UNIVERSIDADE FEDERAL DE UBERLÂNDIA

INSTITUTO DE BIOLOGIA

Programa de Pós-Graduação em Ecologia, Conservação e Biodiversidade

Biologia populacional e ecologia trófica de decápodes dulcícolas do rio Araguari, Minas Gerais

Ana Cláudia Garcia Barboza

Uberlândia – Minas Gerais

Setembro, 2024

Ana Cláudia Garcia Barboza

Biologia populacional e ecologia trófica de decápodes dulcícolas do rio Araguari, Minas Gerais

Tese apresentada à Universidade Federal de Uberlândia, como parte das exigências do Programa de Pós-Graduação em Ecologia, Conservação e Biodiversidade para a obtenção do título de doutor.

Orientador: Prof. Dr. Giuliano Buzá Jacobucci

Uberlândia – Minas Gerais

Setembro, 2024

Dados Internacionais de Catalogação na Publicação (CIP)
Sistema de Bibliotecas da UFU, MG, Brasil.

B239b
2024

Barboza, Ana Cláudia Garcia, 1973-
Biologia populacional e ecologia trófica de decápodes dulcícolas do rio Araguari, Minas Gerais [recurso eletrônico] / Ana Cláudia Garcia Barboza. - 2024.

Orientador: Giuliano Buzá Jacobucci.
Tese (Doutorado) - Universidade Federal de Uberlândia, Programa de Pós-graduação em Ecologia, Conservação e Biodiversidade.
Modo de acesso: Internet.
Disponível em: http://doi.org/10.14393/ufu.te.2024.5031
Inclui bibliografia.
Inclui ilustrações.

1. Ecologia. I. Jacobucci, Giuliano Buzá, 1969-, (Orient.). II. Universidade Federal de Uberlândia. Programa de Pós-graduação em Ecologia, Conservação e Biodiversidade. III. Título.

CDU: 574

André Carlos Francisco
Bibliotecário Documentalista - CRB-6/3408

UNIVERSIDADE FEDERAL DE UBERLÂNDIA
Coordenação do Programa de Pós-Graduação em Ecologia, Conservação e Biodiversidade
Av. Pará, 1720, Bloco 2D, Sala 26 - Bairro Umuarama, Uberlândia-MG, CEP 38405-320
Telefone: (34) 3225-8641 - www.ppgeco.ib.ufu.br - ecologia@umuarama.ufu.br

ATA DE DEFESA - PÓS-GRADUAÇÃO

Programa de Pós-Graduação em:	Ecologia, Conservação e Biodiversidade				
Defesa de:	Tese, número 95, PPGECB				
Data:	vinte e seis de setembro de dois mil e vinte e quatro	Hora de início:	08:00	Hora de encerramento:	13:20
Matrícula do Discente:	12013ECR002				
Nome do Discente:	Ana Cláudia Garcia Barboza				
Título do Trabalho:	Biologia populacional e ecologia trófica de decápodes dulcícolas do rio Araguari, Minas Gerais				
Área de concentração:	Ecologia				
Linha de pesquisa:	Ecologia de comunidades e biodiversidade				
Projeto de Pesquisa de vinculação:	Papel trófico de moluscos invasores na dieta de peixes e decápodes				

Reuniu-se por videoconferência a Banca Examinadora designada pelo Colegiado do Programa de Pós-graduação em Ecologia, Conservação e Biodiversidade assim composta pelos doutores: Sandro Santos - UFSM; Alexandre Ribeiro da Silva - IEAPM; Sergio Schwarz da Rocha - UFRB; Alan Nilo da Costa - INBIO/UFU e Giuliano Buza Jacobucci - INBIO/UFU, orientador(a) do(a) candidato(a).

Iniciando os trabalhos o(a) presidente da mesa, Dr(a). Giuliano Buza Jacobucci, apresentou a Comissão Examinadora e o(a) candidato(a), agradeceu a presença do público e concedeu ao(à) Discente a palavra para a exposição do seu trabalho. A duração da apresentação do(a) Discente e o tempo de arguição e resposta foram conforme as normas do Programa.

A seguir o(a) senhor(a) presidente concedeu a palavra, pela ordem sucessivamente, aos(às) examinadores(as) que passaram a arguir o(a) candidato(a). Ultimada a arguição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu o resultado final, considerando o(a) candidato(a):

Aprovado(a).

Esta defesa faz parte dos requisitos necessários à obtenção do título de Doutor.

O competente diploma será expedido após cumprimento dos demais requisitos, conforme as normas do Programa, a legislação pertinente e a regulamentação interna da UFU.

Nada mais havendo a tratar foram encerrados os trabalhos. Foi lavrada a presente ata que após lida e achada conforme foi assinada pela Banca Examinadora.

Documento assinado eletronicamente por **Giuliano Buza Jacobucci**, **Professor(a) do Magistério Superior**, em 26/09/2024, às 16:58, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Alan Nilo da Costa**, **Coordenador(a)**, em 26/09/2024, às 21:06, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Alexandre Ribeiro da Silva**, **Usuário Externo**, em 30/09/2024, às 10:10, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Sergio Schwarz da Rocha**, **Usuário Externo**, em 30/09/2024, às 10:46, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Sandro Santos**, **Usuário Externo**, em 30/09/2024, às 15:26, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

A autenticidade deste documento pode ser conferida no site https://www.sei.ufu.br/sei/controlador_externo.php?acao=documento_conferir&id_orgao_acesso_externo=0, informando o código verificador **5668051** e o código CRC **6DDA0A08**.

Referência: Processo nº 23117.057853/2024-97 SEI nº 5668051

Agradecimentos

É com imensa alegria e gratidão que expresso meus agradecimentos a todos que contribuíram para a realização desta tese.

Primeiramente, ao meu companheiro, Flávio Barboza, por todo o incentivo e por sua companhia nas idas ao campo. Sua presença e assistência foram essenciais em cada etapa desta jornada.

