	-
	R.L.L	Depth*+dist.bt.ponds+ins.veg.+subst.***	222.27	0	0.10	0.51	0.68
		Depth*+dist.bt.ponds+ins.veg.+subst.***+margin veg.	222.53	0.26	0.09	0.51	0.69
		Subst.	223.66	1.38	0.05	0.13	0.64
		Pine area (1000m^2)*	223.70	1.42	0.05	0.16	0.64
		Dist.bt.ponds*+subst.*	223.84	1.57	0.04	0.22	0.61
		Null	223.91	1.63	0.04	-	-
	BM	Null	131.97	0	0.36	-	-
		Margin veg.	133.72	1.74	0.15	0.06	0.55
AQ	H.S.	Null	204.30	0	0.18	-	-
		Subst.	204.96	0.66	0.13	0.07	0.75

	Margin veg. + subst.	206.65	1.95	0.05	0.08	0.77
E.P.	Null	217.31	0	0.18	-	-
	Depth*	218.32	1.00	0.11	0.06	0.71
	Margin veg.	219.22	1.91	0.07	0.02	0.71
	Subst.	219.49	1.97	0.06	0.04	0.73
E.S.	Null	-155.46	0	0.49	-	-
	Depth***	154.44	1.01	0.29	0.13	0.75
R.L.L	Ins.veg.	235.31	0	0.07	0.10	0.89
	Ins.veg.+margin veg.	235.66	0.34	0.06	0.11	0.89
	Depth*	235.91	0.59	0.05	0.08	0.87
	Null	236.66	1.34	0.04	-	-
	Ins.veg. + pine area (1000m^2)	236.78	1.47	0.04	0.10	0.90
	Ins.veg.+ subst.	238.19	1.87	0.03	0.11	0.89
B.M.	Ins.veg.	129.70	0	0.11	0.19	0.95
	Depth*	130.00	0.30	0.10	0.08	0.94
	Null	130.08	0.38	0.09	-	-
	Ins.veg.+margin veg.	130.70	1.00	0.07	0.19	0.95
	Dist.bt.ponds*	131.17	1.47	0.05	0.08	0.94
	Pine area (1000m^2)	131.33	1.63	0.05	0.05	0.93

Discussion

Patterns of trait variation in anuran metacommunities and their relation with local environmental predictors are complex. ITV is generally the dominant process driving trait variation in arboreal species, species turnover seems to be the driving force behind trait variation in aquatic-terrestrial anurans. Looking into the whole set of species, we can see that turnover is, once again, the dominant process. This pattern may be explained by the fact that the whole set joins taxa with very distinct evolutionary histories, potentially responding very differently to the evaluated environmental predictors (Marques and Nomura, 2015). Also, interspecific variation represented between 60% and 90% of trait variability for the whole species set and for the aquatic-terrestrial species set, while ITV explained up to 100% of the total trait variation in arboreal anurans. Our data also points to significant effects of environmental filtering in the shaping of the trait structure in anuran metacommunities, but again with distinct factors acting depending on the preferred habitat of the species and the analysed functional trait.

The balance between intraspecific and interspecific trait variability

The relative importance of ITV and turnover in trait variability seems to be dependent on the preferred habitat of the species or species group under analysis, as well as the analysed trait. In general, we found a greater variation in the scale between species and a substantial contribution of turnover for most of the traits of aquatic-terrestrial species group and for the total set of species. For the neotropical anuran metacommunity in our study, as well as for several groups of organisms, species turnover seems to be the dominant process behind trait variation (e.g. Siefert et al., 2015 Derroire et al., 2018). Species turnover tends to be stronger at larger spatial scales, where environmental heterogeneity is patent, whereas phenotypic adjustments should be dominant at small spatial scales and within short time frames (Jung et al., 2010; Kichenin et al., 2013; Kumordzi et al., 2015; Chalmandrier et al., 2017).

From an evolutionary point of view, ITV within and between populations is influenced by physiological, ontogenetic, genetic and ecological factors (Miller and Rudolf 2011; Ingram and Shurin 2009; Zhao et al., 2014). Genetic and ecological factors have been pointed out as the main drivers of trait variation in anuran populations and between ecomorphological guilds (e.g. Lampert et al., 2003; Trakimas et al., 2003; Zeisset and Beebee, 2003; Palo et al., 2004; Telles, 2005); this is due – at least partially – to the fact that they are easier to evaluate than physiological and ontogenetic factors *per se*, considering that these should be closely correlated, influencing and being influenced by both genetic and ecological contexts.

Anurans present high phenotypic plasticity in response to environmental conditions (Michel 2011; Marques and Nomura, 2015), which may be higher for some traits, as detected in our study. Terrestrial and arboreal species are subject to distinct microenvironmental conditions, and they may differ considerably in their foraging strategies and habitat use. It should not thus come as a surprise that arboreal and the aquatic-terrestrial anurans show distinct ITV patterns.

Head shape, eye size and eye position presented significant variation within species, contrarily to our predictions. Usually, head and eye characteristics contribute to significant functional dissimilarity between anurans, but most of the arboreal species sampled here seem to be quite redundant in relation to these traits. So, most of the variation turned out to be intraspecific, in agreement with findings for other anuran populations which also showed high functional overlap in these traits (Silva et al., 2008). ITV dominance has been observed for top predators, including between individuals of the same ontogenetic classes or age cohorts (Zhao et al., 2014). If local conditions favour genetic diversification (Silva et al., 2008; Vieira et al., 2008), one would expect within-population variation in functional traits. In fact, significant within-population allelic diversity has already been reported for anuran populations of the Cerrado and Atlantic Forest biomes (Silva et al., 2008; Vieira et al., 2008), potentially contributing to the co-occurrence of phenotypically distinct individuals within populations.

On the other hand, body mass and relative limb length tended to vary more between species and genera than within populations, suggesting that analyses of the functional structure of these attributes may be measured through mean values per species (Garnier et al., 2001; Griffiths et al., 2016). Body mass and relative limb length are strongly related to the rates of dispersion and habitat use; discrepancies in allometric relationships between arboreal and terrestrial species relating to body mass seem to be related to the differential effect that gravity exerts on species in aquatic and terrestrial environments, promoting adequate body mass adjustments for each of these environments (Vidal-García and Keogh, 2015). However, ITV assessments for body mass and relative limb length should not be disregarded, as both high intra and interspecific variation across geographical and temporal scales have been reported for these traits (e.g. Dodd, 2010; Santini et al., 2018; Amado et al., 2019). For example, body mass reflects physiological states and water and heat retention abilities (Wells, 2010; Dodd, 2010) and is often used as proxy for the risk of extinction (Purvis et al., 2000; Cardillo et al., 2005). Because extinction acts on populations, intra and inter-population variation in traits that mirror individual fitness and population health may be important indicators of the extinction risk of the populations under study.

Complex relations between traits and environment in anurans

As predicted, trait-environment relationships were more evident within species sets that share similar habitat preferences than for the total set of species. Overall, for several traits, ITV responded to more than one environmental predictor, showing the complex nature of trait-environment relationships. Pond configuration – particularly area, depth, types of substrate and margin vegetation, as well as the distance between ponds – was the main driver of ITV. All these reflect environmental heterogeneity and tend to vary greatly in narrow spatial scales and short time frames, probably contributing to the high phenotypic plasticity observed (Welborn et al., 1996; Werner et al., 2007; Both et al., 2011). Depth, for instance, significantly affected all the evaluated functional traits and, together with pond area, is a proxy for hydroperiod and evapotranspiration rates of ponds (Welborn et al., 1996; Williams, 2006; Werner et al., 2007). Changes in pond depth and area directly affect the reproductive biology and the physiological processes associated with water conservation in anurans (Wells, 2010; Amado et al., 2019). Again, this is connected to the observed variation in body mass between species and genera. Here, deeper ponds harboured, in average, weightier aquatic and terrestrial species. This reflects the fact that weightier bodies allow for higher water and heat retention, which should be particularly critical in species that are in constant contact with the substrate, as is the case of aquatic and terrestrial anurans (Wells, 2010; Amado et al., 2019).

Other environmental aspects may also influence the ability of anurans to regulate body temperature and osmotic rate, such as the percentage of humidity in the soil around the ponds, as well as pond vegetation (Wells 2007; Olalla-Tárraga and Rodríguez, 2007; Gouveia & Correia, 2016). Behavioural responses, like the use of particular climatic microhabitats – such as those created in humid soils or within semi-aquatic vegetation –, are well known in anurans (Wells 2007, Vitt and Caldwell 2009) and tend to be far more frequent in species and individuals with smaller body sizes or occurring in colder regions (Amado et al., 2019). In addition, variation in individual size is expected to be closely related to resource availability ("resource rule" - McNab, 2010), which is less variable in larger and deeper environments.

In theory, all dimensions of anuran diversity in ponds gradually increase with structural complexity, but decay with distance between ponds and between ponds and forest fragments (e.g. Hill et al., 2017). In fact, increased diversity is driven by the number of niches available, which tends to be higher in complex environments (e.g. Ruhi et al., 2014; Heino et al., 2015; Spasojevic et al., 2016), while limited dispersal ability imposed by limb morphology and physiological restrictions (risk of desiccation) compromise long-distance anuran dispersal (Wells, 2010; Amado et al., 2019). Differences in life history, morphology, and locomotion mode directly affect trait-environment relationships and species turnover dominance (Fabrezi et al., 2017), as observed in our study. According to our predictions, distance between ponds mostly influenced variation patterns in traits associated with habitat exploitation in arboreal species – head shape, eye position and, particularly, limb length. Arboreal species use forest fragments that may often be distant from the ponds and move to reproductive sites through large leaps (da Silva et al., 2012). In contrast, aquatic and terrestrial species have relatively smaller limbs compared to arboreal species, so are more limited in terms of long-distance dispersal, but on the other hand are better adapted to swimming. They use burrows or any type of substrate to take refuge during the day (e.g. leptodactylides).

Trait variation for the whole species set was strongly associated to the area of *Pinus* around ponds (1000 m^2 buffer). Interestingly, the relative area of *Pinus* plantations within that buffer seems to contribute positively to the variation of the traits related to habitat exploitation. *Pinus* trees acidify wetlands, change soil conditions, and create new shaded areas in ponds and adjacent areas (Whatling et al., 2011; Machado et al., 2012; Saccol et al., 2017). In combination, these environmental modifications probably impose physiological and behavioural barriers (e.g. thermoregulation and displacement, Rothermel and Semlitsch, 2002; Parris, 2004; Saccol et al., 2017). As a consequence, population resilience in these environments may be conditioned by the presence of high rates of variation of these attributes (phenotypic plasticity, Werner et al., 2007, Michel, 2011). Nonetheless, this result should be taken with precaution, because while trait variation may be increasing, taxonomic diversity may decrease in the long run. Indeed, herp diversity is known to decrease in areas altered by silviculture in southern Brazil (e.g. Machado et al., 2012; Saccol et al., 2017) and in areas across the globe (e.g. Popescu and Hunter Jr., 2011). The presence of exotic plantations affects the local conditions of the ponds, leading to biotic homogenization between environments and consequently reducing functional and taxonomic diversity on the long-term (Machado et al., 2012; Saccol et al., 2017).

Conclusions

Functional traits related to vertical environmental exploitation in adult anurans (HS, ES and EP) were more variable on the intraspecific level, which may be related to individual adaptations to local conditions (e.g. microhabitat). In contrast, interspecific variation was dominant in traits related to horizontal movement and foraging of adult anurans (BM and RLL). This may be due to differences in dispersal mode and ability, as well as to differences in the species' trophic levels. These may reflect solutions to reduce overlap in the trophic space, facilitating coexistence between species (Cloyed and Eason, 2017). We stress the importance of considering patterns of intraspecific variation in functional traits for the evaluation of the functional structure of metacommunities. Also, ecological differences between species may also influence the outcomes of analyses of ITV versus turnover; thus, analyses should focus the whole set of species under analysis but also distinct functional guilds.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Diego Anderson Dalmolin and Maria João Ramos Pereira. The first draft of the manuscript was written by Diego Anderson Dalmolin and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Supllementary Material

Table S1– Environmental descriptors of ponds measured between October 2016 and March 2017 at Lagoa do Peixe Nation Park, Rio Grande do Sul, Brazil.

Environmental descriptors	Description/levels	Ecological Relevance	Reference
Area	Total surface area of the pond (m^2)	Both are related to the occurrence and persistence of individuals in ponds, as well as the levels of competition and/or predation, and the reproductive success of each species	1, 2
Depth	Maximum depth of the pond (cm)		
Distance to the nearest forest fragment	Distance to the nearest forest fragment (m)	promote routes of dispersion and places for thermoregulation and feeding	3

Distance to the nearest sampled pond	Distance to the nearest other pond (m)	Ensure population persistence due to increased recolonization rates of ponds subject to stochastic extinctions.	4
Pond vegetation	Number of vegetation types inside the pond, according to the following categories their combinations: (i) absent; (ii) macrophytes; (iii) grasses; (iv) herbs; (v) shrubs; (vi) trees.	provides a greater variety of microhabitats in both vertical and horizontal strata and thus insures that several species-specific requirements are met, promoting maintaining of a high diversity of species	3, 5
Margin configuration	(i) flat border; (ii) angular border (margins with ≥15 cm higher than the surface water).	affects microclimatic conditions and foraging and reproductive success	6
Vegetation around the pond	Number of vegetation types around the pond, according to the following categories and		

	their combinations:(i) grasses; (ii) herbs; (iii) shrub; (iv) trees.		
Pond substrate	Number of substrate types of the pond, according to the following categories and combinations: (i) muddly; (ii) with vegetation.	influence habitat use and foraging of tadpoles	6

Table S2: Results of ANOVA tests showing the effects of environmental predictors on anuran morphological traits

	Trait	**Model***	**Environmental predictor**	**Effect**	***F***	***p***
ALL SPECIES	HS	Model 1	Pine.area (1000m^2)	+	7.24	<0.001
	EP	Model 1	Pine.area (1000m^2)	+	6.23	<0.001
	ML	Model 1	Pine.area (1000m^2)	+	3.18	0.05
		Model 2	Margin type	+	1.64	0.21
			Pine.area (1000m^2)	+	3.20	0.05
	BM	Model 1	Pine.area (1000m^2)	-	1.27	0.26
A R	HS		Area	+	13.67	<0.001

	Model 1	Depth	-	7.68	<0.001
		Ins.veg.	+	1.76	0.25
		Margin veg.	+	23.57	<0.001
		Subst.	+	5.95	<0.001
	Model 2	Depth	-	1.09	0.32
		Dist.bt.ponds	+	20.44	<0.001
		Ins.veg.	+	2.45	0.15
		Margin veg.	+	6.66	0.02
		Subst.	+	10.29	<0.001
	Model 3	Area	+	11.84	<0.001
		Ins.veg.	+	2.23	0.17
		Margin veg.	+	17.06	<0.001
		Subst.	+	5.89	<0.001
	Model 4	Dist.bt.ponds	+	11.12	<0.001
		Subst.	+	3.59	0.05
	Model 5	Dist.bt.ponds	+	12.05	<0.001
		Pine.area (1000m^2)	+	7.70	<0.001
	Model 6	Area	+	15.88	<0.001
		Depth	-	17.15	<0.001
		Dist.bt.ponds	+	2.33	0.15
		Ins.veg.	+	4.36	0.04
		Margin veg.	+	3.24	0.09
		Subst.	+	9.13	<0.001
EP	Model 1	Dist.bt.ponds	+	12.72	<0.001
		Subst.	+	4.11	0.03
	Model 2	Area	+	18.61	<0.001
		Depth	-	5.65	0.03
		Ins.veg.	+	1.38	0.35
		Margin veg.	+	22.52	<0.001
		Subst.	+	10.53	<0.001
	Model 3	Area	+	15.02	<0.001

			Ins.veg.	+	1.68	0.27
			Margin veg.	+	19.43	<0.001
			Subst.	+	5.38	<0.001
		Model 4	Depth	-	9.85	<0.001
			Dist.bt.ponds	+	8.30	<0.001
			Ins.veg.	+	1.69	0.27
			Margin veg.	+	2.82	0.11
			Subst.	+	9.81	<0.001
		Model 5	Area	+	19.61	<0.001
			Depth	-	6.34	0.02
			Dist.bt.ponds	+	0.88	0.36
			Ins.veg.	+	2.19	0.18
			Margin veg.	+	10.43	<0.001
			Subst.	+	17.05	<0.001
	M.L.	Model 1	Depth	-	3.82	0.05
			Dist.bt.ponds	+	1.98	0.18
			Ins.veg.	+	2.23	0.18
			Subst.	+	10.19	<0.001
		Model 2	Depth	-	3.70	0.05
			Dist.bt.ponds	+	1.97	0.18
			Ins.veg.	+	2.19	0.18
			Margin veg.	+	0.94	0.35
			Subst.	+	9.96	<0.001
		Model 3	Subst.	+	1.66	0.22
		Model 4	Pine.area (1000m^2)	+	4.50	0.04
		Model 5	Dist.bt.ponds	+	3.55	0.05
			Subst.	+	3.71	0.04
	BM	Model 1	Margin veg.	+	1.85	0.19
AQUATIC-	HF	Model 1	Subst	+	2.05	0.14
		Model 2	Margin veg. + subst.	+	1.44	0.25
	EP	Model 1	Depth	-	3.49	0.05
		Model 2	Margin veg.	+	1.06	0.32

	Model 3	Subst.	+	1.14	0.33
ES	Model 1	Depth	-	7.57	<0.001
M.L.	Model 1	Ins.veg.	+	0.75	0.66
	Model 2	Ins.veg.	+	0.75	0.66
		Margin veg.	+	1.18	0.29
	Model 3	Depth	-	4.61	0.03
	Model 4	Ins.veg.	+	0.73	0.68
		Pine.area (1000m^2)	-	0.12	0.73
	Model 5	Ins.veg.	+	0.75	0.66
		Subst.	+	0.70	0.49
B.M.	Model 1	Ins.veg.	+	1.40	0.30
	Model 2	Depth	+	4.96	0.02
	Model 3	Ins.veg.	+	1.41	0.29
		Margin veg.	+	1.28	0.27
	Model 4	Dist.bt.ponds	+	3.79	0.05
	Model 5	Pine.area (1000m^2)	+	0.55	0.61

S3: Summary of the frist 50 adjusted models produced by GLMM analysis relating environmental predictors and the trait head shape (HS) in the set of all species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m)

	df	logLik	AICc	delta	weight
Pine_area	5	-215,121105381855	440,563066378684	0	0,39557779623032
Null	4	-217,644137966472	443,501041890392	2,93797551170803	0,0910455304038904
Margin_veg	6	-215,800730786154	444,053074475534	3,49000809685077	0,0690854001705055
Area,Pine_area	6	-215,992658965543	444,436930834311	3,8738644556276	0,0570207503913222
Subst+Pine_area	7	-215,383879147812	445,373163701028	4,81009732234486	0,0357052883254901
Dist_bt_ponds+Pine_area	6	-216,493741488054	445,439095879333	4,87602950064928	0,0345474147484152
Margin_conf+Pine_area	7	-215,420469622509	445,446344650423	4,88327827173987	0,0344224282342517
Depth+Pine_area	6	-216,541523705009	445,534660313243	4,97159393455917	0,0329354802610766
Margin_veg	5	-218,001289662823	446,32343494062	5,76036856193628	0,0222015740692745