À minha mãe, Antônia, pelo apoio e encorajamento durante todo o meu percurso acadêmico. Agradeço também à minha família, que valorizou e incentivou minha busca pelo conhecimento, fornecendo o amor e a compreensão necessários para minha jornada acadêmica e pessoal.

Aos meus queridos amigos, que a cada conversa reconfortante tornaram esta jornada mais leve e colorida. Obrigada por compreenderem minhas ausências e por me mostrarem o verdadeiro significado da amizade.

Ao Prof. Giuliano, meu orientador, por ter acreditado em mim e por sua dedicação, respeito e atenção constantes desde o início. Seu suporte foi essencial para meu desenvolvimento profissional e intelectual na academia.

Gostaria de expressar minha profunda gratidão à minha colega de laboratório, a doutoranda Marina C. Calixto, cujas discussões enriquecedoras foram essenciais para oxigenar minhas ideias. Agradeço a doutoranda Barbara R. F. Cruz e aos graduandos Neilson, Bruna e Gabriela pelas valiosas contribuições nas atividades de campo e/ou laboratoriais.

Aos colegas de outros laboratórios, sou grata ao Prof. Denis C. de Oliveira pela autorização para utilizar os equipamentos do LAFIVE e às doutorandas Phabliny M. S. Bomfim e Patrícia D. Santos pela assistência nas atividades laboratoriais. Agradeço também ao doutorando Norberto E. O. Neto, especialista na identificação de algumas plantas terrestres de Cerrado, pela colaboração.

Aos moradores do “Cantinho do Piau”, no rio Araguari, especialmente ao Elias Dantas (Purga), Cláudio e Rose, por gentilmente permitirem o acesso à área de estudo através de suas propriedades e me apoiarem nesse projeto.

Minha sincera gratidão vai também para a Profa. Alessandra A. P. Bueno, da Universidade Federal de Lavras, e ao Prof. Emerson C. Mossolin, da Universidade Federal de Goiás, pelas contribuições e por compartilharem parte de seu conhecimento teórico e prático.

À Dra. Débora Reis de Carvalho, PhD em Ecologia Aplicada e Pesquisadora Associada na Lancaster University, Reino Unido, por suas orientações essenciais, esclarecimentos teóricos e orientação nas análises realizadas em meu trabalho, assim como pela generosidade em dividir seu vasto conhecimento e rigor científico.

Ao Prof. Dr. Vladimir Eliodoro Costa, do Centro de Isótopos Estáveis “Prof. Dr. Carlos Ducatti” – CIE, UNESP, Botucatu, pela parceria e colaboração.

À UFU pela estrutura oferecida, à Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) pelo apoio financeiro concedido através da bolsa [441142/2020-6], e à Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) pelo suporte financeiro [APQ-03372-21].

Finalizar meu doutorado é uma realização imensa. Espero que minha trajetória inspire outras mulheres, mostrando que a dedicação à academia e à pesquisa científica é possível em qualquer fase da vida.

A todos, meu mais sincero obrigada!

Dedico essa tese à minha família, composta por pessoas que buscam tanto a simplicidade quanto o conhecimento e que valorizam o respeito à diversidade de formas de vida, características importantes em qualquer contexto familiar ou social.

Sumário

Introdução geral

Os ecossistemas aquáticos continentais de regiões tropicais abrigam elevada diversidade, particularmente entre os invertebrados bentônicos, como insetos, anelídeos, moluscos e crustáceos (Esteves, 1988; Crowl et al., 2001; Bobeldyk & Ramírez, 2007). Dentre os crustáceos, representados principalmente por decápodes, que incluem caranguejos braquiúros, camarões carídeos, lagostins e anomuros, os dois primeiros grupos destacam-se como os mais diversificados, com altas densidades e que apresentam grande importância ecológica (Collins et al., 2007; Mancinelli et al., 2013; Magalhães et al., 2016; Emery-Butcher et al., 2020; Bauer, 2023), apesar de ainda serem relativamente pouco estudados, em comparação com suas contrapartes marinhas e estuarinas (Hamid & Wardiatno, 2018). Muitas espécies, particularmente de camarões, são anfidromas, ou seja, dependem de ambientes marinhos ou estuarinos para completarem seus ciclos de vida (Bauer, 2004). No entanto, outras espécies, denominadas hololimnéticas, que incluem braquiúros e carídeos, se desenvolvem exclusivamente em ambientes de águas continentais (Chace & Hobbs, 1969; Benstead et al., 2000).

Em ambientes de águas continentais, os caranguejos braquiúros abrangem, aproximadamente, 1.400 espécies, distribuídas em cinco famílias principais (Potamonautidae, Potamidae, Gecarcinucidae, Pseudothelphusidae e Trichodactylidae) (Yeo et al., 2008; Cumberlidge, 2016). Nas regiões neotropicais, as famílias Pseudothelphusidae e Trichodactylidae são predominantes, com destaque para Trichodactylidae, a mais abundante em rios de planície da América do Sul (Alves et al., 2024) e com 47 espécies (Cumberlidge, 2014; Magalhães et al., 2016). *Dilocarcinus pagei* Stimpson, 1861 é a espécie mais amplamente distribuída, ocorrendo no Peru, Bolívia, Paraguai, Argentina e Brasil. No Brasil, esta espécie é encontrada principalmente nas bacias dos rios Amazonas, Paraguai e Paraná (Magalhães, 2003; Herrera et al., 2013). Neste contexto, cabe ressaltar que no alto da bacia do rio Paraná *D. pagei* pode ter sido introduzido em áreas não nativas (Magalhães et al., 2005; Azevedo-Santos & Lima-Stripari, 2010; Latini et al., 2016; Garcia et al., 2021), onde demonstrou uma adaptação eficiente, resultando em um aumento considerável em sua população (Pinheiro & Taddei, 2005; Azevedo-Santos & Lima-Stripari, 2010; Davanso et al., 2013; Herrera et al., 2013; Taddei et al., 2015).