Area	5	-218,130143624515	446,581142864004	6,01807648532019	0,0195174556891143
Ins_veg+Pine_area	16	-206,010089874329	447,111088839568	6,54802246088411	0,014974312617013
Dist_bt_ponds	5	-218,745924277377	447,812704169727	7,2496377910436	0,0105437005343263
Subst	6	-217,714446082528	447,880505068281	7,31743868959785	0,0101922550857698
Area,Margin_veg,Pine_area	7	-216,683564805862	447,97253501713	7,40946863844601	0,00973388553584058
Depth	5	-218,980092403196	448,281040421365	7,71797404268182	0,00834247929702638
Depth+Margin_veg+Pine_area	7	-217,02215364873	448,649712702865	8,08664632418095	0,0069380746582503
Depth+Dist_bt_ponds+Pine_area	7	-217,029211812805	448,663829031015	8,10076265233113	0,00688927700245967
Margin_conf+Margin_veg+Pine_area	8	-215,954263709742	448,691136115137	8,12806973645343	0,00679585320334907
Dist_bt_ponds+Margin_veg+Pine_area	7	-217,104444164667	448,814293734738	8,25122735605487	0,00638999696435006
Subst+Margin_veg+Pine_area	8	-216,025942622427	448,834493940506	8,27142756182207	0,006325782171481
Area+Depth+Pine_area	7	-217,175868011465	448,957141428335	8,39407504965152	0,00594951644512698
Area+Subst+Pine_area	8	-216,161306578733	449,105221853119	8,5421554744355	0,00552492533970211
Margin_conf	6	-218,359131880653	449,169876664531	8,6068102858473	0,00534917491987467
Area+Dist_bt_ponds+Pine_area	7	-217,335368600131	449,276142605668	8,71307622698407	0,00507237605570879
Ins_veg+Margin_veg+Pine_area	17	-205,905241072509	449,30762500216	8,74455862347645	0,00499315592432531
Area+Margin_veg	6	-218,571002467191	449,593617837608	9,03055145892398	0,00432785371757833
Area+Margin_conf+Pine_area	8	-216,495497692347	449,773604080347	9,21053770166338	0,00395538768534285
Dist_bt_ponds+Subst+Pine_area	8	-216,58981023117	449,962229157991	9,39916277930786	0,00359939610111505
Dist_bt_ponds+Margin_conf+Pine_area	8	-216,59557932983	449,973767355313	9,41070097662907	0,00357869061331757
Depth+Margin_conf+Pine_area	8	-216,661576450844	450,105761597339	9,54269521865558	0,00335013238185012
Ins_veg	15	-208,767031368296	450,245927143371	9,6828607646878	0,00312338418607426
Depth+Subst+Pine_area	8	-216,793536945794	450,36968258724	9,80661620855665	0,00293597432867827
Margin_conf+Subst+Pine_area	9	-215,730599838801	450,44480623498	9,88173985629595	0,00282773925676714
Ins_veg+Subst+Pine_area	18	-205,346874993976	450,62478447071	10,0617180920269	0,00258438721407152
Subst+Margin_veg	7	-218,071784295957	450,748973997319	10,1859076186352	0,00242879114416791
Dist_bt_ponds+Margin_veg	6	-219,227464523101	450,906541949428	10,3434755707443	0,00224478486025782
Depth+Margin_veg	6	-219,256918360909	450,965449625044	10,4023832463602	0,00217963154873358
Area+Subst	7	-218,262334865561	451,130075136528	10,5670087578446	0,00200740550035238

Area+Ins_veg+Pine_area	17	-206,905408936068	451,307960729278	10,7448943505943	0,00183657109188588
Area+Dist_bt_ponds	6	-219,442530784222	451,336674471669	10,7736080929853	0,00181039205150032
Depth+Ins_veg+Pine_area	17	-206,928953471245	451,355049799632	10,7919834209487	0,0017938349546468
Area+Depth	6	-219,47326155489	451,398136013006	10,8350696343225	0,00175560346794721
Margin_conf+Margin_veg	7	-218,469283794096	451,543972993597	10,9809066149129	0,00163214347111068
Dist_bt_ponds+Ins_veg+Pine_area	17	-207,049859881351	451,596862619846	11,0337962411621	0,0015895474463364
Ins_veg+Margin_veg	16	-208,273533651568	451,637976394045	11,0749100153612	0,00155720486924653
Depth+Dist_bt_ponds	6	-219,629247333779	451,710107570784	11,1470411920999	0,00150204404223301
Dist_bt_ponds+Subst	7	-218,571366029715	451,748137464835	11,1850710861517	0,00147375258703615
Area+Depth+Margin_veg+Pine_area	8	-217,542424686642	451,867458068936	11,3043916902519	0,00138839947410573
Depth+Dist_bt_ponds+Margin_veg+Pine_area	8	-217,551318570095	451,885245835842	11,3221794571583	0,00137610596057068

S4: Summary of the first 50 adjusted models produced by GLMM analysis relating environmental predictors and the trait relative eye position (EP) in the set of all species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m)

	df	logLik	AICc	delta	weight
Pine_area	5	-244,440413902031	499,201683419036	0	0,299488298499119
Null	4	-246,61615961144	501,445085180327	2,24340176129124	0,0975509168726329
Margin_veg+Pine_area	6	-245,008239076507	502,46809105624	3,26640763720417	0,0584909199739512
Margin_conf+Pine_area	7	-244,052221626143	502,709848657691	3,50816523865512	0,0518312229507033
Ins_veg+Pine_area	16	-233,934849973438	502,960609037785	3,75892561874878	0,0457235067840231
Subst+Pine_area	7	-244,428112329732	503,46163006487	4,25994664583402	0,0355913283942548
Area+Pine_area	6	-245,607767703282	503,667148309789	4,46546489075314	0,0321156323693991
Depth+Pine_area	6	-245,640946279663	503,733505462551	4,53182204351498	0,0310675642543963
Dist_bt_ponds+Pine_area	6	-245,787506777711	504,026626458648	4,82494303961226	0,0268322313407447
Margin_veg	5	-246,910547117295	504,141949849563	4,94026643052712	0,0253288010934969

Ins_veg+Margin_veg+Pine_area	17	-233,77399246184	505,045127780822	5,8434443617864	0,0161247146399707
Area	5	-247,54325273148	505,407361077933	6,20567765889723	0,0134534626259571
Ins_veg	15	-236,485802599225	505,683469605231	6,48178618619465	0,0117186577785398
Margin_conf+Margin_veg+Pine_area	8	-244,492938400497	505,768485496646	6,56680207760974	0,0112309606453722
Subst	6	-246,662910714465	505,777434332155	6,57575091311952	0,011180820892408
Dist_bt_ponds	5	-247,76851165622	505,857878927413	6,65619550837744	0,010740026886582
Depth	5	-247,916085818164	506,153027251302	6,95134383226582	0,00926647854144537
Margin_conf	6	-246,886434849374	506,224482601973	7,02279918293738	0,00894125317202792
Depth+Dist_bt_ponds+Pine_area	7	-245,903807653117	506,413020711639	7,21133729260259	0,00813687907414754
Depth+Margin_veg+Pine_area	7	-245,932248520482	506,469902446368	7,26821902733252	0,00790871908892637
Subst+Margin_veg+Pine_area	8	-244,961046570913	506,704701837478	7,50301841844168	0,00703266791046487
Ins_veg+Subst+Pine_area	18	-233,392697232042	506,716428946843	7,51474552780707	0,00699155213769861
Area+Margin_veg+Pine_area	7	-246,181944292081	506,969293989567	7,76761057053113	0,00616119074365859
Margin_conf+Subst+Pine_area	9	-244,006730735677	506,997068028731	7,79538460969462	0,00607622151732652
Ins_veg+Margin_veg	16	-236,006212874899	507,103334840708	7,901651421672	0,00576179832877056
Dist_bt_ponds+Margin_veg+Pine_area	7	-246,275613365014	507,156632135433	7,95494871639687	0,00561028201583832
Dist_bt_ponds+Margin_conf+Pine_area	8	-245,199344921421	507,181298538495	7,97961511945925	0,00554151421235452
Depth+Margin_conf+Pine_area	8	-245,221956015781	507,226520727215	8,02483730817869	0,00541762047654279
Depth+Ins_veg+Pine_area	17	-234,957266618806	507,411676094755	8,20999267571904	0,00493858576988122
Area+Margin_conf+Pine_area	8	-245,378156334779	507,538921365211	8,33723794617504	0,00463416658405548
Dist_bt_ponds+Ins_veg+Pine_area	17	-235,025429207641	507,548001272424	8,34631785338854	0,00461317536838502
Area+Subst+Pine_area	8	-245,406403821129	507,595416337911	8,39373291887512	0,0045050945887595
Area+Depth+Pine_area	7	-246,547958104516	507,701321614438	8,49963819540176	0,00427274402210685
Area+Ins_veg+Pine_area	17	-235,157668197183	507,812479251508	8,61079583247238	0,00404174864171629
Depth+Subst+Pine_area	8	-245,648305743742	508,079220183137	8,8775367641008	0,00353709922980012

Dist_bt_ponds+Subst+Pine_area	8	-245,687686204429	508,15798110451	8,9562976854744	0,00340051368466543
Ins_veg+Margin_conf+Pine_area	18	-234,151206696269	508,233447875296	9,03176445626053	0,00327459146744786
Area+Margin_veg	6	-247,892357059742	508,236327022709	9,03464360367326	0,00326988084313121
Area+Dist_bt_ponds+Pine_area	7	-246,839004176984	508,283413759373	9,08173034033746	0,0031937959952299
Depth+Ins_veg+Margin_veg+Pine_area	18	-234,215782964006	508,36260041077	9,16091699173438	0,00306981362352046
Depth+Margin_veg	6	-247,979685150499	508,410983204224	9,20929978518797	0,00299644160825994
Margin_conf+Margin_veg	7	-246,944318860158	508,494043125722	9,29235970668594	0,00287454814036824
Ins_veg+Subst+Margin_veg+Pine_area	19	-233,065428351607	508,52392028703	9,32223686799364	0,00283192562371932
Ins_veg+Subst	17	-235,539881159974	508,576905177091	9,3752217580552	0,0027578860646124
Subst+Margin_veg	7	-247,012342526091	508,630090457587	9,42840703855086	0,00268551315101604
Dist_bt_ponds+Margin_veg	6	-248,123285820545	508,698184544316	9,4965011252803	0,00259561837760716
Dist_bt_ponds+Ins_veg+Margin_veg+Pine_area	18	-234,448711888687	508,828458260132	9,62677484109639	0,00243193667645785
Depth+Dist_bt_ponds	6	-248,370067748437	509,1917484001	9,99006498106365	0,00202798533844789
Depth+Dist_bt_ponds+Margin_veg+Pine_area	8	-246,261410946165	509,305430587983	10,1037471689471	0,0019159273517352

S5: Summary of the first 50 adjusted models produced by GLMM analysis relating environmental predictors and the trait relative limbs lenght (RLL) in the set of all species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m)

	df	logLik	AICc	delta	weight
Null	4	-228,43857803643	465,089922030308	0	0,158991063962642
Pine_area	5	-227,457886039053	465,236627693079	0,146705662771183	0,14774608637245
Margin_conf+Pine_area	7	-226,151794147964	466,908993701334	1,81907167102656	0,0640274670299652
Margin_veg+Pine_area	6	-227,619676969575	467,690966842376	2,60104481206866	0,0433074897336448
Depth+Pine_area	6	-227,623747546706	467,699107996637	2,60918596632956	0,0431315615638716
Margin_conf	6	-227,728982979554	467,909578862334	2,81965683202606	0,0388232612263797

Margin_veg	5	-228,817555958844	467,95596753266	2,86604550235268	0,03793314423415
Subst	6	-227,921886859446	468,295386622118	3,20546459180986	0,0320121559224549
Depth	5	-229,129024767953	468,578905150879	3,48898312057122	0,0277811140430141
Subst+Pine_area	7	-227,025090505035	468,655586415474	3,56566438516677	0,0267361292611626
Dist_bt_ponds+Pine_area	6	-228,238269899642	468,928152702511	3,838230672203	0,023329826822361
Dist_bt_ponds	5	-229,443166840864	469,207189296701	4,11726726639381	0,0202917493191865
Margin_conf+Margin_veg+Pine_area	8	-226,456997983284	469,69660466222	4,60668263191258	0,0158870876719186
Area	5	-229,822923654656	469,966702924286	4,87678089397832	0,0138801193279866
Area+Pine_area	6	-228,800599507005	470,052811917236	4,96288988692817	0,0132951998385004
Ins_veg+Pine_area	16	-217,616810616883	470,324530324676	5,2346082943684	0,0116062512284633
Depth+Margin_veg+Pine_area	7	-227,899020747589	470,403446900583	5,31352487027516	0,0111572059645775
Depth+Margin_conf+Pine_area	8	-226,893462193836	470,569533083324	5,47961105301624	0,0102681048330266
Subst+Margin_veg+Pine_area	8	-226,950824246373	470,684257188398	5,5943351580903	0,0096956799478459
Margin_conf+Margin_veg	7	-228,082076101095	470,769557607595	5,67963557728774	0,0092908515388571
Margin_conf+Subst+Pine_area	9	-226,00076983962	470,985146236616	5,89522420630857	0,00834144027240602
Subst+Margin_veg	7	-228,199031971833	471,003469349071	5,91354731876322	0,00826536869742185
Ins_veg	15	-219,173218810011	471,058302026801	5,96837999649313	0,00804184070907074
Area+Margin_conf+Pine_area	8	-227,171368980683	471,125346657019	6,03542462671135	0,00777672801257709
Dist_bt_ponds+Margin_conf+Pine_area	8	-227,189825471179	471,162259638011	6,0723376077035	0,00763451333484826
Depth+Margin_veg	6	-229,363130725762	471,17787435475	6,08795232444248	0,00757514002919443
Depth+Subst+Pine_area	8	-227,292040946863	471,366690589377	6,27676855906964	0,00689270578346634
Depth+Dist_bt_ponds+Pine_area	7	-228,470334560291	471,546074525988	6,45615249568039	0,0063013994982564
Dist_bt_ponds+Margin_veg+Pine_area	7	-228,498339344178	471,602084093762	6,51216206345396	0,00612737825391777
Margin_conf+Subst	8	-227,483785582849	471,750179861351	6,66025783104351	0,00569005027414914
Depth+Margin_conf	7	-228,636513861017	471,87843312744	6,78851109713264	0,00533661976953336
Depth+Subst	7	-228,646288837652	471,897983080709	6,80806105040142	0,00528470856472959
Dist_bt_ponds+Margin_veg	6	-229,74830060284	471,948214108905	6,85829207859746	0,00515363329367526
Ins_veg+Margin_veg+Pine_area	17	-217,232995711661	471,963134280466	6,87321225015808	0,00511532979854535

Dist_bt_ponds+Subst	7	-228,863738431402	472,33288226821	7,24296023790191	0,00425190824162845
Depth+Dist_bt_ponds	6	-229,958695978689	472,369004860603	7,27908283029541	0,00417580261942675
Area+Depth+Pine_area	7	-228,956862472455	472,519130350315	7,42920832000721	0,00387383060979785
Area+Margin_conf	7	-228,96009389324	472,525593191885	7,43567116157737	0,00386133283670455
Area+Margin_veg+Pine_area	7	-228,968935949996	472,543277305397	7,45335527508973	0,00382734121200604
Dist_bt_ponds+Subst	7	-229,015669983731	472,636745372867	7,54682334255926	0,0036525893530248
Dist_bt_ponds+Subst+Pine_area	8	-227,938895631597	472,660399958846	7,57047792853859	0,00360964357534414
Ins_veg+Margin_veg+Subst	16	-218,837649609592	472,766208310092	7,67628627978456	0,00342364187167303
Area+Margin_veg	6	-230,197364625843	472,846342154912	7,75642012460406	0,00328917882660433
Area+Subst	7	-229,158675015406	472,922755436217	7,83283340590935	0,00316588075401533
Ins_veg+Margin_conf+Pine_area	18	-216,539207255611	473,00944899398	7,91952696367281	0,00303158176302823
Depth+Margin_conf+Margin_veg+Pine_area	9	-227,053139361754	473,089885280884	7,99996325057674	0,00291207642214829
Area+Subst+Pine_area	8	-228,225390843198	473,233390382049	8,14346835174138	0,00271044769750159
Ins_veg+Subst+Pine_area	18	-216,688438190364	473,307910863488	8,21798883317985	0,00261131410350003
Area+Depth	6	-230,436461995715	473,324536894656	8,2346148643482	0,00258969618819012
Area+Dist_bt_ponds+Pine_area	7	-229,401868609158	473,409142623722	8,319220593414	0,00248242946201549

S6: Summary of the first 50 adjusted models produced by GLMM analysis relating environmental predictors and the trait Body mass (BM) in the set of all species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m)

	df	logLik	AICc	delta	weight
Null	4	-144,13703097624	296,486827909926	0	0,332479327265423
Pine_area	5	-144,378235307936	299,077326230844	1,99049832091819	0,10010426906075238
Depth	5	-144,527447483805	299,375750582582	2,88892267265624	0,0784229291462309
Dist_bt_ponds	5	-144,836410842997	299,993677300968	3,50684939104212	0,057578716200275
Margin_veg	5	-144,86195308941	300,044761793793	3,55793388386644	0,0561266499044735
Margin_conf	6	-143,949306718939	300,350226341103	3,86339843117702	0,0481768429523534

Depth+Pine_area	6	-144,262296046928	300,976204997081	4,48937708715488	0,0352296881663691
Depth+Margin_veg	6	-144,457485759124	301,366584421474	4,87975651154801	0,0289827095207216
Subst	6	-144,613686791673	301,678986486572	5,19215857664557	0,0247914391051206
Area	5	-145,835523001325	301,991901617624	5,50507370769765	0,0212008405754306
Dist_bt_ponds+Pine_area	6	-144,807515113771	302,066643130768	5,57981522084225	0,0204231706832619
Margin_conf+Pine_area	7	-143,736745855953	302,078897117311	5,59206920738518	0,0202984206155762
Dist_bt_ponds+Margin_veg	6	-145,059192359859	302,569997622944	6,08316971301809	0,0158789261068042
Margin_veg+Pine_area	6	-145,098950615091	302,649514133408	6,16268622348167	0,015259993086124
Depth+Margin_veg+Pine_area	7	-144,372476012978	303,350357431361	6,86352952143443	0,010749002115587
Depth+Dist_bt_ponds	6	-145,634853166779	303,721319236784	7,2344913268584	0,00892924657381913
Margin_conf+Margin_veg	7	-144,605582906965	303,816571219336	7,32974330941011	0,00851395029893964
Subst+Pine_area	7	-144,797931083275	304,201267571955	7,71443966202901	0,00702417558237211
Depth+Margin_conf	7	-144,892601152935	304,390607711276	7,90377980134986	0,00638970297069852
Area+Pine_area	6	-146,020573321	304,492759545227	8,00593163530067	0,00607153749383314
Dist_bt_ponds+Margin_conf	7	-144,960806936644	304,527019278693	8,04019136876673	0,00596841859373003
Depth+Subst	7	-145,105221360529	304,815848126464	8,32902021653774	0,00516583924475747
Area+Depth	6	-146,207736112383	304,867085127992	8,38025721806611	0,00503517899401601
Dist_bt_ponds+Margin_veg+Pine_area	7	-145,192751881801	304,990909169008	8,504081259082	0,00473289494778238
Area+Dist_bt_ponds	6	-146,290873036788	305,033358976801	8,54653106687539	0,00463349828117068
Subst+Margin_veg	7	-145,302763164733	305,210931734871	8,7241038249449	0,00423984101489051
Depth+Dist_bt_ponds+Pine_area	7	-145,392622516296	305,390650437998	8,90382252807228	0,00387546796427918
Dist_bt_ponds+Subst	7	-145,422081194059	305,449567793524	8,96273988359792	0,00376296700283028
Area+Margin_veg	6	-146,550810777851	305,553234458927	9,06640654900076	0,00357288863483987
Margin_conf+Margin_veg+Pine_area	8	-144,398606518309	305,579821732269	9,09299382234337	0,00352570625898236
Margin_conf+Subst	8	-144,419205838817	305,621020373285	9,13419246335934	0,0034538220307453
Depth+Dist_bt_ponds+Margin_veg	7	-145,518231937416	305,641869280238	9,15504137031166	0,00341800483536595
Depth+Margin_conf+Pine_area	8	-144,458111640757	305,698831977165	9,21200406723926	0,00332202870125551
Area+Margin_conf	7	-145,557611802762	305,720629010929	9,23380110100288	0,00328602009200843

Dist_bt_ponds+Margin_conf+Pine_area	8	-144,567411121126	305,917430937904	9,4306030279779	0,00297807217649997
Depth+Subst+Pine_area	8	-144,834452395783	306,451513487218	9,9646855772919	0,00228013555667104
Area+Depth+Pine_area	7	-145,955415048769	306,516235502943	10,0294075930173	0,00220752921539759
Area+Depth+Margin_veg	7	-146,067223849503	306,739853104412	10,2530251944862	0,00197400621074838
Depth+Margin_conf+Margin_veg	8	-144,982801828482	306,748212352617	10,2613844426904	0,00196577282502685
Depth+Subst+Margin_veg	8	-145,02199950087	306,826607697393	10,3397797874665	0,00189020972928738
Area+Subst	7	-146,212901720493	307,031208846392	10,5443809364658	0,00170640226630088
Area+Dist_bt_ponds+Pine_area	7	-146,279522405976	307,164450217358	10,6776223074315	0,0015964246432056
Area+Pine_area	8	-145,199365674471	307,181340044594	10,6945121346683	0,00158299974085053
Area+Dist_bt_ponds+Margin_veg	7	-146,300092823549	307,205591052503	10,7187631425772	0,00156392097481803
Dist_bt_ponds+Margin_conf+Margin_veg	8	-145,218421623674	307,219451943	10,7326240330738	0,00155311977791405
Margin_conf+Subst+Pine_area	9	-144,156453273054	307,296513103485	10,809685193559	0,00149441539128336
Dist_bt_ponds+Subst+Pine_area	8	-145,345504710301	307,473618116254	10,9867902063279	0,00136777123776552
Subst+Margin_veg+Pine_area	8	-145,410650879715	307,603910455081	11,1170825451553	0,00128150659349539
Depth+Dist_bt_ponds+Margin_veg+Pine_area	8	-145,463736456939	307,71008160953	11,2232536996038	0,00121525123685765
Ins_veg	15	-137,662761386495	308,03738717977	11,5505592698444	0,00103179298355131

S7: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait head shape (HS) of the set of arboreal species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Area+Depth+Ins_veg+Subst+Margin_veg	15	-94,9922737818066	226,138393717459	0	0,0619002239126919
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	15	-95,1221757697538	226,398197693354	0,259803975894386	0,05435963142867

Area+Ins_veg+Subst+Margin_veg	14	-96,5482964411357	226,413048578474	0,274654861014511	0,0539574820243423
Dist_bt_ponds+Subst	7	-105,711842931784	226,726011444964	0,587617727504806	0,0461416001867294
Dist_bt_ponds+Pine_area	6	-107,209506658534	227,384530558448	1,24613684098867	0,0331968627680449
Area+Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	16	-94,2344858944837	227,533906853902	1,39551313644304	0,0308077791776524
Area+Depth+Ins_veg+Margin_veg	13	-98,6355203386948	227,82104067739	1,68264695993028	0,0266876341332988
Dist_bt_ponds+Ins_veg+Pine_area	12	-100,093117291086	228,038086434024	1,89969271656491	0,02394303431439
Dist_bt_ponds+Ins_veg+Subst	13	-98,8782180397412	228,306436079482	2,16804236202293	0,0209366794004307
Ins_veg+Subst+Margin_veg	13	-98,8869971253439	228,323994250688	2,18560053322838	0,0207536789633433
Dist_bt_ponds+Ins_veg+Subst+Pine_area	14	-97,5188888601336	228,35423341647	2,21583969901039	0,0204422522476874
Depth+Dist_bt_ponds+Ins_veg+Subst	14	-97,5644158154373	228,445287327077	2,30689360961773	0,0195324462332701
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	16	-94,7392579982125	228,54345106136	2,40505734390072	0,0185969041824623
Dist_bt_ponds+Ins_veg+Subst+Margin_veg	14	-97,6301947040407	228,576845104284	2,43845138682443	0,0182889692265666
Area+Ins_veg+Margin_veg	12	-100,369845167224	228,591542186299	2,45314846883969	0,018155064590654
Dist_bt_ponds	5	-108,96026237198	228,602342925778	2,46394920831827	0,0180572847903983

Dist_bt_ponds+Subst+Margin_veg	8	-105,459544733493	228,613207114045	2,47481339658555	0,0179594618518678
Depth+Dist_bt_ponds+Ins_veg+Subst+Pine_area	15	-96,3665366861573	228,886919526161	2,74852580870134	0,0156623680039068
Dist_bt_ponds+Ins_veg+Margin_veg+Pine_area	13	-99,194087284065	228,93817456813	2,79978085067054	0,0152660799681261
Ins_veg+Margin_veg	11	-101,97864345461	229,176799104343	3,03840538688317	0,0135491132661512
Dist_bt_ponds+Subst+Pine_area	8	-105,777898459857	229,249914566773	3,11152084931314	0,0130627330714577
Area+Ins_veg+Margin_conf+Subst+Margin_veg	16	-95,0970060895785	229,258947244092	3,12055352663273	0,0130038703670916
Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	15	-96,6991007803528	229,552047714552	3,41365399709241	0,0112312132392524
Subst+Margin_veg	7	-107,134987906226	229,572301393847	3,43390767638763	0,0111180505012765
Ins_veg+Margin_veg+Pine_area	12	-100,888563276998	229,628978405849	3,49058468838916	0,0108074039785905
Area+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	15	-96,7721857858834	229,698217725613	3,55982400815344	0,0104396576830467
Margin_veg	5	-109,598360388102	229,878538958022	3,74014524056244	0,00953959638327344
Area+Ins_veg+Margin_veg+Pine_area	13	-99,6854248895547	229,920849779109	3,78245606164998	0,00933990206078501
Area+Dist_bt_ponds+Ins_veg+Margin_veg	13	-99,6874503539251	229,92490070785	3,78650699039073	0,00932100356751141

Area+Depth+Ins_veg+Subst+Margin_veg+Pine_area	16	-95,52419819261	230,113331450155	3,97493773269562	0,00848292170091435
Dist_bt_ponds+Margin_veg+Pine_area	7	-107,466942961756	230,236211504908	4,09781778744863	0,00797741882232126
Depth+Dist_bt_ponds+Ins_veg+Pine_area	13	-99,9155878628779	230,381175725756	4,2427820082963	0,0074196567267308 4
Dist_bt_ponds+Margin_veg	6	-108,708024513969	230,381566269316	4,24317255185699	0,0074182080186028
Area+Depth+Dist_bt_ponds+Ins_veg+Margin_veg	14	-98,5607678995742	230,437991495351	4,29959777789153	0,0072118456845152 3
Depth+Dist_bt_ponds+Ins_veg+Margin_veg+Pine_area	14	-98,6427563299635	230,601968356129	4,46357463867005	0,00664414806935135
Area+Ins_veg+Subst	8	-106,466726305072	230,627570257202	4,48917653974263	0,0065596387126101 9
Depth+Dist_bt_ponds+Subst	8	-106,483933922089	230,661985491237	4,52359177377781	0,00644772857663834
Area+Depth+Ins_veg+Margin_conf+Subst+Margin_veg	17	-94,3081971852471	230,669025949442	4,53063223198211	0,00642507099819136
Pine_area	5	-110,058879913231	230,79957800828	4,66118429082067	0,0060190633144195 5
Area+Ins_veg+Subst+Margin_veg+Pine_area	15	-97,3271822336305	230,808210621107	4,6698169036477	0,00599313918133141
Null	4	-111,190421070073	230,830280342393	4,69188662493357	0,0059273692739217 2
Area+Dist_bt_ponds+Pine_area	7	-107,860330390644	231,022986362683	4,88459264522365	0,0053829011411589
Area+Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	17	-94,559470261562	231,171572102071	5,03317838461192	0,00499748409455735

Area	5	-110,248780590538	231,179379362895	5,04098564543509	0,00497801379082388
Area+Dist_bt_ponds+Ins_veg+Margin_veg+Pine_area	14	-98,9494877414787	231,21543117916	5,07703746170048	0,00488908449519869
Area+Subst+Margin_veg	8	-106,783114762175	231,26034717141	5,12195345395008	0,0047805092096183 9
Margin_veg+Pine_area	6	-109,194922668114	231,355362577608	5,21696886014851	0,0045587085328797
Depth+Dist_bt_ponds+Pine_area	7	-108,028153232888	231,358632047171	5,2202383297118	0,0045512623414139 4
Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst	16	-96,1513488831845	231,367632831304	5,22923911384473	0,0045308258969789 6
Depth	5	-110,350776527637	231,383371237092	5,2449775196325	0,0044953118257003

S8: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait relative eye position (EP) of the set of arboreal species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Dist_bt_ponds+Subst	7	-119,835731520741	254,973788622878	0	0,0778163770797443
Area+Depth+Ins_veg+Subst+Margin_veg	15	-109,538507614336	255,230861382519	0,257072759640749	0,0684302878553284
Area+Ins_veg+Subst+Margin_veg	14	-111,02817023266	255,372796161522	0,399007538644071	0,0637422840383149
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	15	-110,013023333463	256,179892820773	1,20610419789466	0,0425763873650018

Area+Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	16	-108,703775977858	256,47248702065	1,49869839777222	0,0367817836260813
Dist_bt_ponds+Subst+Margin_veg	8	-119,729053786352	257,152225219763	2,17843659688549	0,0261836092250594
Area+Ins_veg+Margin_conf+Subst+Margin_veg	16	-109,153720552463	257,372376169861	2,39858754698332	0,0234544006402322
Depth+Dist_bt_ponds+Ins_veg+Subst	14	-112,03447543153	257,385406559263	2,41161793638497	0,0233020873675628
Dist_bt_ponds+Ins_veg+Subst	13	-113,446034209192	257,442068418385	2,46827979550687	0,0226511814924063
Dist_bt_ponds	5	-123,418679867973	257,519177917765	2,54538929488666	0,0217944917074813
Dist_bt_ponds+Pine_area	6	-122,30232653713	257,57017031564	2,59638169276161	0,0212458390112451
Area+Depth+Ins_veg+Margin_veg	13	-113,528148531922	257,606297063843	2,63250844096558	0,0208655128015647
Dist_bt_ponds+Ins_veg+Subst+Margin_veg	14	-112,270889579878	257,858234855959	2,88444623308101	0,0183959180482837
Area+Depth+Ins_veg+Subst+Margin_veg+Pine_area	16	-109,43120891038	257,927352885695	2,95356426281745	0,0177710331381496
Dist_bt_ponds+Subst+Pine_area	8	-120,249689872561	258,19349739218	3,21970876930243	0,0155567950936616
Ins_veg+Subst+Margin_veg	13	-113,883545437156	258,317090874312	3,34330225143384	0,0146245377477252
Area+Ins_veg+Margin_veg	12	-115,255868736222	258,363589324295	3,38980070141741	0,0142884506006076
Dist_bt_ponds+Ins_veg+Subst+Pine_area	14	-112,593910039553	258,504275775308	3,53048715243057	0,0133178912115418

Depth+Dist_bt_ponds+Subst	8	-120,430498903311	258,555115453682	3,58132683080379	0,0129836191293986
Area+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	15	-111,214625048603	258,583096251051	3,6093076281735	0,0128032378664758
Depth+Dist_bt_ponds+Ins_veg+Subst+Pine_area	15	-111,30053182831	258,754909810466	3,78112118758827	0,0117492724267821
Area+Dist_bt_ponds+Subst	8	-120,53196729948	258,758052246019	3,78426362314082	0,0117308262563572
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	16	-109,910397565701	258,885730196337	3,91194157345893	0,011005345668454
Area+Depth+Ins_veg+Subst+Margin_veg	17	-108,503095919609	259,058823418165	4,08503479528679	0,0100929232878603
Dist_bt_ponds+Margin_veg	6	-123,136055841121	259,237628923621	4,26384030074303	0,0092297481394043 7
Ins_veg+Margin_veg	11	-117,13347514465	259,486462484421	4,51267386154308	0,0081499759845760 3
Margin_veg	5	-124,408228177119	259,498274536057	4,52448591317892	0,0081019838768109 9
Area+Dist_bt_ponds+Ins_veg+Margin_veg	13	-114,503968324254	259,557936648508	4,58414802563016	0,0078638625045271 3
Subst+Margin_veg	7	-122,13298727513	259,568300131655	4,59451150877663	0,0078232193932513
Dist_bt_ponds+Ins_veg+Pine_area	12	-115,891794857609	259,635441567069	4,66165294419113	0,0075649477412081 3
Area	5	-124,483184544962	259,648187271743	4,67439864886518	0,0075168907390511 7
Depth+Dist_bt_ponds+Subst+Margin_veg	9	-119,760159331958	259,663175806773	4,68938718389524	0,0074607677121346 5
Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	15	-111,762120086857	259,678086327559	4,70429770468149	0,0074053525699338 7

Area+Subst	7	-122,207960832404	259,718247246204	4,74445862332618	0,00725813275648076
Area+Subst+Margin_veg	8	-121,027485744305	259,749089135669	4,77530051279069	0,00714706408535649
Area+Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	17	-108,942467326918	259,937566232783	4,96377760990504	0,0065042974616756
Area+Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Margin_veg	14	-113,326305053153	259,969065802508	4,99527717963025	0,0064026586715095
Dist_bt_ponds+Margin_conf+Subst	9	-119,942486157731	260,02782945832	5,05404083544198	0,00621727366800558
Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst	16	-110,496615768297	260,058166601529	5,08437797865093	0,00612367815686853
Area+Ins_veg+Subst+Margin_veg+Pine_area	15	-111,954848912693	260,063543979231	5,08975535635358	0,00610723560603596
Dist_bt_ponds+Margin_veg+Pine_area	7	-122,380957782344	260,064241146084	5,09045252320601	0,00610510709592693
Area+Margin_veg	6	-123,584990311402	260,135497864183	5,16170924130506	0,00589142138740259
Dist_bt_ponds+Ins_veg+Margin_veg+Pine_area	13	-114,887656042177	260,325312084355	5,35152346147709	0,00535799683600132
Area+Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst+Margin_veg	18	-107,630940377719	260,381880754379	5,40809213150158	0,00520857260256372
Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst+Margin_veg	17	-109,166632132229	260,385895843406	5,41210722052779	0,00519812665007993
Area+Ins_veg+Margin_veg+Pine_area	13	-115,006472559151	260,562945118302	5,58915649542445	0,00475774427269516
Null	4	-126,060600756083	260,570639714414	5,59685109153571	0,00473947497865007

Dist_bt_ponds+Subst+Margin_veg+Pine_area	9	-120,244065555921	260,630988254699	5,65719963182102	0,00459860085573475
Area+Dist_bt_ponds	6	-123,900425865297	260,766368971973	5,79258034909509	0,00429762152865703
Ins_veg+Margin_veg+Pine_area	12	-116,48897741351	260,829806678872	5,85601805599441	0,00416344511148924

S9: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait relative eye size (ES) of the set of arboreal species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Null	4	58,8454460413602	-109,241453880473	0	0,890493765086918
Margin_veg	5	56,6501340142394	-102,618449846661	6,62300403381246	0,0324686199925485
Depth	5	56,0450068861463	-101,408195590474	7,8332582899987	0,0177280291724078
Pine_area	5	56,0359445336471	-101,390070885476	7,85138299499712	0,0175680972969953
Area	5	55,8228932096881	-100,963968237558	8,27748564291504	0,0141970369829408
Dist_bt_ponds	5	55,7079512941245	-100,734084406431	8,50736947404232	0,0126554931762265
Subst	6	56,1166600483511	-99,2678028553229	9,97365102515025	0,00607967103569599
Margin_conf	6	55,3004939016032	-97,635470561827	11,6059833186461	0,00268796510765975
Depth+Margin_veg	6	54,4279767373496	-95,8904362333198	13,3510176471533	0,00112329606382476
Margin_veg+Pine_area	6	53,9687026348055	-94,9718880282317	14,2695658522414	0,00070963336829428
Dist_bt_ponds+Margin_veg	6	53,6997165659414	-94,4339158905035	14,8075379899696	0,000542269106736983
Area+Margin_veg	6	53,697707640467	-94,4298980395547	14,8115558409184	0,000541180822021937

Depth+Dist_bt_ponds	6	53,339786573105	-93,7140559048307	15,5273979756424	0,000378354804749656
Depth+Pine_area	6	53,2571397487569	-93,5487622561345	15,6926916243386	0,000348342282898104
Area+Dist_bt_ponds	6	53,1510870327294	-93,3366568240796	15,9047970563935	0,00031329111930702
Area+Depth	6	53,1355301536339	-93,3055430658884	15,9359108145847	0,00030845500222125
Area+Pine_area	6	53,0639383722409	-93,1623595031025	16,0790943773707	0,00028714410317826
Subst+Pine_area	7	54,1496390160775	-92,9969524507596	16,2445014297135	0,000264351766541239
Dist_bt_ponds+Pine_area	6	52,9295636709916	-92,8936101006039	16,3478437798692	0,000251039297385502
Subst+Margin_veg	7	53,9512560047594	-92,6001864281234	16,6412674523497	0,000216783173582284
Depth+Subst	7	53,3462569304316	-91,3901882794678	17,8512656010054	0,000118379856799972
Margin_conf+Margin_veg	7	53,2773930682973	-91,2524605551993	17,9889933252738	0,00011050212123425
Area+Subst	7	53,1174642865236	-90,9326029916518	18,3088508888213	9,41704026875903e-05
Dist_bt_ponds+Subst	7	53,0501415584734	-90,7979575355514	18,4434963449217	8,80392913672536e-05
Depth+Margin_conf	7	52,6157898058776	-89,9292540303598	19,3121998501133	5,70216747909077e-05
Margin_conf+Pine_area	7	52,5234409766639	-89,7445563719325	19,4968975085406	5,19916238516216e-05
Area+Margin_conf	7	52,4165246448612	-89,530723708327	19,7107301721461	4,67197176021632e-05
Dist_bt_ponds+Margin_conf	7	52,2282405224116	-89,1541554634279	20,0872984170452	3,87016475537503e-05
Depth+Margin_veg+Pine_area	7	51,7487481605641	-88,1951707397329	21,0462831407402	2,3960096714331e-05
Depth+Dist_bt_ponds+Margin_veg	7	51,7183099202882	-88,1342942591811	21,1071596212921	2,32417811230699e-05
Area+Depth+Margin_veg	7	51,5362463589474	-87,7701671364995	21,4712867439736	1,93731484754129e-05
Margin_conf+Subst	8	52,7060905762805	-87,7180635055021	21,5233903749711	1,88749603149745e-05
Subst+Margin_veg+Pine_area	8	52,4441863866428	-87,1942551262267	22,0471987542464	1,45258816977353e-05
Area+Dist_bt_ponds+Margin_veg	7	51,1933495234772	-87,0843734655591	22,1570804149141	1,37493448079103e-05
Dist_bt_ponds+Margin_veg+Pine_area	7	51,0710867704498	-86,8398479595042	22,4016059209689	1,21670127852209e-05
Area+Margin_veg+Pine_area	7	51,0479647117123	-86,7936038420293	22,4478500384439	1,18889139001995e-05
Area+Depth+Dist_bt_ponds	7	50,9269042361293	-86,5514828908632	22,6899709896099	1,05333444288446e-05