Dilocarcinus pagei possui desenvolvimento embrionário direto, no qual os juvenis eclodem dos ovos com morfologia semelhante aos adultos, o que favorece uma rápida colonização e crescimento populacional (Vogt, 2013). Além disso, esses animais são crípticos e noturnos, o que pode ajudar a evitar predadores e a sobreviver em novos habitats (Sant'Anna et al., 2014). A espécie também é capaz de construir tocas em encostas ou viver associado às raízes de macrófitas aquáticas flutuantes, como *Eichhornia crassipes* (Mart.) Solms (aguapé) (Magalhães, 2003; Sant'Anna et al., 2014; Viana et al., 2023) e *Salvinia* sp. (Barboza et al., 2023).

Em ecossistemas aquáticos, especialmente nos artificiais, as macrófitas aquáticas frequentemente ocorrem em grande abundância, criando micro-habitats que servem de abrigo e fonte de alimento para *D. pagei*, o que facilita sua sobrevivência e reprodução (Magalhães et al., 2005; Herrera et al., 2013). Nesse sentido, variações ambientais, como nos níveis de precipitação e água podem mudar a disponibilidade desses recursos alimentares e os micro-habitats (Hawkins et al., 2003; Qin et al., 2024) (Hipótese da Disponibilidade de Recursos), influenciando assim a estrutura populacional da espécie, incluindo a sazonalidade reprodutiva e a razão sexual (Davanso et al., 2013; Taddei et al., 2015; Hudson et al., 2021). Esses efeitos, semelhantes aos observados em outros crustáceos (Gomes et al., 2012; Ozga et al., 2018; da Cruz et al., 2021, 2023) são essenciais para a compreensão de sua dinâmica populacional.

As respostas de *D. pagei* às variações ambientais não apenas moldam sua distribuição, mas também influenciam seu papel nas interações tróficas dos ecossistemas aquáticos. Com características generalistas e oportunistas, *D. pagei* utiliza os recursos disponíveis, atuando como processador de matéria orgânica, predador (Williner & Collins, 2002; Sichieri et al., 2021) e presa de diversas espécies, incluindo peixes (Peixer & Petrere Jr, 2007), marsupiais (Aragon & Marinho-Filho, 2009) e aves (Olmos et al., 2006), sendo fundamental na transferência de energia entre os ambientes aquático e terrestre por ocupar diferentes níveis tróficos.

Além do seu importante papel ecológico, *D. pagei* tem demonstrado significativa relevância econômica, especialmente no cultivo aquático. Estudos experimentais, baseados na análise de diferentes densidades de cultivo, indicam que é possível otimizar tanto o crescimento quanto a viabilidade econômica de *D. pagei* (Sant'Anna et al., 2015). A finalidade principal é fornecer dados que possam auxiliar no desenvolvimento de técnicas de aquicultura dessa espécie, que é utilizada como isca na pesca esportiva, reduzindo a pressão sobre as populações naturais e oferecendo uma alternativa sustentável para pescador.

Em um outro experimento focado na preferência alimentar e no efeito de abrigos naturais no crescimento e na sobrevivência do *D. pagei*, Viana (2019) explora o potencial dessa espécie para ser cultivada como um recurso pesqueiro (como isca viva para a pesca esportiva, reabastecimento de populações naturais ou, potencialmente, para consumo humano) na região amazônica. O estudo destaca tanto o consumo de material de origem animal quanto de macrófitas, como *E. crassipes* e *Salvinia auriculata* Aubl., evidenciando uma dieta diversificada da espécie e suas implicações para o cultivo.

A espécie também é valorizada como fonte natural de astaxantina, um pigmento importante para a aquicultura de salmonídeos, devido à sua coloração marrom-avermelhada e à sua relativa estabilidade em diversas condições de processamento (Calvo et al., 2020; Pok et al., 2023). *Dilocarcinus pagei* também tem sido reportado como isca na pesca esportiva em algumas regiões do Brasil (Taddei & Herrera, 2010; Garcia et al., 2021), especialmente na captura de *Pseudoplatystoma* spp. (surubim ou pintado) e *Megaleporinus* *obtusidens* Valenciennes, 1837 (piapara) na região do Pantanal(Magalhães, 2000; Mussato et al., 2019) e *Megaleporinus macrocephalus* Garavello & Britsky, 1988 (piavuçu) no rio Araguari, Minas Gerais (observação pessoal do autor).

Os camarões carídeos, com cerca de 800 espécies dulcícolas descritas, apesar de possuírem uma diversidade de espécies menor em comparação aos caranguejos braquiúros, estão amplamente distribuídos em ecossistemas continentais ao redor do mundo, com maior prevalência em regiões tropicais (Magalhães et al., 2016). Na América do Sul, a fauna de camarões de água doce é dominada por duas famílias principais: Atyidae, com 10 espécies, e Palaemonidae, com 53 espécie (Magalhães et al., 2016). A família Palaemonidae se destaca por sua ampla distribuição em diferentes ambientes, permitindo uma variedade maior de comportamentos e interações ecológicas, como predação e competição (De Grave et al., 2008). Dentro da família Palaemonidae, o gênero *Macrobrachium* C.S. Bate, 1868 é um dos táxons mais diversos e numerosos de camarões de água doce, com cerca de 40 espécies nas águas doces tropicais e subtropicais da América do Sul (Bauer, 2023), incluindo *Macrobrachium pantanalense* Dos Santos, Hayd & Anger, 2013, uma espécie endêmica do Pantanal (Soares et al., 2017; Freitas et al., 2021).