Depth+Subst+Margin_veg	8	51,9215795029239	-86,149041358789	23,0924125216842	8,61345158670286e-06
Depth+Dist_bt_ponds+Pine_area	7	50,5729749137957	-85,843624246196	23,3978296342771	7,39361332200803e-06
Area+Dist_bt_ponds+Pine_area	7	50,4565138564244	-85,6107021314535	23,6307517490197	6,58079465044778e-06
Area+Depth+Pine_area	7	50,3959091919092	-85,489492802423	23,7519610780502	6,19381269332629e-06
Area+Subst+Pine_area	8	51,3267696607459	-84,9594216744329	24,2820322060402	4,75176095674779e-06
Depth+Subst+Pine_area	8	51,2724426686043	-84,8507676901498	24,3906861903234	4,50049902439892e-06
Depth+Margin_conf+Margin_veg	8	51,2255687272448	-84,7570198074307	24,4844340730424	4,29441071550389e-06
Dist_bt_ponds+Subst+Pine_area	8	51,1863330731067	-84,6785484991547	24,5629053813185	4,12917937813285e-06
Dist_bt_ponds+Subst+Margin_veg	8	51,0929809276398	-84,4918442082207	24,7496096722524	3,76115670339663e-06
Area+Subst+Margin_veg	8	51,0355201186209	-84,376922590183	24,8645312902901	3,55112954637439e-06
Depth+Dist_bt_ponds+Subst	8	50,9791595353847	-84,2642014237107	24,9772524567625	3,35652143911676e-06
Margin_conf+Margin_veg+Pine_area	8	50,6044808769397	-83,5148441068207	25,7266097736525	2,3076426214741e-06
Area+Margin_conf+Margin_veg	8	50,5729111731202	-83,4517046991815	25,7897491812917	2,23592897271396e-06

S10: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait relative limbs lenght (RLL) of the set of arboreal species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Depth+Dist_bt_ponds+Ins_veg+Subst	14	-94,4794062713808	222,275268238964	0	0,0984954093011877
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	15	-93,1906047022565	222,535055558359	0,259787319394974	0,0864975665623672

Subst	6	-105,346746003967	223,659009249314	1,38374101034964	0,0493106181343981
Pine_area	5	-106,508080463436	223,697979108689	1,42271086972522	0,048359104400603
Dist_bt_ponds+Subst	7	-104,271475562038	223,845276705472	1,570008466508	0,0449255065362294
Null	4	-107,729904532648	223,909247267544	1,63397902857963	0,0435112892199745
Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst	16	-92,8355466309027	224,73602832674	2,46076008777635	0,0287785378883866
Subst+Margin_veg	7	-104,808070348928	224,918466279251	2,64319804028725	0,0262695617457526
Depth+Dist_bt_ponds+Ins_veg+Subst+Pine_area	15	-94,5039605398393	225,161767233525	2,88649899456064	0,0232605884073305
Margin_veg	5	-107,48445539989	225,650728981599	3,37546074263463	0,0182156218567765
Subst+Pine_area	7	-105,191041143246	225,684407867887	3,40913962892239	0,0179114491653012
Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst+Margin_veg	17	-91,8599460025931	225,772523584134	3,49725534516946	0,0171394404782595
Area+Subst	7	-105,255408323252	225,8131422279	3,5378739889361	0,0167948609964273
Dist_bt_ponds	5	-107,605105894582	225,892029970982	3,61676173201801	0,0161453014427734

Area+Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	16	-93,4450509279525	225,95503692084	3,67976868187583	0,015644596723311
Dist_bt_ponds+Pine_area	6	-106,520734010394	226,006985262168	3,73171702320406	0,0152434732740064
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	16	-93,4791698890036	226,023274842942	3,74800660397807	0,0151198226173163
Area+Depth+Dist_bt_ponds+Ins_veg+Subst	15	-95,0390590683119	226,23196429047	3,95669605150587	0,0136216701124
Margin_veg+Pine_area	6	-106,634407636589	226,234332514557	3,95906427559237	0,0136055500746197
Area	5	-107,909069789092	226,499957760002	4,22468952103793	0,0119134162436371
Dist_bt_ponds+Subst+Margin_veg	8	-104,466717346672	226,627552340403	4,35228410143876	0,0111771094780192
Dist_bt_ponds+Subst+Pine_area	8	-104,555425750424	226,804969147906	4,52970090894192	0,0102283112337003
Depth	5	-108,089541766586	226,86090171499	4,58563347602541	0,00994622620153983
Depth+Subst	7	-105,835953366331	226,974232314058	4,69896407509418	0,00939829136868926
Margin_conf	6	-107,094856645013	227,155230531405	4,87996229244095	0,0085851055999502
Area+Pine_area	6	-107,123218701192	227,211954643763	4,93668640479859	0,0083450348946866

Area+Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	17	-92,5931854388225	227,239002456592	4,96373421762829	0,0082329371320822
Margin_conf+Subst	8	-104,859272108059	227,412661863176	5,13739362421225	0,00754823022807986
Depth+Pine_area	6	-107,24622590426	227,457969049899	5,1827008109351	0,00737915796740349
Margin_conf+Pine_area	7	-106,135019664899	227,572364911194	5,2970966722296	0,00696892935171257
Area+Dist_bt_ponds+Subst	8	-104,967315106283	227,628747859626	5,3534796206616	0,00677520842873738
Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst+Pine_area	17	-92,7963481871342	227,645327953216	5,37005971425154	0,0067192738044850
Subst+Margin_veg+Pine_area	8	-104,992900630066	227,679918907191	5,40465066822728	0,0066040599701
Depth+Dist_bt_ponds+Subst	8	-104,994876465371	227,6838705778	5,40860233883629	0,00659102431769692
Area+Subst+Margin_veg	8	-105,114790076652	227,923697800363	5,64842956139839	0,0058462191918372
Depth+Dist_bt_ponds+Ins_veg+Pine_area	13	-98,6921268492041	227,934253698408	5,65898545944412	0,00581544443021811
Area+Depth+Ins_veg+Margin_veg	13	-98,7341693479719	228,018338695944	5,74307045697958	0,00557601694585007
Dist_bt_ponds+Margin_veg	6	-107,610943554751	228,187404350882	5,91213611191785	0,00512403331133077

Margin_conf+Subst+Margin_veg	9	-104,023699179339	228,190255501535	5,91498726257075	0,00511673382009374
Dist_bt_ponds+Margin_veg+Pine_area	7	-106,489273418599	228,280872418594	6,00560417962947	0,00489007602889839
Depth+Dist_bt_ponds+Ins_veg+Margin_veg+Pine_area	14	-97,5165128127834	228,349481321769	6,07421308280516	0,0047251693407235
Depth+Subst+Margin_veg	8	-105,329861307403	228,353840261865	6,07857202290094	0,00471488219001467
Depth+Dist_bt_ponds+Ins_veg+Margin_veg	13	-98,9259399482987	228,401879896597	6,12661165763325	0,00460298088544193
Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst+Margin_veg+Pine_area	18	-91,6794006356836	228,478801271367	6,20353303240304	0,00442930826855205
Area+Depth+Dist_bt_ponds+Ins_veg+Subst+Pine_area	16	-94,7314282959956	228,527791656926	6,2525234179621	0,00432212954934001
Margin_conf+Margin_veg	7	-106,67013799768	228,642601576756	6,36733333779205	0,00408100496124591
Area+Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst	17	-93,3184045451796	228,689440669307	6,4141724303424	0,00398654015574242
Area+Margin_veg	6	-107,863182200007	228,691881641393	6,4166134024286	0,00398167760706209
Area+Depth+Ins_veg+Subst+Margin_veg	15	-96,2860043047782	228,725854763403	6,45058652443842	0,00391461380175749
Depth+Margin_veg	6	-107,885576896804	228,736671034987	6,46140279602247	0,00389350018286405

S11: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait Body mass (BM) of the set of arboreal species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Null	4	-61,7620317641671	131,973501730581	0	0,362022548014307
Margin_veg	5	-61,5199346566261	133,72168749507	1,74818576448894	0,15105040891423
Subst	6	-61,3391230138236	135,643763269027	3,67026153844512	0,057776130773852
Dist_bt_ponds	5	-62,5157039233746	135,713226028567	3,73972429798596	0,0558039328577555
Pine_area	5	-62,661704999061	136,00522817994	4,03172644935881	0,0482233465738007
Area	5	-62,7967577845053	136,275333750829	4,30183202024733	0,0421312812392827
Depth	5	-62,8531430267057	136,388104235229	4,41460250464809	0,0398214314057299
Subst+Margin_veg	7	-60,9060112746496	137,114348130694	5,14084640011305	0,0276958697938756
Margin_conf	6	-62,5201005772738	138,005718395927	6,03221666534552	0,0177360300134445
Depth+Margin_veg	6	-62,6381164346628	138,241750110705	6,26824838012351	0,0157616899207725
Margin_veg+Pine_area	6	-62,664375281451	138,294267804281	6,32076607369982	0,0153531929222763
Dist_bt_ponds+Margin_veg	6	-62,7122423525629	138,390001946505	6,41650021592375	0,0146355922774475
Area+Margin_veg	6	-62,8028576942391	138,571232629857	6,59773089927609	0,0133676959655047
Dist_bt_ponds+Subst	7	-61,7713940929812	138,845113767358	6,87161203677641	0,0116569256389803
Margin_conf+Margin_veg	7	-62,2094766711914	139,721278923778	7,74777719319678	0,00752189349353512
Area+Subst	7	-62,2765748692286	139,855475319853	7,88197358927118	0,00703374796596213
Dist_bt_ponds+Pine_area	6	-63,50136800144	139,968253244259	7,99475151367795	0,00664809761214527
Subst+Pine_area	7	-62,3428783829613	139,988082347318	8,01458061673651	0,00658251037706768
Area+Dist_bt_ponds	6	-63,5590162988584	140,083549839096	8,11004810851472	0,00627568374834237
Depth+Dist_bt_ponds	6	-63,6270032180128	140,219523677405	8,24602194682353	0,00586319996585898
Depth+Subst	7	-62,4677171615703	140,237759904536	8,2642581739546	0,00580998163681064
Area+Pine_area	6	-63,8344730333854	140,63446330815	8,66096157756874	0,00476465774866885
Depth+Pine_area	6	-63,8618742394604	140,6892657203	8,71576398971871	0,00463587286816571
Area+Depth	6	-64,0094461801566	140,984409601693	9,01090787111116	0,00399983280566581

Depth+Subst+Margin_veg	8	-61,7671225288247	141,228362704708	9,25486097412679	0,00354052850129993
Dist_bt_ponds+Subst+Margin_veg	8	-61,9253552499715	141,544828147002	9,57132641642036	0,00302237603621999
Subst+Margin_veg+Pine_area	8	-61,9270361227165	141,548189892492	9,57468816191047	0,00301730007393384
Margin_conf+Subst	8	-61,9505345467287	141,595186740516	9,62168500993485	0,0029472248307717
Depth+Dist_bt_ponds+Ins_veg+Subst	14	-54,1732223141066	141,662900324416	9,68939859383431	0,00284911152567644
Margin_conf+Pine_area	7	-63,3183592445756	141,939044070547	9,96554233996517	0,00248167895037105
Dist_bt_ponds+Margin_conf	7	-63,320518461921	141,943362505237	9,96986077465596	0,00247632624704027
Area+Subst+Margin_veg	8	-62,1510308371034	141,996179321266	10,0226775906841	0,00241178636176518
Depth+Margin_conf	7	-63,3495273895942	142,001380360584	10,0278786300024	0,00240552261195009
Depth+Dist_bt_ponds+Margin_veg	7	-63,5074456165536	142,317216814502	10,343715083921	0,00205412292274352
Area+Margin_conf	7	-63,523633765761	142,349593112917	10,376091382336	0,0020211381757012
Area+Dist_bt_ponds+Margin_veg	7	-63,7317450843562	142,765815750108	10,7923140195264	0,00164139991996804
Depth+Margin_veg+Pine_area	7	-63,7489813493607	142,800288280117	10,8267865495354	0,00161335074192348
Margin_conf+Subst+Margin_veg	9	-61,3784146535387	142,899686449935	10,9261847193531	0,00153512857161579
Dist_bt_ponds+Margin_veg+Pine_area	7	-63,8041741140387	142,910673809473	10,9371720788913	0,00152671818996318
Area+Depth+Margin_veg	7	-63,8546074452296	143,011540471854	11,0380387412731	0,00145163009230656
Depth+Dist_bt_ponds+Subst	8	-62,7305174466334	143,155152540326	11,1816508097442	0,0013510486819575
Area+Margin_veg+Pine_area	7	-63,9659220860808	143,234169753557	11,2606680229754	0,00129871132678704
Area+Dist_bt_ponds+Subst	8	-62,7910834179134	143,276284482886	11,3027827523043	0,00127164981083401
Dist_bt_ponds+Subst+Pine_area	8	-62,8893035963863	143,472724839831	11,49922310925	0,0011526860823479
Depth+Dist_bt_ponds+Ins_veg	12	-57,845271970241	143,542395792334	11,5688940617524	0,00111322306092555
Depth+Margin_conf+Subst	8	-62,9810017605496	143,656121168158	11,6826194375766	0,00105168830083457
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	15	-53,7642039384114	143,682254030669	11,7087523000875	0,00103803587642324
Margin_conf+Margin_veg+Pine_area	8	-63,2399341352619	144,173985917583	12,2004841870012	0,000811772138118082
Area+Dist_bt_ponds+Pine_area	7	-64,4616676142181	144,225660809832	12,2521590792502	0,000791066659435526
Depth+Dist_bt_ponds+Ins_veg+Margin_conf+Subst	16	-52,5948852856155	144,254705636166	12,2812039055846	0,000779661478385933

S12: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait head form (EP) of the set of aquatic-terrestrial species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Null	4	-97,938625591478	204,30278309785	0	0,178493523869007
Subst	6	-96,0233869109684	204,959817300198	0,657034202348143	0,128513662101732
Subst+Margin_veg	7	-95,7116639277116	206,654097086192	1,95131398834281	0,0550859848598688
Margin_veg	5	-98,0566250290342	206,758411348391	2,45562825054142	0,0522864991053451
Depth	5	-98,1290539041934	206,903269098709	2,60048600085989	0,0486333407462725
Pine_area	5	-98,3511703844518	207,347502059226	3,04471896137662	0,0389466530421861
Depth+Subst	7	-96,3865338285796	208,003836887928	3,70105379007882	0,0280510320544318
Subst+Pine_area	7	-96,4180882630115	208,066945756792	3,76416265894264	0,0271797168272244
Dist_bt_ponds	5	-98,7660554143995	208,177272119122	3,87448902127201	0,0257210007772163
Ins_veg+Subst	15	-86,2374118320059	208,257956194132	3,95517309628261	0,0247040147663748
Area	5	-98,8080935043251	208,261348298973	3,95856520112321	0,0246621509739678
Ins_veg	13	-89,0588922920872	208,400137525351	4,09735442750124	0,0230087621394246
Area+Depth	6	-97,9312697620821	208,775583002425	4,47279990457554	0,0190706855371639
Area+Subst	7	-97,082863868746	209,396496968261	5,09371387041156	0,0139809457468929
Dist_bt_ponds+Subst	7	-97,1009708880404	209,43271100685	5,12992790900049	0,0137300706470113
Subst+Margin_veg+Pine_area	8	-95,9472101190026	209,494420238005	5,19163714015556	0,0133129034569778
Ins_veg+Margin_veg	14	-88,3182423500774	209,636484700155	5,3337016023053	0,0124000625699625
Area+Dist_bt_ponds	6	-98,3806621527715	209,674367783804	5,3715846859543	0,0121673967471914
Margin_veg+Pine_area	6	-98,4372261309604	209,787495740182	5,48471264233217	0,011498263207737
Depth+Margin_veg	6	-98,4434977771673	209,800039032596	5,49725593474597	0,0114263758306342
Depth+Pine_area	6	-98,4979769426238	209,908997363509	5,60621426565893	0,0108205292566657

Area+Pine_area	6	-98,5537406041687	210,020524686598	5,71774158874859	0,0102336522029946
Ins_veg+Subst+Margin_veg	16	-85,8698695956226	210,373885532709	6,07110243485909	0,00857628728329641
Depth+Subst+Margin_veg	8	-96,4071444152386	210,414288830477	6,11150573262765	0,00840477043351415
Dist_bt_ponds+Pine_area	6	-98,7987625027932	210,510568483847	6,20778538599762	0,00800975061763097
Depth+Dist_bt_ponds	6	-98,8145633088172	210,542170095895	6,23938699804563	0,00788418473534035
Area+Margin_veg	6	-98,9319828088768	210,777009096014	6,4742259981648	0,00701071238949875
Depth+Subst+Pine_area	8	-96,6057567650182	210,811513530036	6,50873043218675	0,00689079941450375
Ins_veg+Subst+Pine_area	16	-86,0971001321804	210,828346605824	6,52556350797454	0,00683304612242543
Ins_veg+Pine_area	14	-88,9265601783032	210,853120356606	6,55033725875674	0,00674892808692649
Area+Depth+Subst	8	-96,6312169478152	210,86243389563	6,55965079778085	0,00671757294786271
Dist_bt_ponds+Margin_veg	6	-99,0036836342716	210,920410746804	6,61762764895457	0,00652563649278497
Area+Depth+Pine_area	7	-97,8818565341861	210,994482299141	6,69169920129187	0,00628837517806446
Area+Subst+Margin_veg	8	-96,7345818718832	211,069163743766	6,76638064591671	0,00605789267834485
Depth+Dist_bt_ponds+Subst	8	-96,8040336584051	211,20806731681	6,9052842189607	0,00565143904091361
Dist_bt_ponds+Subst+Margin_veg	8	-96,8230005067799	211,24600101356	6,94321791571022	0,00554525918522491
Area+Subst+Pine_area	8	-96,9278527699838	211,455705539968	7,15292244211807	0,00499327046384571
Area+Depth+Margin_veg	7	-98,1904825500545	211,611734330878	7,30895123302864	0,00461853106483187
Dist_bt_ponds+Subst+Pine_area	8	-97,045218736069	211,690437472138	7,38765437428847	0,00444031416831957
Area+Dist_bt_ponds+Subst	8	-97,1834884202089	211,966976840418	7,66419374256819	0,00386690887833687
Area+Ins_veg	14	-89,5555109338619	212,111021867724	7,80823876987412	0,00359819717310474
Ins_veg+Margin_veg+Pine_area	15	-88,185716321018	212,154565172157	7,85178207430695	0,00352070510180266
Area+Dist_bt_ponds+Pine_area	7	-98,4683354539569	212,167440138683	7,86465704083346	0,00349811341645193
Area+Depth+Dist_bt_ponds	7	-98,5008142167495	212,232397664268	7,92961456641868	0,00338632423448798
Depth+Ins_veg+Margin_veg	15	-88,2399384415477	212,263009413216	7,96022631536621	0,00333488822156083
Area+Dist_bt_ponds+Margin_veg	7	-98,5997109711545	212,430191173078	8,1274080752286	0,00306745516727647
Dist_bt_ponds+Ins_veg+Subst	16	-86,9425520128076	212,519250367079	8,21646726922904	0,00293385918716501
Dist_bt_ponds+Ins_veg	14	-89,774792278938	212,549584557876	8,24680146002643	0,00288969681900464
Depth+Ins_veg+Subst	16	-86,9604433920557	212,555033125575	8,25225002772515	0,0028818351781639

Depth+Ins_veg	14	-89,8822506226714	212,764501245343	8,4617181474932	0,00259527697744685

S13: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait relative eye position (EP) of the set of aquatic-terrestrial species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Null	4	-104,443900571702	217,313333058298	0	0,181743982310956
Depth	5	-103,835925298305	218,317011886933	1,00367882863495	0,110030719154064
Margin_veg	5	-104,288019574812	219,221200439947	1,90786738164931	0,0700119061424215
Subst	6	-103,28890793193	219,490859342121	1,97752628382374	0,0611809498589921
Pine_area	5	-104,751124043914	220,147409378151	2,83407631985349	0,0440603747256664
Dist_bt_ponds	5	-104,796074335165	220,237309960652	2,92397690235472	0,0421237011508214
Subst+Margin_veg	7	-102,632817507686	220,496404246142	3,18307118784421	0,0370053838766179
Depth+Subst	7	-102,893513449805	221,017796130379	3,70446307208093	0,0285132094713543
Depth+Margin_veg	6	-104,094519527005	221,102082532271	3,78874947397287	0,0273365400105238
Ins_veg	13	-95,4834549777575	221,249262896692	3,93592983839378	0,0253970769568366
Depth+Pine_area	6	-104,172722843687	221,258489165634	3,94515610733663	0,0252801866483046
Area+Depth	6	-104,45622471043	221,825492899121	4,51215984082341	0,0190395631585758
Depth+Dist_bt_ponds	6	-104,469685680341	221,852414838943	4,53908178064563	0,018784989420495
Margin_veg+Pine_area	6	-104,617940953824	222,148925385908	4,83559232761036	0,0161966242736434
Ins_veg+Margin_veg	14	-94,5811093096799	222,16221861936	4,84888556106208	0,0160893284918176
Area	5	-105,80678355124	222,258728392802	4,94539533450401	0,015331374335147
Dist_bt_ponds+Pine_area	6	-104,747881549257	222,408806576776	5,09547351847789	0,0142230266586572
Subst+Pine_area	7	-103,62600085254	222,482770935849	5,16943787755085	0,013706635619805
Dist_bt_ponds+Margin_veg	6	-104,946018985851	222,805081449964	5,49174839166585	0,0116665387715971
Ins_veg+Subst	15	-93,580925153007	222,944982836134	5,63164977783671	0,0108783450147353

Dist_bt_ponds+Subst	7	-103,929959205602	223,090687641973	5,77735458367479	0,0101140112433802
Depth+Subst+Margin_veg	8	-102,878879456021	223,357758912042	6,04442585374389	0,00884972229372748
Subst+Margin_veg+Pine_area	8	-102,914065347129	223,428130694258	6,11479763596068	0,00854375142415051
Ins_veg+Pine_area	14	-95,2367701625044	223,473540325009	6,16020726671107	0,00835195274170971
Area+Dist_bt_ponds	6	-105,308535221913	223,530113922087	6,21678086378927	0,00811901283115326
Depth+Subst+Pine_area	8	-103,142141221513	223,884282443027	6,57094938472912	0,00680137170930168
Depth+Margin_veg+Pine_area	7	-104,391266111314	224,013301453398	6,69996839509989	0,00637647099416358
Depth+Dist_bt_ponds+Pine_area	7	-104,475464561216	224,181698353202	6,86836529490435	0,00586156339350683
Area+Margin_veg	6	-105,658075258848	224,229193995956	6,91586093765824	0,00572400386734342
Depth+Dist_bt_ponds+Subst	8	-103,343967880677	224,287935761354	6,97460270305621	0,00555832972874383
Area+Depth+Pine_area	7	-104,540165536672	224,311100304112	6,99776724581463	0,00549432303240855
Area+Pine_area	6	-105,72169552621	224,356434530682	7,04310147238391	0,0053711834713607
Area+Subst	7	-104,590829690974	224,412428612717	7,09909555441956	0,00522289177792709
Ins_veg+Margin_veg+Pine_area	15	-94,3366217595347	224,45637604919	7,14304299089221	0,00510937716216494
Ins_veg+Subst+Margin_veg	16	-92,9429188658239	224,519984073111	7,20665101481342	0,00494943534696071
Ins_veg+Subst	14	-95,7796748978589	224,559349795718	7,24601673741998	0,00485296878088023
Depth+Dist_bt_ponds+Margin_veg	7	-104,68557772179	224,601924674349	7,28859161605115	0,00475075331514437
Area+Depth+Margin_veg	7	-104,70863256448	224,648034359729	7,33470130143084	0,00464247837156891
Depth+Ins_veg	14	-95,8795056619329	224,759011323866	7,44567826556809	0,00439189094434131
Area+Depth+Subst	8	-103,608636734164	224,817273468328	7,50394041003014	0,00426579600943024
Dist_bt_ponds+Subst+Margin_veg	8	-103,612937726992	224,825875453984	7,51254239568627	0,00424748825038011
Dist_bt_ponds+Margin_veg+Pine_area	7	-104,888213197297	225,007195625363	7,69386256706511	0,00387935042206973
Dist_bt_ponds+Subst+Pine_area	8	-103,832923670727	225,265847341454	7,95251428315626	0,00340873707882976
Ins_veg+Subst+Pine_area	16	-93,3338170632465	225,301780467956	7,98844740965859	0,003348040674105
Area+Depth+Dist_bt_ponds	7	-105,050448403504	225,331666037777	8,01833297947908	0,00329838355424999
Depth+Ins_veg+Margin_veg	15	-94,8257974370097	225,43472740414	8,12139434584216	0,0031327206154919
Area+Subst+Margin_veg	8	-103,930162604425	225,460325208851	8,1469921505529	0,0030928807274982

Dist_bt_ponds+Ins_veg+Margin_veg	15	-94,9191526810239	225,621437892168	8,3081048338706	0,00285350079392852
Area+Dist_bt_ponds+Pine_area	7	-105,35132147282	225,93341217641	8,62007911811187	0,0024413702196185
Depth+Subst+Margin_veg+Pine_area	9	-103,047176547115	226,116825004343	8,80349194604531	0,00222744019860712

S14: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait relative eye size (ES) of the set of aquatic-terrestrial species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Null	4	81,9404413019865	-155,455350689079	0	0,488020868435252
Depth	5	82,544345802329	-154,443530314335	1,01182037474393	0,294255365583932
Margin_veg	5	80,9902513275827	-151,335341364843	4,12000932423649	0,0621999070895932
Dist_bt_ponds	5	80,9725175170899	-151,299873743857	4,15547694522212	0,0611065887277263
Pine_area	5	80,4210894144661	-150,19701753861	5,2583331504697	0,0352051223347668
Depth+Margin_veg	6	80,5186123460174	-148,124181213774	7,3311694753053	0,0124880655279553
Depth+Pine_area	6	80,399601308581	-147,886159138901	7,56919155017815	0,0110868796207408
Depth+Dist_bt_ponds	6	79,9976317835828	-147,082220088905	8,37313060017456	0,00741713502982143
Area	5	78,8069716957721	-146,968782101222	8,4865685878577	0,00700815081772748
Area+Depth	6	79,4266003478357	-145,940157217411	9,51519347166882	0,00419025433383609
Dist_bt_ponds+Subst	6	79,1439067668512	-145,374770055442	10,0805806336377	0,0031584072044763
Margin_veg+Pine_area	6	79,1014053249241	-145,289767171587	10,1655835174921	0,00302698298631064
Dist_bt_ponds+Pine_area	6	78,968570591802	-145,024097705343	10,4312529837361	0,00265045593530562
Subst	6	78,6881667811227	-144,463290083984	10,9920606050948	0,00200236276460281
Area+Dist_bt_ponds	6	77,944497803048	-142,975952127835	12,4793985612442	0,000951856384206959
Depth+Subst	7	79,0314963691696	-142,83222350757	12,6231271815093	0,000885851966861033

Area+Margin_veg	6	77,8392118201533	-142,765380162046	12,6899705270336	0,000856734598203544
Area+Pine_area	6	77,3039798811809	-141,694916284101	13,7604344049784	0,00050164677903967
Depth+Dist_bt_ponds+Pine_area	7	78,4299943199345	-141,6292194091	13,8261312799795	0,000485436170358582
Depth+Margin_veg+Pine_area	7	78,3602579140042	-141,489746597239	13,9656040918401	0,000452737008264549
Subst+Margin_veg	7	78,2607388865639	-141,290708542359	14,1646421467207	0,00040985046503598
Depth+Dist_bt_ponds+Margin_veg	7	78,0170912358825	-140,803413240996	14,6519374480836	0,00032122593505413
Area+Depth+Pine_area	7	77,6750750404372	-140,119380850105	15,3359698389741	0,000228178570788248
Dist_bt_ponds+Subst	7	77,400366044239	-139,569962857709	15,8853878313705	0,000173368525047978
Area+Depth+Margin_veg	7	77,3753929600447	-139,52001668932	15,9353339997592	0,000169092592115125
Dist_bt_ponds+Margin_veg+Pine_area	7	77,1460072776785	-139,061245324588	16,3941053644916	0,000134432305144208
Subst+Pine_area	7	77,0776084392882	-138,924447647807	16,5309030412722	0,000125544707032582
Area+Depth+Dist_bt_ponds	7	76,9308205723047	-138,63087191384	16,8244787752392	0,000108404983314878
Area+Dist_bt_ponds+Margin_veg	7	76,0628010377222	-136,894832844675	18,5605178444042	4,55064705122167e-05
Depth+Subst+Margin_veg	8	77,244026795419	-136,888053590838	18,5672970982412	4,53524816845781e-05
Area+Dist_bt_ponds+Pine_area	7	76,0065953717085	-136,782421512648	18,6729291764316	4,30193002876519e-05
Area+Margin_veg+Pine_area	7	75,9915282957268	-136,752287360684	18,703063328395	4,23759838406877e-05
Area+Subst	7	75,7768630412757	-136,322956851782	19,1323938372971	3,4189429879945e-05
Depth+Subst+Pine_area	8	76,8808661655803	-136,161732331161	19,2936183579187	3,15415040716589e-05
Depth+Dist_bt_ponds+Subst	8	76,5789375198025	-135,557875039605	19,8974756494743	2,33214986120704e-05
Depth+Dist_bt_ponds+Margin_veg+Pine_area	8	76,4207544412297	-135,241508882459	20,2138418066199	1,99094111848296e-05
Subst+Margin_veg+Pine_area	8	76,2430070449786	-134,886014089957	20,5693365991221	1,66672405229937e-05
Area+Depth+Subst	8	75,9744977086852	-134,348995417371	21,1063552717088	1,27424101404806e-05
Dist_bt_ponds+Subst+Margin_veg	8	75,9471772401139	-134,294354480228	21,1609962088515	1,23989940296909e-05
Area+Depth+Dist_bt_ponds+Pine_area	8	75,70725422268	-133,81450844536	21,6408422437192	9,75414502316454e-06

Area+Depth+Margin_veg+Pine_area	8	75,6075360065112	-133,615072013022	21,840278676057	8,82840274859373e-06
Dist_bt_ponds+Subst+Pine_area	8	75,4299230147296	-133,259846029459	22,1955046596201	7,39172489674861e-06
Area+Subst+Margin_veg	8	75,2618135784382	-132,923627156876	22,5317235322029	6,24793919769092e-06
Area+Depth+Dist_bt_ponds+Margin_veg	8	74,9346277315171	-132,269255463034	23,1860952260451	4,50445016688421e-06
Area+Dist_bt_ponds+Subst	8	74,5712779886494	-131,542555977299	23,9127947117805	3,13213879167031e-06
Area+Subst+Pine_area	8	74,2895998630545	-130,979199726109	24,4761509629703	2,36325041427652e-06
Area+Dist_bt_ponds+Margin_veg+Pine_area	8	74,1368917429971	-130,673783485994	24,781567203085	2,0285674323171e-06
Depth+Subst+Margin_veg+Pine_area	9	75,0786271000559	-130,13478229	25,3205683990798	1,54934033120217e-06
Depth+Dist_bt_ponds+Subst+Pine_area	9	75,0361220719936	-130,049772233875	25,4055784552044	1,48486553525605e-06
Depth+Dist_bt_ponds+Subst+Margin_veg	9	74,8888919757201	-129,755312041328	25,7000386477515	1,2815805530213e-06

S15: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait relative limbs lenght (RLL) of the set of aquatic-terrestrial species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Ins_veg	13	-102,516004718636	235,314362378448	0	0,0704153179604396
Ins_veg+Margin_veg	14	-101,328712999834	235,657425999669	0,343063621220324	0,0593159958145586
Depth	5	-112,630749278964	235,90665984825	0,592297469801906	0,0523662389723981
Null	4	-114,116087693952	236,657707302797	1,34334492434826	0,0359719102116555
Ins_veg+Pine_area	14	-101,891187684314	236,782375368627	1,46801299017886	0,0337980912523965

Ins_veg+Subst	15	-100,702235637959	237,187603806038	1,87324142758928	0,027599291728048
Ins_veg+Margin_veg+Pine_area	15	-100,705512561685	237,194157653491	1,87979527504251	0,0275089989761757
Depth+Ins_veg	14	-102,134251908359	237,268503816718	1,95414143826991	0,0265051778646918
Dist_bt_ponds	5	-113,356327304467	237,357815899257	2,04345352080838	0,0253476003233839
Depth+Subst	7	-111,107377531942	237,445524294653	2,13116191620486	0,0242600233513017
Dist_bt_ponds+Ins_veg	14	-102,251563845016	237,503127690032	2,1887653115835	0,0235712598836742
Ins_veg+Subst+Margin_veg	16	-99,5338976653959	237,701941672255	2,38757929380674	0,0213408094710919
Depth+Ins_veg+Subst+Margin_veg	17	-98,0781282212975	237,711811998151	2,39744961970212	0,021235748558515
Depth+Ins_veg+Margin_veg	15	-101,026230501195	237,835593532511	2,52123115406289	0,0199612969680149
Subst	6	-112,522713353722	237,958470185705	2,64410780725623	0,0187718220911078
Margin_veg	5	-113,664947030548	237,975055351418	2,66069297296929	0,0186167988609115
Depth+Margin_veg	6	-112,554502262932	238,022048004125	2,70768562567682	0,0181844714221752
Dist_bt_ponds+Ins_veg+Margin_veg	15	-101,143142224583	238,069416979287	2,75505460083832	0,0177588418402864
Depth+Pine_area	6	-112,583171028651	238,079385535563	2,76502315711448	0,0176705470588111
Pine_area	5	-113,750249207974	238,14565970627	2,83129732782118	0,0170945920696066
Subst+Margin_veg	7	-111,555201897726	238,341173026221	3,02681064777227	0,0155025650956487
Depth+Dist_bt_ponds	6	-112,937143626765	238,78733073179	3,47296835334143	0,0124028544970101
Ins_veg+Subst+Pine_area	16	-100,080360185682	238,794866712827	3,48050433437814	0,0123562085947126

Depth+Ins_veg+Subst	16	-100,093644344921	238,821435031305	3,50707265285646	0,0121931521836709
Depth+Ins_veg+Pine_area	15	-101,556486361005	238,89610525213	3,58174287368149	0,0117463128027308
Depth+Ins_veg+Subst+Margin_veg+Pine_area	18	-97,1967850212563	238,943570042513	3,62920766406421	0,0114708265693118
Dist_bt_ponds+Ins_veg+Pine_area	15	-101,622352378984	239,027837288087	3,71347490963899	0,0109975593327832
Dist_bt_ponds+Pine_area	6	-113,076931425964	239,066906330188	3,75254395173963	0,0107848120023749
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	19	-95,8292198400366	239,27869284463	3,96433046618176	0,00970116121344219
Dist_bt_ponds+Subst	7	-112,04730013954	239,325369509848	4,01100713139982	0,00947737385581639
Depth+Subst+Margin_veg	8	-110,868743813663	239,337487627325	4,0231252488768	0,00942012350769714
Dist_bt_ponds+Ins_veg+Margin_veg+Pine_area	16	-100,359510666995	239,353167675454	4,03880529700504	0,00934655826615468
Ins_veg+Subst+Margin_veg+Pine_area	17	-98,9083800086836	239,372315572923	4,05795319447435	0,0092575017877939
Dist_bt_ponds+Ins_veg+Subst+Margin_veg	17	-98,9213303512987	239,398216258153	4,08385387970441	0,00913838692178392
Dist_bt_ponds+Margin_veg	6	-113,248302716537	239,409648911335	4,09528653288694	0,00908629793828229
Depth+Ins_veg+Margin_veg+Pine_area	16	-100,395705877499	239,425558096461	4,11119571801217	0,00901430684977523
Dist_bt_ponds+Ins_veg+Subst	16	-100,403127504347	239,440401350157	4,1260389717086	0,00894765367149047
Depth+Dist_bt_ponds+Ins_veg	15	-101,869679760771	239,522492051662	4,20812967321302	0,00858782916523702

Ins_veg+Margin_veg	7	-112,241471464004	239,713712158778	4,39934978032966	0,00780477662432284
Depth+Subst+Pine_area	8	-111,069314009118	239,738628018236	4,42426563978756	0,00770814840906639
Margin_veg+Pine_area	6	-113,431217622635	239,77547872353	4,46111634508154	0,00756742349074235
Dist_bt_ponds+Ins_veg+Subst+Margin_veg+Pine_area	18	-97,6572864321905	239,864572864381	4,55021048593244	0,00723771523411682
Depth+Dist_bt_ponds+Ins_veg+Subst+Margin_veg	18	-97,6992604317967	239,948520863593	4,63415848514495	0,00694020686414902
Depth+Dist_bt_ponds+Ins_veg+Margin_veg	16	-100,701752556025	240,037651453513	4,72328907506474	0,00663770510232234
Area+Ins_veg	14	-103,594476160177	240,188952320353	4,87458994190484	0,00615408354917242
Area+Dist_bt_ponds+Ins_veg	16	-100,778631631547	240,191409604557	4,8770472261086	0,0061465270261072
Depth+Margin_veg+Pine_area	7	-112,480598405332	240,191966041433	4,87760366298494	0,00614481718682328
Area+Depth	6	-113,681885343555	240,27681416537	4,96245178692155	0,00588958143046106
Depth+Dist_bt_ponds+Pine_area	7	-112,547795891048	240,326361012865	5,0119986344165	0,00574546878614739
Depth+Dist_bt_ponds+Subst	8	-111,386865231531	240,373730463063	5,05936808461416	0,00561098779656692

S16: Summary of adjusted models produced by GLMM analysis relating environmental predictors and the trait body mass (BM) of the set of aquatic-terrestrial species. Environmental predictors: Area; Depth; dist.bt.ponds (distance to nearest pond); Ins.veg. (types of insgiht vegetation); margin (margin configuration); margin veg. (types of margin vegetation); pine_area (Pine área in a buffer of 1000 m^2)

	df	logLik	AICc	delta	weight
Ins_veg	13	-49,7075514763673	129,697455893911	0	0,114160087303444

Depth	5	-59,6777769433583	130,000715177039	0,303259283128085	0,0980985020027851
Null	4	-60,8253181992633	130,07616831342	0,378712419509043	0,0944665239816431
Ins_veg+Margin_veg	14	-48,8499694761819	130,699938952364	1,00248305845255	0,0691556809457842
Dist_bt_ponds	5	-60,2622443628188	131,16965001596	1,4721941220491	0,0546803644452924
Ins_veg+Pine_area	14	-49,1638060697801	131,32761213956	1,63015624564909	0,0505277967271171
Pine_area	5	-60,6723049240022	131,989771138327	2,2923152444159	0,0362864399253757
Ins_veg+Margin_veg+Pine_area	15	-48,3071515084977	132,397435547116	2,69997965320479	0,029595191870025
Margin_veg	5	-60,9539158669239	132,55299302417	2,85553713025914	0,0273805572687513
Depth+Margin_veg	6	-59,8849241013324	132,682891680926	2,98543578701447	0,0256587294821981
Depth+Pine_area	6	-59,9114598767694	132,7359632318	3,03850733788852	0,0249868095835208
Dist_bt_ponds+Ins_veg	14	-49,9594981388385	132,918996277677	3,22154038376593	0,0228016190871104
Depth+Subst	7	-58,9285816947609	133,087932620291	3,39047672637977	0,0209547085881278
Depth+Ins_veg	14	-50,2001145122391	133,400229024478	3,70277313056704	0,0179253367448201
Depth+Dist_bt_ponds	6	-60,2943114019493	133,501666282159	3,80421038824829	0,017038858739734
Dist_bt_ponds+Pine_area	6	-60,3489491063147	133,61094169089	3,91348579697905	0,0161328705451508
Subst	6	-60,4270602187556	133,767163915772	4,06970802186095	0,0149206733877473
Dist_bt_ponds+Margin_veg	6	-60,4611233828217	133,835290243904	4,13783434999317	0,0144209868096671
Area+Depth	6	-60,5204180644408	133,953879607142	4,25642371323124	0,0135907563471642
Dist_bt_ponds+Ins_veg+Margin_veg	15	-49,2624338806305	134,308000291382	4,61054439747036	0,011385373885711
Ins_veg+Subst	15	-49,3863904409032	134,555913411927	4,85845751801574	0,0100580466808654
Depth+Ins_veg+Margin_veg	15	-49,3980718260237	134,579276182168	4,88182028825665	0,00994123833392125
Margin_veg+Pine_area	6	-60,8676020395282	134,648247557317	4,95079166340611	0,00960425189559953
Dist_bt_ponds+Ins_veg+Pine_area	15	-49,6196802893835	135,022493108887	5,32503721497622	0,00796520858269999
Dist_bt_ponds+Subst	7	-59,9258176452561	135,082404521281	5,38494862737033	0,00773014348273265
Depth+Ins_veg+Pine_area	15	-49,7762819649464	135,335696460013	5,63824056610221	0,00681060839649647
Depth+Margin_veg+Pine_area	7	-60,062570989917	135,355911210603	5,65845531669211	0,00674211773493378
Area+Dist_bt_ponds	6	-61,2316832088914	135,376409896044	5,67895400213246	0,00667336837929922