Muitas espécies do gênero Macrobrachium possuem relevância econômica. Entre elas, *Macrobrachium rosenbergii* De Man, 1879, *Macrobrachium amazonicum* Heller, 1862, *Macrobrachium acanthurus* Wiegmann, 1836 e *Macrobrachium carcinus* são amplamente utilizadas tanto na pesca (comercial e recreativa) quanto no cultivo em ambientes controlados, incluindo para consumo humano (Gomes et al., 2012; David et al., 2021; Hooper et al., 2023). Enquanto isso, *Macrobrachium pantanalense* tem ganhado atenção no aquarismo como espécie ornamental e é reconhecido como um importante bioindicador ambiental, dada sua sensibilidade a mudanças antrópicas e seu papel nas teias tróficas de águas continentais (Freitas et al., 2021).

Em geral, a influência dos decápodes nos ecossistemas aquáticos está fortemente relacionada aos seus hábitos alimentares e à variabilidade na composição de suas dietas em diferentes locais (Collins et al., 2012). Embora sejam onívoros, exibem alta variabilidade intra e interespecífica na composição e frequência relativa dos diferentes itens em sua dieta (Albertoni et al., 2003; M. S. de Melo & Nakagaki, 2013; Sethi et al., 2013). Essa variabilidade pode ser influenciada por pressão competitiva, tanto inter quanto intraespecífica, diferenças de sexo, ciclos ontogenéticos, ciclo de ecdise, características demográficas, além de variações diárias, sazonais e anuais. (Collins et al., 2007; Viozzi et al., 2021; Gonçalves-Silva et al., 2022). Em adição, o tipo de ambiente e a disponibilidade de recursos alimentares são fatores que influenciam a adaptabilidade desses crustáceos às condições ecológicas específicas (Lavajoo et al., 2019).

No rio Araguari, localizado na bacia do alto Paraná, Sudeste do Brasil, tanto *D. pagei* quanto *M. pantanalense* coexistem em um ambiente influenciado pela construção de barragens e reservatórios. A construção de barragens, especialmente as UHE (Usina Hidrelétrica de Energia), altera intensamente o ambiente, criando um ecossistema com estrutura e biota diferentes do curso d'água original (Stanford & Ward, 2001). Essas alterações impactam a disponibilidade de recursos alimentares para os decápodes, afetando diretamente sua abundância e interações ecológicas (Baxter, 2003). Além disso, há mudanças na dinâmica hidrológica, como a transformação de ambientes lóticos em lênticos (Nilsson et al., 2005), nos processos de produção de matéria e energia, ciclagem de nutrientes, retenção de sedimentos (Rodrigues & Silva, 2012) e na distribuição da biodiversidade, tanto no espaço quanto no tempo (Havel et al., 2005; Alho, 2020), incluindo a dispersão e estabelecimento de novas espécies (Linares et al., 2017, 2020; Alho, 2020; Wang et al., 2021).

Esses impactos se manifestam claramente no rio Araguari, onde o sistema hidrográfico é caracterizado pela presença de hidrelétricas em cascata, que incluem as usinas de Nova Ponte, Miranda, Amador Aguiar I (AAI) e Amador Aguiar II (AAII), dispostas sequencialmente de montante para jusante (Loures & Pompeu, 2019). As modificações causadas por essas barragens incluíram desde o alagamento de áreas, a supressão da vegetação ripária e aquática, mudanças na dinâmica dos fluxos de água até o aumento da disponibilidade de nutrientes (Rodrigues & Silva, 2012; Santiago do Vale et al., 2021). Atualmente, nota-se também a presença de algumas espécies de moluscos invasores no rio Araguari (Maroneze et al., 2011; Linares et al., 2017; Anacléto et al., 2018).

Entre as espécies não nativas no rio Araguari estão o gastrópode *Melanoides tuberculata* Müller, 1774 e os bivalves *Corbicula fluminea* Müller, 1774 (amêijoa asiática) e *Limnoperna fortunei* Dunker, 1856 (mexilhão dourado), todos originários, principalmente, do sudeste asiático (Linares et al., 2020). O mexilhão dourado tem alto poder de incrustação em tubulações de usinas hidrelétricas, gerando impactos socioeconômicos consideráveis (Mansur et al., 2004; Darrigran et al., 2020), além dos ecológicos, como alterações na composição do substrato, na disponibilidade de nutrientes e na qualidade da água, o que, por sua vez, impacta as comunidades biológicas que dependem desses habitats (Linares et al., 2019).

Além dos impactos diretos no ambiente físico, esses moluscos invasores também podem competir por recursos, predar ou introduzir doenças as espécies nativas (Sala et al., 2000; Strayer & Dudgeon, 2010; Thomaz et al., 2014; Milardi et al., 2019). Um aspecto importante é que larvas e jovens mexilhões têm sido incorporados nas dietas de vários predadores, incluindo os decápodes (Dudgeon & Catherine, 1990; Quinn, 2020). Isso sugere que esses invasores não apenas representam uma ameaça, mas também podem criar interações ecológicas e servir como um novo recurso alimentar para os decápodes do rio Araguari.

Estudos experimentais laboratoriais têm demonstrado a importância de *L. fortunei* como recurso alimentar para diferentes espécies de caranguejos de água doce da bacia do rio Paraná. Torres et al. (2012) revelaram que tamanhos variados do mexilhão dourado foram selecionados e incorporados na dieta pelo caranguejo *Zilchiopsis collastinensis* Pretzmann, 1968. Complementando esses achados, Carvalho et al. (2013) confirmaram o mesmo para *Trichodactylus borellianus* Nobili, 1896. Em um experimento piloto conduzido por nós, utilizando aquários experimentais, foram oferecidos simultaneamente três organismos aquáticos: o molusco bivalve *Corbicula fluminea*, o mexilhão dourado *Limnoperna fortunei* e o camarão *Macrobrachium pantanalense* como parte das interações alimentares com o caranguejo *D. pagei*. Através da observação visual direta e da captura de imagens em vídeo, foi possível registrar a manipulação e ingestão de partes do mexilhão dourado e do camarão pelo caranguejo. Esses resultados, embora preliminares e não publicados, fornecem indícios sobre o comportamento alimentar do caranguejo em condições controladas (dados não publicados – observação pessoal do autor).