Depth+Dist_bt_ponds+Pine_area	7	-60,2060503818977	135,642869994565	5,94541410065344	0,00584095720040309
Depth+Subst+Margin_veg	8	-59,0379022362298	135,67580447246	5,97834857854841	0,00574556037934521
Ins_veg+Subst+Margin_veg	16	-48,5730935348823	135,780333411228	6,0828775173168	0,00545298398626558
Area	5	-62,5868693486197	135,818899987562	6,12144409365087	0,00534883987227282
Depth+Dist_bt_ponds+Ins_veg	15	-50,0318477226785	135,846827975477	6,14937208156633	0,00527466777919543
Area+Ins_veg	14	-51,4251221102451	135,85024422049	6,15278832657904	0,00526566569097175
Subst+Margin_veg	7	-60,3110025088991	135,852774248567	6,15531835465626	0,00525900876139247
Subst+Pine_area	7	-60,3482494735964	135,927268177962	6,22981228405095	0,005066729781032
Depth+Subst+Pine_area	8	-59,1919589424047	135,983917884809	6,28646199089823	0,00492522885943652
Dist_bt_ponds+Ins_veg+Margin_veg+Pine_area	16	-48,7024621842222	136,039070709908	6,34161481599665	0,00479126433641738
Area+Depth+Margin_veg	7	-60,4470381860448	136,124845602859	6,42738970894774	0,00459012328615627
Depth+Dist_bt_ponds+Margin_veg	7	-60,4629764267727	136,156722084315	6,45926619040338	0,00451754471998702
Area+Depth+Pine_area	7	-60,4642279956648	136,159225222099	6,46176932818773	0,00451189423826765
Depth+Ins_veg+Margin_veg+Pine_area	16	-48,8313539540093	136,296854249482	6,59939835557083	0,00421185243877665
Ins_veg+Subst+Pine_area	16	-48,8370968540606	136,308340049585	6,61088415567343	0,00418773351376638
Dist_bt_ponds+Margin_veg+Pine_area	7	-60,539537214064	136,309843658897	6,61238776498598	0,0041845863393899
Depth+Dist_bt_ponds+Subst	8	-59,5272839297753	136,654567859551	6,95711196563943	0,00352205897645744
Area+Ins_veg+Margin_veg	15	-50,5721087076676	136,927349945456	7,22989405154456	0,00307300131829889
Depth+Dist_bt_ponds+Ins_veg+Margin_veg	16	-49,2792823747119	137,192711090887	7,49525519697599	0,00269116487638268
Area+Depth+Dist_bt_ponds	7	-61,0132958962564	137,257361023282	7,55990512937089	0,00260556403840657
Area+Ins_veg+Pine_area	15	-50,7856471808101	137,354426891741	7,65697099782946	0,002482127955902
Dist_bt_ponds+Ins_veg+Subst	16	-49,3811710604351	137,396488462334	7,69903256842235	0,00243047194295627

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Comprovante de Submissão do Capítulo

Aquatic Sciences

TURNOVER OR INTRASPECIFIC TRAIT VARIATION: EXPLAINING FUNCTIONAL VARIABILITY IN A NEOTROPICAL ANURAN METACOMMUNITY

--Manuscript Draft--

Manuscript Number:	AQSC-D-19-00277
Full Title:	TURNOVER OR INTRASPECIFIC TRAIT VARIATION: EXPLAINING FUNCTIONAL VARIABILITY IN A NEOTROPICAL ANURAN METACOMMUNITY
Article Type:	Research Article
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Corresponding Author's Institution:	Universidade Federal do Rio Grande do Sul
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Funding Information:	Conselho Nacional de Desenvolvimento Científico e Tecnológico (163440/2015-8) — Dr. Diego Anderson Dalmolin
Abstract:	Trait variation across environmental gradients results from two processes: intraspecific variation (ITV) and turnover. Tadpoles are known to exhibit phenotypic plasticity in several traits in response to the environment, resulting from intra or interspecific variation. Here we evaluate patterns of intraspecific variation in functional traits of adult anurans (head shape, eye size and position, limb length and body mass) and their relationship with environmental variables in an anuran metacommunity in southern Brazil. From anurans sampled from 33 ponds, we decomposed trait variation into ITV and turnover and modelled trait-environment relationships. We predict that the contribution of ITV and turnover to trait variation and trait-environment relationships should vary according to the preferred habitat of the species and the analysed traits. Intraspecific variation accumulated the highest rate of trait variation for arboreal species, while interspecific variation was greater for aquatic-terrestrial species and for the whole set of species. The contributions of turnover and ITV to shifts in community mean trait values were similar between traits, but differed between species sets. Depth, distance between ponds, area of *Pinus* surrounding the ponds, and types of pond vegetation and substrate strongly influenced trait variation, but their relative contribution depended on the analysed traits and species sets. The great contribution of ITV for head shape and eye size and position suggests the existence of intraspecific adaptations to microhabitats, while turnover dominance in the variation of body mass and limb length suggests differences in dispersal and trophic segregation between species.
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CAPÍTULO 4

LIVING IN A CHANGING WORLD: EFFECTS OF ANTHROPOGENIC, ENVIRONMENTAL AND SPATIAL FACTORS ON ANURAN ASSEMBLAGE COMPOSITION IN SOUTHERN BRAZIL

CAPÍTULO 4

Living in a changing world: effects of anthropogenic, environmental and spatial factors on anuran assemblage composition in southern Brazil

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Abstract

Amphibians represent a significant part of the biomass of aquatic systems contributing to several ecosystem services in these environments. Amphibian populations are undergoing global-scale declines due to the increased incidence anthropogenic stressors. The loss of anuran species with unique evolutionary histories and functional traits poses a serious risk to the maintenance of ecosystem functions in aquatic environments already directly affected by several anthropogenic land-use changes. Here we investigate the influence of ecological variables, including anthropogenic, local environmental and spatial factors on functional, phylogenetic and taxonomic composition of anuran assemblages from a metacommunity of 33 ponds in southern Brazil. We expect the relative influence of ecological predictors to vary according to the compositional facet. We also expect stronger influence of spatial predictors on functional composition, while anthropogenic and environmental predictors should affect mostly phylogenetic and taxonomic compositions. To evaluate this we used redundancy analyses with partition variance (pRDA) for each of the compositional facets evaluated – functional, phylogenetic, and taxonomic and for each type of ecological factor – anthropogenic, local environmental and spatial. Although the sets of selected ecological predictors were similar for the three compositional facets, ecological predictors explained varying degrees of variation in functional, phylogenetic and taxonomic compositions. These varying patterns may result from different responses of species with distinct functional traits and belonging to distinct evolutionary clades. Anuran functional structure fits mostly the pattern predicted by the neutral theory of metacommunities, phylogenetic structure the species sorting paradigm, and taxonomic structuring the pattern predicted by the mass effects model. Our results suggest that the distinct metacommunity paradigms may concurrently explain different facets of anuran assemblage structuring and that the effects of different sets of ecological predictors should be considered when designing management plans for anuran assemblages of subtropical ponds.

Key-words

Aquatic ecology; freshwater ponds; functional, phylogenetic and taxonomic structure; metacommunity patterns; variation partitioning.

Introduction

The transformation of natural habitats into anthropogenic landscapes is considered one of the major threats to biodiversity in the 21st century (Bitar et al., 2014). Habitat loss and fragmentation resulting from agricultural, monoculture forestry and infrastructure expansion creates altered landscapes directly affecting the structure and functioning of ecosystems throughout the planet (Lion et al., 2014; Costa et al., 2017; Berriozabal-Islas et al., 2018). In this new era, known as the Anthropocene, attention to the effects of anthropogenic changes on all levels and dimensions of biological diversity has become indispensable (Shanafelt et al., 2018).

The conservation of species with complex life histories, such as anurans, is truly a challenge (Salice et al., 2011). Anuran life-cycle alternates between a strictly aquatic or semi-aquatic larval phase and an adult phase, when animals are able to move between aquatic and terrestrial environments. These characteristics of the anuran life-cycle make them particularly vulnerable to anthropogenic disorders. Increased levels of ultraviolet (UV) radiation (Hite et al., 2016), pollution (Rouse et al., 1999) and the introduction of exotic species (Both et al., 2014; Both and Melo, 2015) are associated with the increased incidence of pathogens and, subsequently, increased mortality rates (Lips et al., 2006), as well as decreased recruitment (Hayes et al., 2010). Consequently, population declines have been reported for several anuran species in anthropized areas (Pineda et al., 2005; Lion et al., 2014; Berriozabal-Islas et al., 2018). Some studies however, have reported an increase in anuran diversity, in environments with moderate levels of anthropogenic change (Wanger et al., 2010; Bitar et al., 2014; Pelinson et al., 2016), eventually supporting the intermediate disturbance hypothesis (Wilkinson, 1999) and demonstrating that, at least to a certain degree, anthropogenic disturbance is not always associate with biodiversity decrease (Berriozabal-Islas et al., 2018).

Many ecological models ignore the effect of anthopogenic changes in the landscape on biological communities (Schmitz, 2016; Shanafelt et al., 2018). Additionally, ecological interpretations are mostly based on taxonomic information, ignoring ecological-evolutionary relationships (Webb et al., 2002; Sobral and Cianciaruso, 2016; Arnan et al., 2017). Ignoring potential distinct responses of taxonomic, functional and phylogenetic compositions is a major shortcoming in ecological studies, as human activities may cause severe changes in composition by eliminating unique evolutionary lineages (Magurran, 2004) or functional traits (Tilman, 2001). Also, changes in functional and phylogenetic composition of communities may drastically alter ecosystem balance and the relative importance of different ecological processes (Hof et al. 2010) resulting in short-term changes in biodiversity (Alberti, 2015). Thus, the inclusion of functional and phylogenetic information, as well as taxonomic information, potentially leads to more accurate assessments of the actual conservation status of ecosystems facing anthropogenic threats (Webb et al., 2002).

In this study we investigate patterns of variation in the functional, phylogenetic and taxonomic composition of anuran metacommunities in the Lagoa do Peixe National Park (PNLP), one of the two Ramsar sites of in the southern region of Brazil. Several human activities occur within the park and also in its surroundings. Tourism is intense, particularly during the austral summer; illegal fishing is also known to occur frequently in the area; and the park has been invaded by *Pinus* in some of its areas (Machado et al., 2012), resulting from monocultures implemented and exploited in the region since the 1970's.

Here we tested the effects of potential anthropogenic stressors – roads and *Pinus* plantations – on the composition of anuran communities in PNLP. Roads and *Pinus* monocultures were selected because they reflect the main anthropogenic changes in the region's landscape and have known effects on community structure and acoustic behaviour of anurans (particularly traffic), potentially affecting the reproductive patterns of species of the group (e.g.Saccol et al., 2017; Caorsi et al., 2017). Additionally, we tested the influence of spatial and local environmental variables (e.g. area, depth, vegetation structure of the ponds sampled for anurans), known to influence diversity patterns of anuran communities (e.g. Melchior et al., 2017; Knauth et al., 2019), including in the PNLP (Dalmolin et al., 2019).

The distribution of anurans is conditioned by the adequacy of their morphological characteristics and physiological functions to environmental conditions and, especially, by their dispersion abilities, which may be limited for some groups (Semlitsch, 2008; Oliveira et al., 2016). Many of these traits are phylogenetically conserved in anurans (Lourenço-de-Moraes et al., 2019). However, functional, phylogenetic and taxonomic structures may follow distinct patterns resulting from variation in composition (Ouchi-Melo et al., 2018). We thus expected the relative influence of each variable type – anthropogenic stressor, local environmental and spatial – to vary with each compositional facet – taxonomic, functional, phylogenetic (Ouchi-Melo et al., 2018). We expected greater effects of anthropogenic variables on phylogenetic and taxonomic composition. Indeed, up to a certain level, environmental disturbance allows for the coexistence between dominant competitors and fast colonizers (Chesson and Huntly, 1997; Roxburgh et al., 2004), favoring the coexistence of a larger number of evolutionary lineages (Yuan et al., 2016). However, anthropogenic effects on functional composition may be minor. Indeed, there seems to exist a trend for functional diversity to be similar along anthropogenic modification gradients, i.e., a tendency for functional homogenization; Su et al., 2015), despite differences in the sets of functional attributes and evolutionary lineages.

Material and Methods

Ethics statement

We obtained the collecting permits from Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) (licence 55409). Our sampling did not involve any endangered or protected species. We restricted amphibian manipulation in the field to the minimum necessary (see section 2.3); specimens collected were identified to the species level, measured and immediately released after these procedures in the same pond/site where they were captured.

Study Area

Lagoa do Peixe National Park (PNLP; 31°02_-31°48_S; 50°77_-51°15_W; figure 1) comprises over 34,000 hectares of protected wetlands. PNLP has 64 km of length and 6 km of width, and integrates one of the regions of southern Brazil with higher concentration of wetlands: the coastal plain of the state of Rio Grande do Sul RAMSAR (2018). PNLP presents subtropical humid climate, and temperatures range between 13 °C and 24 °C with annual average of 17.5 °C. The mean annual precipitation varies between 1200 and 1500 mm (Maltchik et al., 2003).

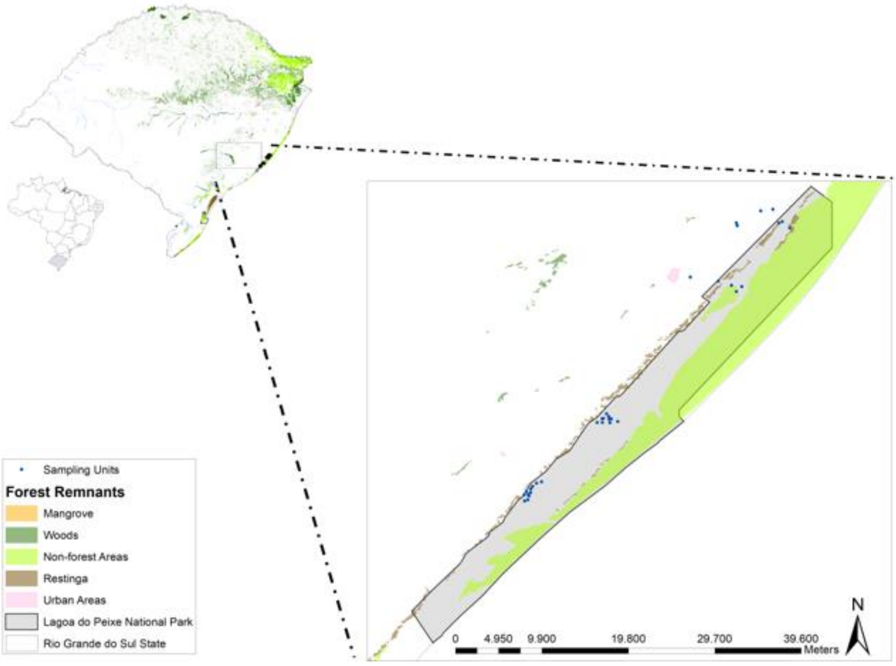

Figure 1: Study area at Lagoa do Peixe National Park, southern Brazil. Sampled ponds are represented by blue circles (N = 33).

Anuran surveys, trait measurement and phylogenetic hypothesis

From October 2016 to March 2017 we sampled adult anurans in 33 ponds throughout the study region (Fig. 1). We selected ponds according their biotic and abiotic characteristics (see Table S2), spatial independence, accessibility and landowner permission. Distances between ponds ranged from 0.7 to 39 km. We recorded the number of calling males of each species in each pond by using both calling surveys and active search at breeding sites from 6 p.m. to 0 a.m. The total effort per pond was 1 hour per month, totalling 6 hours of sampling per pond.

We measured five morphological traits for each individual captured: head shape; eye position; eye size; relative limb lenght; and body mass (see Supplementary Material Table S1 for more information). Additionally, we compiled six additional life history traits from the available literature: reproductive mode; number of eggs per reproductive event; activity period; preferred habitat type; presence/absence of fossorial habits; reproductive season. All attributes were used to build a pairwise distance matrix of specie, using the Gower standardization for mixed variables (Legendre and Legendre, 2012).

Finally, we built a phylogenetic tree by pruning the amphibian phylogeny proposed by Jetz and Pyron (2018) to include only the species found in the whole of the sampled ponds using the function *prune.sample* of the R package picante (Kembel et al., 2010). Then a matrix of phylogenetic distances between the species occurring in the ponds was built.

Anthropogenic stressors, local environmental and spatial variables

The anthropogenic and environmental descriptors evaluated and their description are presented in Table S2. The anthropogenic variables included the total area occupied by roads and pine forest within a buffer of 1 km^2 around the sampled pond, as well as the distance of each pond to the nearest road and *Pinus* plantation. These values were obtained using high-resolution aerial photographs available from Google Earth (http://earth.google.com/). The local environmental descriptors measured included area, depth and number of vegetation types around the pond (within a buffer of 5 m), margin configuration pond vegetation and substrate. Spatial variables were created using distance-based Moran's Eigenvector Maps (dbMEM). This procedure is based on the Euclidean distance matrix calculated using the geographical coordinates of each pond. We obtained the spatial eigenvectors by first defining which ponds are neighbours and which are not, and then by generating a neighbourhood matrix. We used three types of spatial neighbourhood graphs: I) 'Delaunay triangulation', II) 'Gabriel graph', and III) 'Minimum spanning trees'; as spatial weights we used the linear distances between ponds. We selected the best neighbourhood matrix based on AICc.

The most parsimonious model was the one based on the 'Gabriel graph', and the truncation distance was 18.03 km. This model generated 23 spatial variables (eigenvectors), eight of which with positive autocorrelation.

Data Analysis

Figure 2 summarizes the sequence of the analytical procedures employed.