Apesar disso, os poucos estudos da dieta natural realizados sobre o caranguejo *D. pagei* na Argentina (Williner & Collins, 2002) e no pantanal (Viana et al., 2023), indicam uma dieta predominantemente composta por material vegetal. Em contraste, a dieta natural de *M. pantanalense* ainda não foi documentada, evidenciando uma lacuna significativa no conhecimento sobre suas interações ecológicas.

Nesse cenário, a presente pesquisa tem como objetivo explorar a biologia populacional e a ecologia trófica de *D. pagei*, bem como comparar a dieta desse braquiúro com a do carídeo *M. pantanalense* no rio Araguari, Minas Gerais, Brasil, proporcionando uma visão abrangente de suas interações e adaptabilidades em um ambiente sujeito a múltiplas pressões antropogênicas. Para isso, foram realizadas uma caracterização populacional e uma avaliação da dieta do caranguejo, considerando suas variações demográficas e sazonais, bem como a avaliação da sobreposição de nicho e das posições tróficas de ambas as espécies por meio da análise de isótopos estáveis. Esses elementos são essenciais para uma compreensão mais aprofundada de como essas espécies interagem com seu ambiente e para o desenvolvimento de estratégias de gestão sustentável em ecossistemas aquáticos impactados.

Assim, este trabalho foi dividido em três capítulos brevemente apresentados a seguir:

Capítulo 1 - Biologia populacional do caranguejo de água doce *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) no rio Araguari, sudeste do Brasil

No primeiro capítulo, nós investigamos a biologia reprodutiva de *D. pagei* em uma área do rio Araguari, bioma Cerrado. Apesar da representatividade da família Trichodactylidae, ainda existem lacunas na literatura acerca de dados básicos da espécie. Assim, nós caracterizamos a estrutura populacional, incluindo *(i)* a distribuição geral e mensal dos indivíduos por classe de tamanho, *(ii)* a razão sexual, *(iii)* recrutamento, *(iv)* aspectos reprodutivos, *(v)* a relação entre a frequência dos grupos demográficos (juvenis e adultos) e fatores ambientais (pluviosidade e nível d'água) e *(vi)* e determinamos a existência de sazonalidade em relação ao aparecimento de fêmeas ovígeras.

Capítulo 2 - Alimentação natural do caranguejo de água doce *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) na planície de inundação do rio Araguari, sudeste do Brasil

Neste capítulo, avaliamos a dieta natural do caranguejo de água doce *Dilocarcinus pagei* no Rio Araguari, Minas Gerais, Brasil. Diferentes grupos demográficos (fêmeas e machos adultos, fêmeas e machos juvenis) e sazonalidade foram considerados para prever variações na plenitude estomacal, no volume e na frequência dos alimentos consumidos.

Capítulo 3 - Diferenciação de nicho entre duas espécies de decápodes: insights a partir de isótopos estáveis de carbono e nitrogênio

Neste capítulo nós analisamos as assinaturas isotópicas estáveis (de carbono e nitrogênio) de duas espécies de decápodes (*Dilocarcinus pagei* e *Macrobrachium pantanalense*) para entender como as diferenças em suas dietas se refletem em suas composições isotópicas e o que isso revela sobre sua diferenciação de nicho e posição trófica, no rio Araguari, Minas Gerais, Brasil.

Referências

Albertoni, E. F., Palma-Silva, C., & Esteves, F. D. A. (2003). Natural diet of three species of shrimp in a tropical coastal lagoon. *Brazilian Archives of Biology and Technology*, *46*(3), 395–403. https://doi.org/10.1590/S1516-89132003000300011

Alho, C. J. R. (2020). Hydropower dams and reservoirs and their impacts on Brazil's biodiversity and natural habitats: A Review. *World Journal of Advanced Research and Reviews*, *6*(3), 205–215. https://doi.org/10.30574/WJARR.2020.6.3.0197

Alves, D. F. R., Martinez, P. A., Magalhães, C., Barros-Alves, S. de P., de Almeida, A. C., & Amado, T. F. (2024). Global patterns and predictors of primary freshwater crab richness across taxa and realms. *Hydrobiologia 2024 851:17*, *851*(17), 4149–4165. https://doi.org/10.1007/S10750-024-05572-9

Anacléto, M. J. P., Ligeiro, R., Barbosa, J. E. L., Molozzi, J., & Callisto, M. (2018). Effects of an atypical drought on the benthic macroinvertebrate community in a tropical reservoir. *Biota Neotropica*, *18*(2), e20170352. https://doi.org/10.1590/1676-0611-BN-2017-0352

Aragon, M., & Marinho-Filho, J. (2009). História natural e biologia reprodutiva de marsupiais no pantanal, Mato Grosso, Brasil. *Zoologia*, *26*(2), 220–230. https://doi.org/10.1590/S1984-46702009000200004

Azevedo-Santos, V. M., & Lima-Stripari, N. (2010). Primeiro registro de *Dilocarcinus pagei* Stimpson, 1861 (Decapoda, Trichodactylidae) no estado de Minas Gerais. *Biotemas*, *23*(2), 199–202. https://doi.org/10.5007/2175-7925.2010V23N2P199

Barboza, A. C. G., Nogueira, C. S., Calixto-Cunha, M., Londe, B. P., & Jacobucci, G. B. (2023). Population biology of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) in the Araguari River, south-eastern Brazil. *Journal of Natural History*, *57*(5–8), 427–444. https://doi.org/10.1080/00222933.2023.2190547

Bauer, R. T. (2004). *Remarkable shrimps: adaptations and natural history of the carideans*. University of Oklahoma Press.

Bauer, R. T. (2023). The Shrimps: An Overview. In *Shrimps: Their diversity, intriguing adaptations and varied lifestyles* (Vol. 42, pp. 1–17). Springer Nature. https://doi.org/10.1007/978-3-031-20966-6_1

Baxter, R. M. (2003). Environmental Effects of Dams and Impoundments. *Annual Review of Ecology and Systematics*, *8*(1), 255–283. https://doi.org/10.1146/ANNUREV.ES.08.110177.001351

Benstead, J. P., March, J. G., & Pringle, C. M. (2000). Estuarine larval development and upstream post-larval migration of freshwater shrimps in two tropical rivers of Puerto Rico. *Biotropica*, *32*(3), 545–548. https://doi.org/10.1111/j.1744-7429.2000.tb00500.x

Bobeldyk, A. M., & Ramírez, A. (2007). Leaf breakdown in a tropical headwater stream (Puerto Rico): The role of freshwater shrimps and detritivorous insects. *Journal of Freshwater Ecology*, *22*(4), 581–590. https://doi.org/10.1080/02705060.2007.9664819

Calvo, N. S., Reynoso, C. M., Resnik, S., Cortés-Jacinto, E., & Collins, P. (2020). Thermal stability of astaxanthin in oils for its use in fish food technology. *Animal Feed Science and Technology*, *270*, 114668. https://doi.org/10.1016/J.ANIFEEDSCI.2020.114668

Carvalho, D. A., Collins, P. A., & De Bonis, C. J. (2013). Predation ability of freshwater crabs: Age and prey-specific differences in *Trichodactylus borellianus* (Brachyura: Trichodactylidae). *Journal of Freshwater Ecology*, *28*(4), 573–584. https://doi.org/10.1080/02705060.2013.806273

Chace, F. A., & Hobbs, H. H. (1969). The freshwater and terrestrial decapod crustaceans of the West Indies with special reference to Dominica. *United States National Museum Bulletin*, *292*, 1–258. https://doi.org/10.5479/si.03629236.292.1

Collins, P. A., Carnevali, R. P., Carvalho, D., & Williner, V. (2012). Dynamics of decapod crustaceans in a trophic web of continental aquatic environments in Southern south America. In *Advances in environmental research* (Vol. 21, pp. 159–185).

Collins, P., Williner, V., & Giri, F. (2007). Trophic relationships in crustacean decapods of a river with a floodplain. In *Predation in Organisms: A Distinct Phenomenon* (pp. 59–86). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-46046-6_5

Crowl, T., McDowell, W., Covich, A., & Johnson, S. (2001). Freshwater shrimp effects on detrital processing and nutrients in a tropical headwater stream. *Ecology*, *82*(3), 775–783. https://doi.org/10.1890/0012-9658(2001)082[0775:FSEODP]2.0.CO;2

Cumberlidge, N. (2014). Freshwater decapod conservation: recent progress and future challenges. In *Crustaceana Monographs* (Vol. 19, pp. 53–69). Brill. https://doi.org/10.1163/9789004207615_005

Cumberlidge, N. (2016). Global diversity and conservation of freshwater crabs (Crustacea: Decapoda: Brachyura). In *A Global Overview of the Conservation of Freshwater Decapod Crustaceans* (pp. 1–22). Springer International Publishing. https://doi.org/10.1007/978-3-319-42527-6_1

da Cruz, B. R. F., Cunha, M. C., Bueno, A. A. P., & Jacobucci, G. B. (2021). Natural diet of *Macrobrachium brasiliense* (Crustacea, decapoda) in a cerrado stream. *Iheringia - Serie Zoologia*, *111*, 1–11. https://doi.org/10.1590/1678-4766e2021003 da Cruz, B. R. F., Nogueira, C. S., Bueno, A. A. P., & Jacobucci, G. B. (2023). Natural diet of the freshwater prawn *Macrobrachium amazonicum* (Heller, 1862) in the Rio Grande, southeastern Brazil. *Studies on Neotropical Fauna and Environment*. https://doi.org/10.1080/01650521.2023.2286677

da Silva, A. R., & Nogueira, C. S. (2023). From color to shape: ontogenetic shifts in traits of the freshwater crab *Dilocarcinus pagei* (Brachyura: Trichodactylidae). *Canadian Journal of Zoology*, 1–14. https://doi.org/10.1139/CJZ-2023-0039

Darrigran, G., Agudo-Padrón, I., Baez, P., Belz, C., Cardoso, F., Carranza, A., Collado, G., Correoso, M., Cuezzo, M. G., Fabres, A., Gutiérrez Gregoric, D. E., Letelier, S., Ludwig, S., Mansur, M. C., Pastorino, G., Penchaszadeh, P., Peralta, C., Rebolledo, A., Rumi, A., … Damborenea, C. (2020). Non-native mollusks throughout South America: emergent patterns in an understudied continent. *Biological Invasions*, *22*(3), 853–871. https://doi.org/10.1007/S10530-019-02178-4

Davanso, T. M., Taddei, F. G., Simões, S. M., Fransozo, A., & Da Costa, R. C. (2013). Population dynamics of the freshwater crab *Dilocarcinus pagei* in tropical waters in southeastern Brazil. *Journal of Crustacean Biology*, *33*(2), 235–243. https://doi.org/10.1163/1937240X-00002129

David, F. S., Proença, D. C., Flickinger, D. L., Wolff Bueno, G., & Valenti, W. C. (2021). Carbon budget in integrated aquaculture systems with Nile tilapia (*Oreochromis niloticus*) and Amazon river prawn (*Macrobrachium amazonicum*). *Aquaculture Research*, *52*(11), 5155–5167. https://doi.org/10.1111/are.15384

De Grave, S., Cai, Y., & Anker, A. (2008). Global diversity of shrimps (Crustacea: Decapoda: Caridea) in freshwater. *Hydrobiologia*, *595*(1), 287–293. https://doi.org/10.1007/s10750-007-9024-2

Dudgeon, D., & Catherine, C. P. S. (1990). Selection of gastropod prey by a tropical freshwater crab. *Journal of Zoology*, *220*(1), 147–155. https://doi.org/10.1111/J.1469-7998.1990.TB04299.X