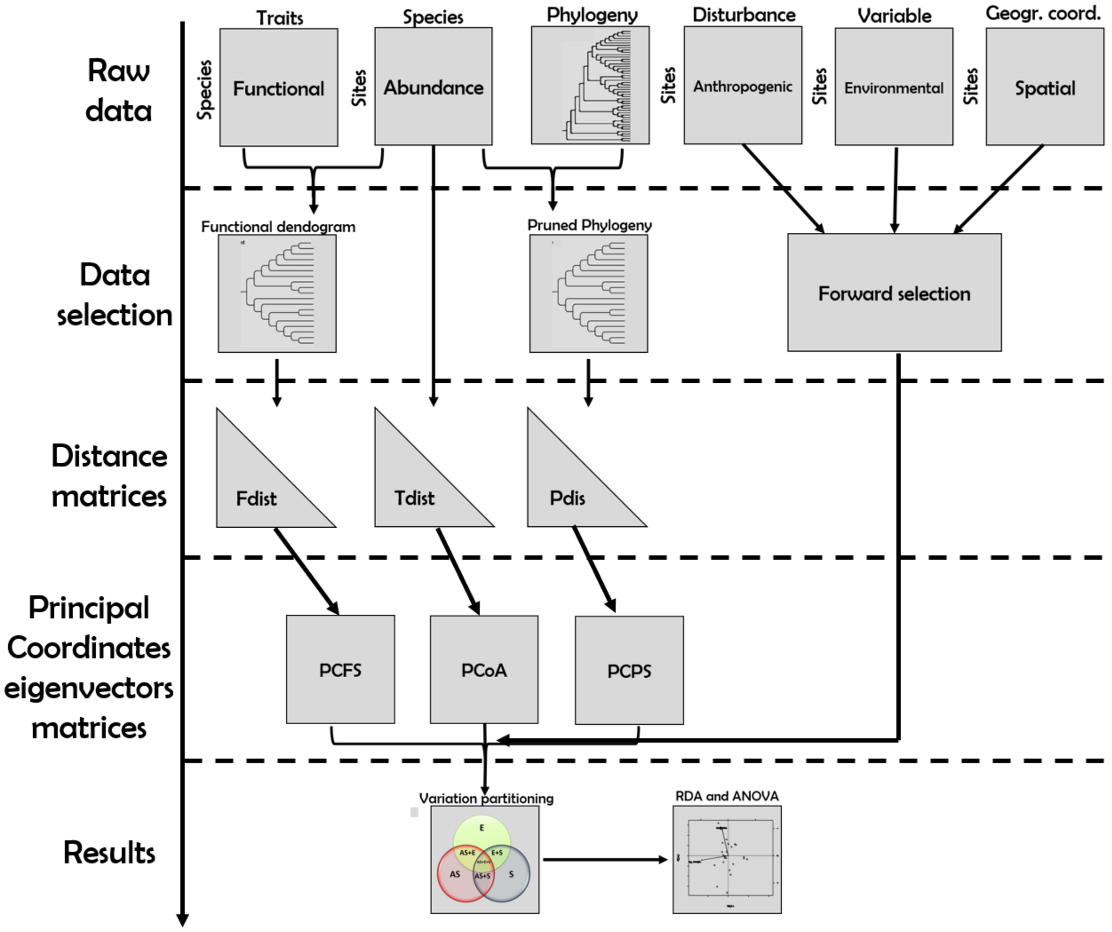

Fig. 2. A brief flow chart of the analytical approach followed. For detailed descriptions and procedures, see the main text. Abbreviations: Fdist, Pdist and Tdist represent

functional, phylogenetic and taxonomic compositional dissimilarity matrices; PCFS, PCPS and PCoA represent "eigenvectors" matrices of the principal components of functional, phylogenetic and taxonomic structure analysis, respectively.

Data matrices

Initially we created an abundance matrix containing the total species count for each pond in the month of highest recorded abundance. This procedure prevents underestimates of population abundance caused by calculating the mean of successive samples and prevents overestimates caused by the re-counting of individuals if successive samples are summed (Scott and Woodward, 1994). We used the Hellinger distance to transform the abundance data; this procedure homogenizes variation between species abundances (Legendre and Legendre, 2012). We then created a trait matrix containing the average trait values for each species in the abundance matrix. Following, we created three matrices for the predictors: (i) an anthropogenic stressor matrix, containing all anthropogenic stressors measured in each pond (area and distance to roads and pine forests); (ii) a local environmental matrix, containing all the local environmental descriptors measured in each pond; and (iii) a spatial matrix, containing all dbMEM. We standardized the values of the anthropogenic and local environmental descriptors by subtracting each value from the average of the corresponding variable and dividing the result by its standard deviation.

Anuran functional, phylogenetic and taxonomic composition

We used a principal coordinates of phylogenetic structure analysis (PCPS) to assess the relationship of all clades occurring in the ponds (Duarte 2011). This analysis results in vector ordination expressing orthogonal gradients in phylogenetic composition across communities (Duarte, 2011; Carlucci et al., 2017), thus allowing the identification of lineages that better represent different parts of anthropogenic, local environmental and spatial gradients (Duarte et al., 2014; Carlucci et al., 2017). PCPS analysis is built according to the phylogenetic distance between each pair of species recorded in the communities. Finally, the correlation between PCPS vectors and species is used to evaluate the lineage commonness across communities (Duarte, 2011; Carlucci et al., 2017). This analysis was run using the function "pcps" of PCPS package. We used this same approach for the functional composition. First, we built a functional dendogram with the information present in the abundance and the functional matrices. Then, we used the functional distance between each pair of species recorded in the communities to build the vectors of the principal coordinates of functional structure (in this case, PCFS; Pillar et al., 2009). Finally, we assessed the taxonomic composition by using principal coordinates analysis (PCoA) in the ape R package. Similar to the PCPS, the "pcoa" function takes into account a matrix of taxonomic distance between each pair of species to compute a principal coordinate decomposition (Gower, 1966).

Compositional predictors

We used a forward selection with 9999 permutations to identify and select anthropogenic, local environmental and spatial descriptors contributing most to the variation in functional, phylogenetic and taxonomic composition (Blanchet et al., 2008). In this procedure we used the matrices containing each component and the predictors. The selection stopped either when the tested variable reached a p-value below 0.05 or when the adjusted R^2 (Blanchet et al., 2008) of the full model was exceeded. The forward selection procedure was run with the "forward.sel" function from the R package vegan (Blanchet et al., 2008). The summary results of the forward selection procedure are presented in the Table S3-S5.

Variation partitioning for anuran composition

We assessed the relative contributions of the anthropogenic, local environmental and spatial variables to anuran functional, phylogenetic and taxonomic composition using partial Redundancy Analysis (pRDA) with variation partitioning (Peres-Neto et al., 2012). This analysis partitions the community composition variance resulting from each explanatory variable ([AS] = anthropogenic stressors, [E] = local environmental variables and [S] = spatial variables), (2) the unique contribution of each explanatory variable ([AS/E+S] = anthropogenic stressors - purely anthropogenic variables; [E/AS+S] = environmental - purely environmental variables – or [S/AS+E] = spatial – purely spatial variables) and (3) the total variance explained by all variables together. The variance explained by each fraction was based on the adjusted R^2 (Blanchet et al., 2008).

The significance of pRDA fractions was tested through a RDA for each fraction followed by ANOVA-like permutation test to assess the significance of the constraints, using 9999 permutations. The RDA and pRDA analyses were done using the functions “rda” and “var.part”, and the permutations using the “anova.cca” function, of the R package vegan.

Results

Anuran richness and abundance

Eleven species belonging to three families (Bufonidae, Hylidae and Leptodactylidae) were registered. The most frequent species were *Dendropsophus sanborni* and *Pseudis minuta*, occurring in 19 of the 33 ponds evaluated. *Physalaemus biligonigerus* and *Scinax fuscovarius* were less frequent occurring, respectively, in three and four of the sampled ponds (for the complete list of species and occurrence pattern in the sampled ponds see Table S6).

Predictors of compositional dimensions

Functional composition was mostly affected by the distance to roads and pond area. Phylogenetic composition was mostly influenced by distance to *Pinus* monocultures, pond area, number of types of pond vegetation and pond substrate (Table 1, Figure 3). Taxonomic composition was mostly affected by the distance to roads and to *Pinus* monocultures, as well as by the number of types of pond vegetation, pond substrate, and types of vegetation around ponds (Table 2, Figure 3). Spatial predictors significantly affected all dimensions of anuran composition (Table 3, Figure 3).

Table1: Contribution of anthropogenic variables towards anuran functional, phylogenetic and taxonomic composition from Redundancy Analysis (RDA). Analyses were run for functional, phylogenetic and taxonomic compositions. Full models and marginal tests of significance for single anthropogenic variables are shown (i.e., separate significance test for each variable in a model when all other terms are in the model)

Functional composition			Phylogenetic composition			Taxonomic composition		
R^2 *adj*:0.03; F:1.64; p= 0.04			R^2 *adj*:0.02; F:1.19; p = 0.05			R^2 *adj*:0.03; F:1.29; p =0.048		
Predictor variables	F	p	Predictor variables	F	p	Predictor variables	F	p
Distance to the nearest road	2.99	0.02	Distance to the nearest pine forest	2.42	0.03	Distance to the nearest pine forest	1.65	0.05
						Distance to the nearest road	1.63	0.05

Table 2: Contribution of local environmental variables towards anuran functional, phylogenetic and taxonomic composition from Redundancy Analysis (RDA). Analyses were run for functional, phylogenetic and taxonomic compositions. Full models and marginal tests of significance for single environmental variables are shown (i.e., separate significance test for each variable in a model when all other terms are in the model)

Functional composition			Phylogenetic composition			Taxonomic composition		
R^2 *adj* <0.01; F:1.15; p = 0.31			R^2 *adj*:0.24; F:1.74; p <0.001			R^2 *adj*:0.13; F:1.35; p = 0.016		
Predictor variables	F	p	Predictor variables	F	p	Predictor variables	F	p
Pond area	1.15	0.31	Pond area	2.05	0.02	Pond substrate	1.52	0.02

			Pond substrate	1.55	0.04	Pond vegetation	1.21	0.11
			Pond vegetation	1.74	<0.001	Veg. around the pond	1.98	0.002

Table 3: Contribution of spatial variables towards anuran functional, phylogenetic and taxonomic composition from Redundancy Analysis (RDA). Analyses were run for functional, phylogenetic and taxonomic compositions. Full models and marginal tests of significance for single spatial variables are shown (i.e., separate significance test for each variable in a model when all other terms are in the model)

Functional composition			Phylogenetic composition			Taxonomic composition		
R^2 *adj*:0.21; *F*:2.02; p <0.001			R^2 *adj*:0.08; *F*:1.67; p <0.001			R^2 *adj*:0.07; *F*:1.54; p <0.001		
Predictor variables	F	p	Predictor variables	F	p	Predictor variables	F	p
dbMEN 1	2.19	0.003	dbMEN 1	1.51	0.05	dbMEN 1	1.86	0.003
dbMEN 2	2.36	<0.001	dbMEN 5	1.83	0.01	dbMEN 5	1.44	0.05
dbMEN 7	1.93	0.01	dbMEN 11	1.66	0.02	dbMEN 7	1.32	0.16
dbMEN 12	1.32	0.23						
dbMEN 13	2.87	<0.001						
dbMEN 14	1.45	0.12						

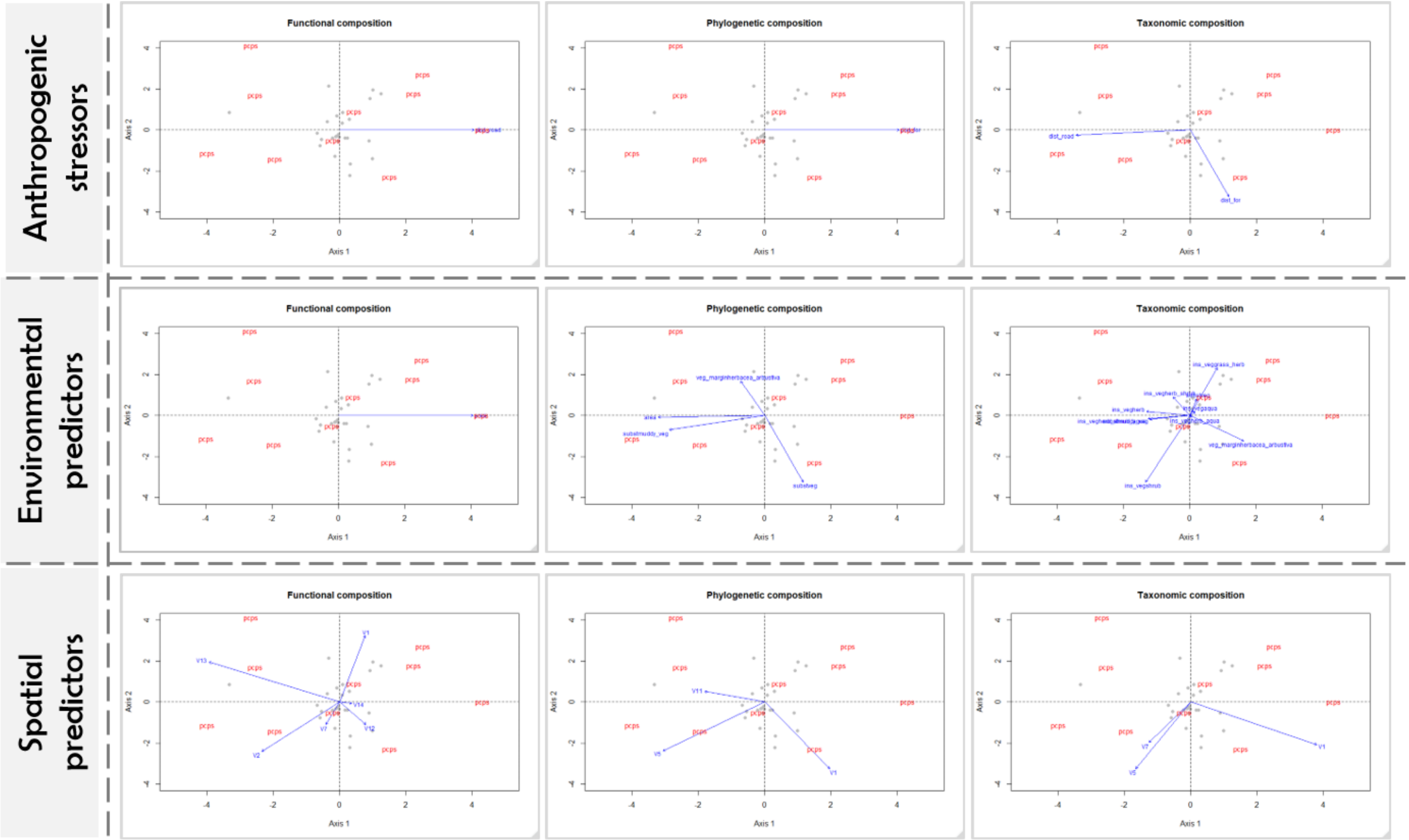

Figure 3: RDA plots based on the relationships between ecological predictors and facets of anuran composition.

Variation partitioning for functional, phylogenetic and taxonomic composition

Variation partitioning analyses identified significant effects of anthropogenic stressors, local environmental and spatial components on the structure of anuran communities (Table S7). The amount of variation explained by the models varied from 14 % for the taxonomic composition to 40% for the functional composition. Space mostly influenced functional composition (35%; Figure 4a), while phylogenetic composition was determined by both spatial and local environmental predictors (respectively, 10% and 12%; Figure 4b). The shared fractions of anthropogenic stressors + space and local environment + space were responsible for the greatest amount of explained variation of the taxonomic composition (respectively, 10% and 11%; Figure 4c). Anthropogenic stressors + space and local environment + space contributed towards a small part of the explained variation of the phylogenetic composition (Figure 4b).

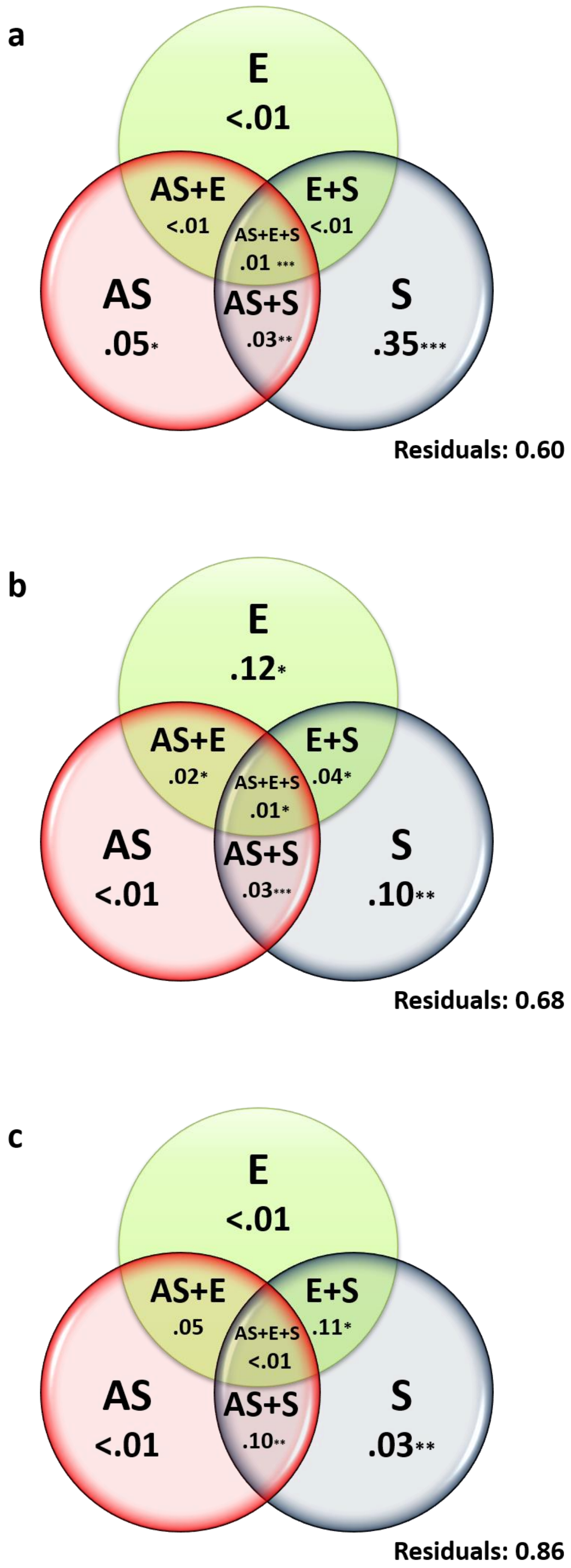
a
E
<.01
AS+E
<.01
E+S
<.01
AS+E+S
.01 ***
AS
.05*
AS+S
.03**
S
.35***
Residuals: 0.60
b
E
.12*
AS+E
.02*
E+S
.04*
AS+E+S
.01*
AS
<.01
AS+S
.03***
S
.10**
Residuals: 0.68
c
E
<.01
AS+E
.05
E+S
.11*
AS+E+S
<.01
AS
<.01
AS+S
.10**
S
.03**
Residuals: 0.86

Figure4: Variation partitioning for: (a) Functional Composition; (b) Phylogenetic Composition; (c) Taxonomic Composition; AS = anthropogenic stressors; E = environment; S = spatial component. (*) $p < 0.05$; (**) $p < 0.001$.

Discussion

The degrees of habitat modification by natural or human-induced factors lead to changes in the patterns of metacommunity structure in anurans (Salice et al., 2011; Shanafelt et al., 2018). All compositional dimensions were affected by anthropogenic, local environmental and spatial variables, although the weight of these relations varies with each composition evaluated.

The relative distance to roads promoted changes in anuran functional and taxonomic compositions. In general, anuran abundance reduces largely in response to road proximity (Marsh et al., 2017), with ponds near roads also presenting the lower values of diversity (e.g. Cosentino et al., 2014). One potential cause for these changes may be related to fluctuations in frequency and duration of anuran calls resulting from adaptions to traffic noise (Caorsi et al., 2017). As calls are part of the reproductive repertoire of anurans, such acoustic changes promoted by road traffic may reduce the reproductive success of several species.