Emery-Butcher, H. E., Beatty, S. J., & Robson, B. J. (2020). The impacts of invasive ecosystem engineers in freshwaters: A review. *Freshwater Biology*, *65*(5), 999–1015. https://doi.org/10.1111/FWB.13479

Esteves, F. de A. (1988). Fundamentos de Limnologia. In *Interciência* (2a. ed.). https://doi.org/10.1515/znc-1987-0514

Garcia, D. A. Z., Casimiro, A. C. R., Geller, I. V., Ferraz, J. D., Jarduli, L. R., & Orsi, M. L. (2021). Live bait trade as a pathway for the introduction of non-native species: The first record of *Dilocarcinus pagei* in the paranapanema river basin. *Oecologia Australis*, *25*(3), 775–785. https://doi.org/10.4257/oeco.2021.2503.14

Gomes, A. F. T., Mossolin, E. C., & Mantelatto, F. L. (2012). Populational and reproductive aspects of Southern *Macrobrachium acanthurus* (Wiegmann, 1836) (Crustacea: Palaemonidae), Brazil. *Brazilian Journal of Aquatic Science and Technology*, *16*(1), 9. https://doi.org/10.14210/bjast.v16n1.p9-18

Gonçalves-Silva, M., Luduvice, J. S. V., Gomes, M. V. T., Rosa, D. C. O., & Brito, M. F. G. (2022). Influence of ontogenetic stages and seasonality on the diet of the longtail knifefish *Sternopygus macrurus* (Gymnotiformes, Sternopygidae) in a large Neotropical river. *Studies on Neotropical Fauna and Environment*, *57*(1), 11–17. https://doi.org/10.1080/01650521.2020.1806007

Hamid, A., & Wardiatno, Y. (2018). Diversity of Decapod Crustaceans in Lasongko Bay, South-east Sulawesi, Indonesia. *Biodiversity Journal*, *9*(3), 303–311. https://doi.org/10.31396/Biodiv.Jour.2018.9.3.303.311

Havel, J., Lee, C., & Vander Zanden, M. J. (2005). Do reservoirs facilitate invasions into landscapes? *BioScience*, *55*(6), 518–525. https://academic.oup.com/bioscience/article-abstract/55/6/518/363697

Hawkins, B. A., Field, R., Cornell, H. V., Currie, D. J., Guégan, J. F., Kaufman, D. M., Kerr, J. T., Mittelbach, G. G., Oberdorff, T., O'Brien, E. M., Porter, E. E., & Turner, J. R. G. (2003). ENERGY, WATER, AND BROAD-SCALE GEOGRAPHIC PATTERNS OF SPECIES RICHNESS. *Ecology*, *84*(12), 3105–3117. https://doi.org/10.1890/03-8006

Herrera, D. R., Davanso, T. M., Costa, R. C., & Taddei, F. G. (2013). The relative growth and sexual maturity of the freshwater crab *Dilocarcinus pagei* (Brachyura, Trichodactylidae) in the northwestern region of the state of São Paulo. *Iheringia. Série Zoologia*, *103*(3), 232–239. https://doi.org/10.1590/s0073-47212013000300004

Hooper, C., Debnath, P. P., Stentiford, G. D., Bateman, K. S., Salin, K. R., & Bass, D. (2023). Diseases of the giant river prawn *Macrobrachium rosenbergii*: A review for a growing industry. In *Reviews in Aquaculture* (Vol. 15, Issue 2, pp. 738–758). John Wiley & Sons, Ltd. https://doi.org/10.1111/raq.12754

Hudson, D. M., Phillips, G., Lasso, C. A., & Campos, M. R. (2021). Threats to Endemic Colombian Freshwater Crabs (Decapoda: Pseudothelphusidae, Trichodactylidae) Associated with Climate Change and Human-Mediated Activities. *Recent Advances in Freshwater Crustacean Biodiversity and Conservation*, 425–444. https://doi.org/10.1201/9781003139560-14

Latini, A. O., Resende, D. C., Pombo, V. B., & Coradin, L. (2016). *Espécies Exóticas Invasoras de Águas Continentais no Brasil: Vol. Biodiversidade 39*. Ministério do Meio Ambiente.

Lavajoo, F., Biuki, N. A., Khanipour, A. A., Mirzajani, A., Fruitos, J. G., & Akbarzadeh, A. (2019). Natural diet of macrobrachium nipponense shrimp from three habitats in anzali wetland, iran. *Caspian Journal of Environmental Sciences*, *17*(2), 101–111. https://doi.org/10.22124/cjes.2019.3404

Linares, M. S., Assis, W., de Castro Solar, R. R., Leitão, R. P., Hughes, R. M., & Callisto, M. (2019). Small hydropower dam alters the taxonomic composition of benthic macroinvertebrate assemblages in a neotropical river. *River Research and Applications*, *35*(6), 725–735. https://doi.org/10.1002/RRA.3442

Linares, M. S., Callisto, M., & Marques, J. C. (2017). Invasive bivalves increase benthic communities complexity in neotropical reservoirs. *Ecological Indicators*, *75*, 279–285. https://doi.org/10.1016/j.ecolind.2016.12.046

Linares, M. S., Macedo, D. R., Massara, R. L., & Callisto, M. (2020). Why are they here? Local variables explain the distribution of invasive mollusk species in neotropical hydropower reservoirs. *Ecological Indicators*, *117*, 106674. https://doi.org/10.1016/J.ECOLIND.2020.106674

Loures, R. C., & Pompeu, P. S. (2019). Temporal changes in fish diversity in lotic and lentic environments along a reservoir cascade. *Freshwater Biology*, *64*(10), 1806–1820. https://doi.org/10.1111/FWB.13372

Magalhães, C. (2000). Diversity and Abundance of Decapod Crustaceans in the Rio Negro Basin, Pantanal, Mato Grosso Do Sul, Brasil. *Rap Bulletin of Biological Assessment*, *18*, 56–62. http://decapoda.nhm.org/pdfs/31285/31285.pdf