Distance to *Pinus* monocultures affected anuran phylogenetic and taxonomic compositions. This may be related to phylogenetic homogenization in ponds near monocultures as these exotic plantations show much lower plant diversity around ponds when compared to native forests (Martínez-Jauregui, 2016), as well as a much lower number of vegetation types within the pond; indeed, several of the sampled ponds located within *Pinus* forests did not present any kind of vegetation. Exotic – *Pinus* and *Eucalyptus* – plantations alter soil characteristics through the release of toxic substances, also contributing with lower quality litter (Ferreira et al., 2015), making these areas inhospitable for anurans dependent on higher soil/water quality or the presence of vegetation for foraging or reproducing. On the other hand, anuran species with higher reproduction rates and rapidly reaching sexual maturity may be less susceptible to those road or exotic plantation effects (Grace et al., 2017) and may thrive even better in the absence of more sensitive species.

Local environmental variables affected mostly phylogenetic composition. The area and types of vegetation and substrate of the ponds explained a considerable portion of the variation in phylogenetic composition. These predictors are associated with the effects of environmental heterogeneity and area effects (Stein et al., 2014; Hill et al., 2019) and confer greater structural complexity to ponds (da Silva et al., 2012, 2011; Bitar et al., 2014). For example, ponds with larger areas may be less desiccated than smaller ones, expanding the supply of available niches and favoring the establishment of a larger number of species with unique evolutionary histories (Wellborn et al., 1996; Babbitt, 2005; Werner et al., 2007; da Silva et al., 2011). Thus, the tendency seems to be for diversity in ponds to increase progressively along the complexity gradient (Welborn et al., 1996; Werner et al., 2007; Hill et al., 2019). The presence of several different types of vegetation and substrate – even with patchy distribution – is paramount for the occurrence and resilience of anuran populations in anthropized landscapes (e.g. Berriozabal-Islas et al., 2018). These sites serve as climatic refuges (for thermoregulation) and as source of resources for foraging and reproduction, making these landscapes less inhospitable for anurans.

Space was the predictor that mostly conducted to variations in the three compositional components, corroborating with the patterns of beta diversity previously observed (Dalmolin et al., 2019). Our findings suggest that functional, phylogenetic and taxonomic compositions of anurans are still strongly spatially structured even in human-altered landscapes (Salice et al., 2011). This type of structure can emerge, mainly, as a result of the effects of dispersion (Rittenhouse et al., 2009; Provete et al., 2014; Leão-

Pires et al., 2018). Anurans have a relatively small body and short locomotor members, characteristics that affect locomotion abilities. Besides this, the rates of dislocation and survival during dispersal vary between species and lineages, as a result of variations in physiological tolerances and the morphology of the locomotor members (Rittenhouse et al., 2009; Nowakowski et al., 2017). As such, the occurrence of certain species and evolutionary lineages, but especially of functional traits, in a given pond depends on the dispersal abilities of the individuals resulting in the compositional changes detected, a pattern already observed in other anuran communities from more modified areas (Nowakowski et al., 2017; Shanafelt et al., 2018).

The results from the variation partitioning for functional, phylogenetic and taxonomic composition suggest that, in our study area, these three compositional facets of anuran assemblage structuring follow distinct and complementary paradigms of metacommunity organization. Anuran functional structure seems to better fit the neutral theory, according to which extinction, emigration and immigration rates determine the occurrence of species and functional traits in communities, but also, to a lesser extent, the patch dynamics model, where dispersion allows weaker competitors to migrate to sites where they are most likely to settle (Hubbel, 2001; Leibold et al., 2004). Anuran phylogenetic structure seems to adjust better to the pattern predicted by the species sorting paradigm where the environment selects lineages that will occur in local communities according to their ability to withstand local conditions. Phylogenetic structure, partially, as well as taxonomic structure, also fit the mass effects model, where both environmental factors and dispersal rates are key, with dispersal allowing species to occur in communities with suboptimal environmental conditions (Leibold et al., 2004).

In conclusion, we found the use of a multifaceted approach in the study of community structuring patterns to be paramount for the assessment of the relative impacts of different ecological factors on the assembly and maintenance of anuran communities in natural and human-modified landscapes (Hof et al., 2010). Neglecting one of those facets, especially when planning for ecosystem and assemblage management may put at risk the maintenance of several traits, lineages and species, all representing different aspects of biodiversity and, consequently, the integrity of several ecosystem functions. Indeed, if we have only looked at the taxonomic composition, as is rule, stochastic effects would have better explained the observed compositional patterns. However, by looking at other compositional facets we were able to show that anuran occurrence and distribution in ponds result from ecological-evolutionary relationships affected by space, the natural environment and recent human-induced changes in the landscape (Jetz & Pyron, 2018; Campos et al., 2019).

Anurans are one of the most diverse and, simultaneously, one of the most threatened vertebrate taxa in the world (Frost, 2011). The rapid transformation of natural habitats into anthropogenic landscapes is an insurmountable reality, especially in Brazil, where the area coverage of the agricultural land has almost doubled in the last two decades (Zalles et al., 2019). Here we showed that roads and exotic monocultures significantly affect anuran metacommunities, even if in combination with other environmental and spatial factors. We underline the importance of ensuring high soil and water quality within and around ponds, and of maintaining buffers of native vegetation and their connectivity in the surrounding areas, guaranteeing the existence of gradients of environmental heterogeneity in both vegetation and substrate (McKinney, 2002;; Lion et al., 2014; Berriozabal-Islas et al., 2018; Hansen et al., 2019). These measures are rather simple to implement, particularly in protected areas, as is the case of the PNLP, but should be able to increase anuran species' and assemblages' resilience, compensating for the energetic demands resulting from the physiological adjustments required to inhabit the suboptimal habitats created by anthropogenic modifications of the landscape (Morley et al., 2019; Rivera-Ordonez et al., 2019; Rubalcaba et al., 2019). These simple measures should also favor dispersal between ponds, increasing the chances of colonization of other assemblages and, consequently, promoting gene flow (Rittenhouse et al., 2009).

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Supllementary Material

Table S1 - Functional traits measured (in adults).

Functional Trait	Category	Levels
Head shape	continuous	head length / head width
Eyes position	continuous	Interorbital distance / head width
Relative length of limbs	continuous	(Length of thigh + tibia length + tarsus length + foot length) / (arm length + forearm length + hand length)
Eye size	continuous	Eye diameter / head length
Body mass	continuous	grams
Reproductive mode	categorical	From 1 to 40
Relative number of eggs	continuous	number
Daily activity period	categorical	Diurnal; nocturnal; diurnal & nocturnal
Type of habitat	categorical	Lentic; lotic; lentic & lotic
Fossorial habit	binary	Present; absent
Reproductive season	categorical	Dry; rain; dry & rain

Table S2 – Anthropogenic stressors and environmental descriptors of ponds measured between October 2016 and March 2017 at Lagoa do Peixe Nation Park, Rio Grande do Sul, Brazil.

Descriptors	**Description/levels**	**Ecological Relevance**
ANTHROPOGENIC STRESSORS		
Distance to the nearest pine forest	Distance to the nearest pine forest (m)	Both can affect the physiological control and survival of individuals
Pine forest Area	Area (m^2)	
Distance to the nearest road	Distance to the nearest pine forest (m)	Both can affect the dispersion, reproduction rates and survival of individuals
Road Areas	Area (m^2)	
ENVIRONMENTAL DESCRIPTORS		
Pond Area	Total surface area of the pond (m^2)	Both are related to the occurrence and persistence of individuals in ponds, as well as the levels of competition and/or predation, and the reproductive success of each species
Depth	Maximum depth of the pond (cm)	
Distance to the nearest forest fragment	Distance to the nearest forest fragment (m)	promote routes of dispersion and places for thermoregulation and feeding
Distance to the nearest sampled pond	Distance to the nearest other pond (m)	Ensure population persistence due to increased recolonization

		rates of ponds subject to stochastic extinctions.
Pond vegetation	Number of vegetation types inside the pond, according to the following categories their combinations: (i) absent; (ii) macrophytes; (iii) grasses; (iv) herbs; (v) shrubs; (vi) trees.	provides a greater variety of microhab- itats in both vertical and horizontal strata and thus insures that several species-specific requirements are met, promoting maintaining of a high diversity of species
Margin configuration	(i) flat border; (ii) angular border (margins with ≥15 cm higher than the surface water).	affects microclimatic conditions and foraging and reproductive success
Vegetation around the pond	Number of vegetation types around the pond, according to the following categories and their combinations:(i) grasses; (ii) herbs; (iii) shrub; (iv) trees.	
Pond substrate	Number of substrate types of the pond, according to the following categories and combinations: (i) muddly; (ii) with vegetation.	influence habitat use and foraging of tadpoles

Table S3 – Results for the forward selection of environmental variables to compose the anthropogenic model of taxonomic and functional beta diversity during the pRDA analysis.

Facet of Composition	Predictor Variable	R^2	*adjusted R^2 cumulated*	*F*	*p*

Functional	Distance to the nearest road	0.12	0.08	2.99	0.02
Phylogenetic	Distance to the nearest pine forest	0.10	0.06	2.42	0.03
Taxonomic	Distance to the nearest pine forest	0.07	0.03	1.69	0.05
	Distance to the nearest road	0.07	0.15	1.63	0.05

Table S4 – Results for the forward selection of environmental variables to compose the environmental model of functional, phylogenetic and taxonomic composition during the pRDA analysis.

Facet of Composition	Predictor Variable	*R^2*	*adjusted R^2 cumulated*	*F*	*p*
Functional	Pond Area	0.009	0.009	1.53	0.05
Phylogenetic	Pond Area	0.14	0.09	1.74	0.03
	Ins.veg	0.29	0.17	1.79	0.005
	Subst.	0.38	0.24	1.71	0.01
Taxonomic	Margim vegetation	0.09	0.07	1.98	0.005
	Subst.	0.06	0.11	1.59	0.01
	Ins.veg	0.04	0.13	1.36	0.03

Table S5 – Results for the forward selection of environmental variables to compose the spatial model of taxonomic and functional beta diversity during the pRDA analysis.

Facet of Composition	Predictor Variable	R^2	*adjusted R^2 cumulated*	*F*	*p*
Functional	MEM 12	0.11	0.07	2.79	0.03
	MEM 7	0.10	0.14	2.95	0.02
	MEM 1	0.09	0.20	2.53	0.03
	MEM 14	0.08	0.25	2.56	0.03
	MEM 13	0.08	0.31	2.63	0.02
	MEM 2	0.07	0.37	2.77	0.02
Phylogenetic	MEM 1	0.11	0.07	2.73	0.02
	MEM 11	0.10	0.13	2.68	0.02
	MEM 5	0.08	0.18	2.21	0.04
Taxonomic	MEM 1	0.10	0.06	2.53	0.01
	MEM 7	0.09	0.12	2.40	0.03
	MEM 5	0.09	0.17	2.57	0.01

Table S6 – Anuran species composition in each of the sampled ponds.

POND	*D. min.*	*D. sanb.*	*H. pul.*	*L. lat.*	*Ph. bil.*	*Ps. fal.*	*Ph. gra.*	*Pse. min.*	*R. dorb.*	*Sc. fusc.*	*Sc. squa.*
p1	0	21	0	4	0	0	0	1	0	0	0
P2	2	3	0	0	0	0	0	0	0	0	0
P3	0	0	1	2	0	0	0	0	0	1	0
p4	0	1	4	3	0	0	1	2	0	0	0
p5	9	0	0	0	0	0	0	0	0	0	0
P6	0	0	0	0	0	0	0	2	0	3	1
p7	0	20	5	0	0	0	0	0	0	0	1
p8	0	1	6	6	0	8	4	0	0	1	8
p9	0	0	1	5	0	1	4	2	0	0	0
p10	0	10	0	0	0	0	1	10	0	1	10
p11	22	12	4	6	0	0	0	0	0	0	1
p12	10	3	0	1	0	0	14	6	0	0	1

p13	0	24	7	2	0	0	34	9	1	0	2
p14	0	1	6	0	0	21	6	14	2	0	1
p16	0	23	0	1	0	0	10	1	0	0	7
p17	0	0	3	1	0	50	10	0	2	0	0
p18	0	0	0	7	0	0	0	0	1	0	0
P19	2	6	0	4	0	23	8	1	0	0	0
p20	0	0	0	0	1	0	9	0	0	0	0
p21	0	1	0	3	1	35	6	1	1	0	0
p23	0	1	0	1	0	0	2	1	0	0	0
P24	0	1	9	1	12	0	0	0	0	0	0
p25	0	7	0	2	0	1	6	0	0	0	8
p26	0	5	21	1	0	0	6	6	1	0	0
p27	0	0	4	0	0	0	0	1	0	0	0
p28	6	23	30	2	0	0	11	12	0	0	23
P29	0	0	0	0	0	14	17	53	0	0	0
p30	2	10	0	0	0	0	20	56	0	0	5
p31	0	0	0	0	0	0	0	3	0	0	0
p32	0	0	5	0	0	0	0	5	0	0	0
p33	0	0	5	0	0	0	0	0	0	0	1

Dendropsophus minutus (D. min.); *Dendropsophus sanborni* (D. sanb); *Hypsiboas pulchellus (H. pul.); Leptodactylus latrans (L. lat.); Physalaemus biligonigerus (Ph. bil.); Pseudopaludicola falcipes (Ps. fal.); Physalaemus gracilis (Ph. gra.); Pseudis minuta (Pse. min.); Rhinella dorbignyi (R. dorb.); Scinax fuscovarius (Sc. fusc.); Scinax squalirostris (Sc. squa.)*

Table S7: Variation partitioning for the facets of anuran composition based on **abundance** data. The table shows the variation explained (R^2 *adjusted*) for total taxonomic and functional beta diversity and turnover and nestedness compontens versus environment and space. AS = anthropogenic stressors; E = environment; S =

spatial component obtained from dbMEM; A+E+S = shared contribution between environment and space; AS/E+S = the unique contribution of the anthropogenic component; E/AS+S = the unique contribution of the environmental component; S/AS+E = the unique contribution of the spatial component.

Facet of Composition		**R^{2}adjusted**	***F***	***p***
Functional	AS	0.08	2.99	0.02
	E	-0.02	0.55	0.70
	S	0.37	3.34	<0.001
	AS+E+S	0.01	3.01	<0.001
	AS+E	<0.01	1.71	0.11
	AS+S	0.02	3.45	<0.001
	E+S	<0.01	2.84	0.002
	AS/E+S	0.05	2.81	0.03
	E/AS+S	-0.01	0.49	0.72
	S/AS+E	0.35	3.24	<0.001
	Residuals	0.60	-	-
Phylogenetic	AS	0.06	2.42	0.03
	E	0.18	1.52	0.04
	S	0.18	2.71	<0.001
	AS+E+S	0.02	1.71	0.01
	AS+E	0.02	1.55	0.04
	AS+S	0.03	2.43	0.003
	E+S	0.04	1.78	0.01
	AS/E+S	<0.01	1.42	0.18
	E/AS+S	0.12	1.42	0.05
	S/AS+E	0.10	2.30	0.006
	Residuals	0.68	-	-
Taxonomic	AS	0.05	1.66	0.05
	E	0.05	1.12	0.31
	S	0.18	2.67	<0.001
	AS+E+S	-0.06	1.26	0.16
	AS+E	0.05	1.26	0.15
	AS+S	0.10	2.13	0.005

	E+S	0.11	1.39	0.05
	AS/E+S	-0.03	1.52	0.17
	E/AS+S	-0.05	0.99	0.52
	S/AS+E	0.03	2.25	0.01
	Residuals	0.86	-	-

Conclusão Geral

Conclusão Geral da Tese

A compreensão da estrutura das comunidades e do efeito relativo das espécies sobre as funções ecossistêmicas é melhorada quando os estudos utilizam abordagens integradoras (multifacetadas; Srivastava et al., 2012; Arnan et al., 2017). Nossos resultados corroboraram esta ideia, visto que a utilização concomitante de diferentes facetas de diversidade permitiu uma avaliação mais precisa dos processos estruturadores nas comunidades avaliadas. Porém, observamos que as respostas das facetas de diversidade para os processos metacomunitários nem sempre foram convergentes. Em resumo, as principais interpretações que podem ser feitas a partir dos nossos achados é de que os padrões de estrutura de metacomunidades de anuros são dependentes: (i) da fase ontogênica em análise (girinos ou adultos); (ii) da faceta de diversidade utilizada; (iii) do tipo de atributos funcionais e da escala espacial de observação.

Embora tenhamos observado algum tipo de relação entre todas as facetas de diversidade analisadas com os preditores ecológicos, as diversidades funcional e filogenética foram as facetas mais associadas aos processos metacomunitários conduzidos pelos descritores aqui analisados. Através da diversidade filogenética fomos capazes de perceber que o ambiente seleciona de forma não-aleatória as espécies que se distribuem ao longo dos gradientes ecológicos (por exemplo, de profundidade das poças e complexidade estrutural dos ambientes). Mais precisamente, a diversidade filogenética nos permitiu corroborar os pressupostos de que os processos determinísticos (aqui representados por filtros ambientais) podem dominar a organização de comunidades de anuros em poças ao longo de diferentes escalas espaciais (Cavender-Bares et al., 2009), embora o espaço também se tenha demonstrado como um importante estruturados dessas metacomunidades (conforme demonstrado nos capítulos 2 e 4).

O balanço entre as variáveis ambientais e espaciais na estruturação das comunidades aqui analisadas reforça a importância que ambas têm na organização de comunidades de organismos de poças que possuem capacidades limitadas de dispersão (Soininen, 2011; Heino et al., 2015). Porém, reforçamos que esta estrutura pode, em algumas ocasiões, variar ao longo do tempo (Welborn et al., 1996). Este padrão se aplica especialmente para poças com hidroperíodo temporário ou efêmero, conforme demonstramos no primeiro capítulo desta tese, onde as poças somente foram organizadas por processos determinísticos em épocas onde as condições ambientais são menos variáveis.

A diversidade funcional se demonstrou mais associada ao espaço. Em escalas espaciais mais amplas a distribuição das espécies e atributos funcionais é, em grande parte, determinada por processos biogeográficos que envolvem especiação, extinção e dispersão (Cavender-Bares et al., 2009). Porém, este padrão pode não ser tão rígido, já que há casos em que as correlações entre o espaço e os atributos funcionais ocorrem de forma indireta em função de efeitos de variáveis ambientais sobre os atributos funcionais (Pavoine et al., 2011). Tal acontece quando variáveis ambientais são espacialmente estruturadas, conforme evidenciamos no segundo capítulo desta tese.

A abordagem funcional geralmente é baseada em conjuntos definidos de atributos funcionais. Estes conjuntos muitas vezes não representam fielmente as características envolvidas na ocupação e persistência das espécies ao longo dos gradientes ambientais podendo até mesmo ser apenas uma parte dos atributos englobados nas hipóteses filogenéticas disponíveis (Straub et al., 2016), frequentemente construídas com dados referentes a parcelas de regiões não codificantes do genoma e, assim, pouco ou nada sujeitas a seleção natural. Desta forma, relações mais robustas com os processos determinísticos poderiam ser mais facilmente detectadas pela diversidade filogenética (Safi et al., 2011). Porém, demonstramos que os atributos funcionais de anuros variam entre os níveis taxonômicos e que as respostas dos diferentes grupos de atributos para os preditores ambientais podem divergir amplamente intrapopulações. Assim, sugerimos que trabalhos futuros utilizem algum tipo de análise ou métrica de diversidade que considere a variação individual dos atributos funcionais de anuros.

Proteger simultaneamente as múltiplas facetas da diversidade facilita a manutenção das espécies e o funcionamento dos ecossistemas. Mais do que isto, nossos resultados demonstram que as interações complexas entre facetas de entidades de anfíbios anuros e os preditores ecológicos podem frequentemente ocorrer. Desta forma, a utilização da abordagem multifacetada deve ser um tópico a ser considerado em todas as esferas de pesquisa básica e aplicada, incluindo os esforços de planejamento para a conservação da anurofauna. Por fim, alertamos aos trabalhos futuros para que considerem os efeitos dos distúrbios antrópicos sobre a estrutura das metacomunidades de anuros, já que muitas comunidades estão distribuídas ao longo de paisagens amplamente modificadas.

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