Magalhães, C. (2003). Famílias Pseudothelphusidae e Trichodactylidae. In *Manual de Identificação dos Crustacea Decapoda de Água doce do Brasil* (pp. 143–287). https://www.researchgate.net/profile/Gustavo-Melo-4/publication/267849392_MANUAL_DE_IDENTIFICACAO_DOS_CRUSTACEA_DECAPODA_DE_AGUA_DOCE_DO_BRASIL/links/5666f9c908ae34c89a01fd89/MANUAL-DE-IDENTIFICACAO-DOS-CRUSTACEA-DECAPODA-DE-AGUA-DOCE-DO-BRASIL.pdf

Magalhães, C., Bueno, S. L. S., Bond-Buckup, G., Valenti, W. C., Melo Da Silva, H. L., Kiyohara, F., Mossolin, E. C., & Rocha, S. S. (2005). Exotic species of freshwater decapod crustaceans in the state of São Paulo, Brazil: Records and possible causes of their introduction. *Biodiversity and Conservation*, *14*(8), 1929–1945. https://doi.org/10.1007/s10531-004-2123-8

Magalhães, C., Campos, M. R., Collins, P. A., & Mantelatto, F. L. (2016). Diversity, distribution and conservation of freshwater crabs and shrimps in South America. *A Global Overview of the Conservation of Freshwater Decapod Crustaceans*, 303–322. https://doi.org/10.1007/978-3-319-42527-6_10

Mancinelli, G., Sangiorgio, F., & Scalzo, A. (2013). The effects of decapod crustacean macroconsumers on leaf detritus processing and colonization by invertebrates in stream habitats: A meta-analysis. *International Review of Hydrobiology*, *98*(4), 206–216. https://doi.org/10.1002/iroh.201301539

Mansur, M., Callil, C., Cardoso, F., & Ibara, J. (2004). Uma retrospectiva e mapeamento da invasão de espécies de *Corbicula* (Mollusca, Bivalvia, Veneroida, Corbiculidae) oriundas do sudeste asiático, na América do Sul, Brasil. In J. SILVA & R. SOUZA (Eds.), *Água de Lastro e Bioinvasão* (pp. 39–58). Interciência.

Maroneze, D. M., Coscarelli, D., Vidigal, T. H. D. A., & Callisto, M. (2011). First record of Corbicula fluminea (Müller, 1774) in the drainage basin of the Araguari River, Minas Gerais, Brazil. *Brazilian Journal of Biology*, *71*(1), 221–222. https://doi.org/10.1590/S1519-69842011000100033

Melo, M. S. de, & Nakagaki, J. M. (2013). Evaluation of the feeding habits of *Macrobrachium brasiliense* (Heller, 1862) in the Curral de Arame stream (Dourados/Mato Grosso do Sul, Brazil). *Nauplius*, *21*(1), 25–33. https://doi.org/10.1590/s0104-64972013000100004

Milardi, M., Gavioli, A., Soininen, J., & Castaldelli, G. (2019). Exotic species invasions undermine regional functional diversity of freshwater fish. *Scientific Reports*, *9*(1), 1–10. https://doi.org/10.1038/s41598-019-54210-1

Mussato, J. H. M., Vercesi, K., & Hayd, L. (2019). Redução da mortalidade de *Dilocarcinus Pagei* durante o armazenamento in loco no Pantanal de Porto Murtinho, Brasil. *Oecologia Australis*, *23*(04), 1091–1099. https://doi.org/10.4257/oeco.2019.2304.29

Nilsson, C., Reidy, C. A., Dynesius, M., & Revenga, C. (2005). Fragmentation and flow regulation of the world's large river systems. *Science*, *308*(5720), 405–408. https://doi.org/10.1126/SCIENCE.1107887

Olmos, F., Pacheco, J. F., Luís, E., & Silveira, F. (2006). Notas sobre aves de rapina (Cathartidae, Acciptridae e Falconidae) brasileiras. *Revista Brasileira de Ornitologia*, *14*(4), 401–404.

Ozga, A. V., Castro, V. da S. de, & Castiglioni, D. da S. (2018). Population structure of two freshwater amphipods (Crustacea: Peracarida: Hyalellidae) from southern Brazil. *Nauplius*, *26*, e2018025. https://doi.org/10.1590/2358-2936E2018025

Peixer, J., & Petrere Jr, M. (2007). Hook selectivity of the Pacu *Piaractus mesopotamicus* (Holmberg, 1887) in the Pantanal, the state of Mato Grosso do Sul, Brazil. *Brazilian Journal of Biology*, *67*(2), 339–345. https://doi.org/10.1590/S1519-69842007000200021

Pinheiro, M. A. A., & Taddei, F. G. (2005). Crescimento do caranguejo de água doce, *Dilocarcinus pagei* Stimpson (Crustacea, Brachyura, Trichodactylidae). *Revista Brasileira de Zoologia*, *22*(3), 522–528. https://doi.org/10.1590/s0101-81752005000300002

Pok, P. S., Stefanini, M. I., & Calvo, N. S. (2023). Sustainable production of astaxanthin from *Dilocarcinus pagei* crab and optimisation of its extraction with edible oils. *Heliyon*, *9*(6). https://doi.org/10.1016/j.heliyon.2023.e17381

Qin, W., Sun, Y., Müller-Schärer, H., & Huang, W. (2024). Responses of non-native and native plant species to fluctuations of water availability in a greenhouse experiment. *Ecology and Evolution*, *14*(7), e11692. https://doi.org/10.1002/ECE3.11692

Quinn, B. K. (2020). Potential kleptoparasitism-scavenging interactions between crabs and shell-boring gastropods feeding on bivalve prey: a global survey. *Plankton and Benthos Research*, *15*(2), 132–145. https://doi.org/10.3800/PBR.15.132

Rodrigues, S. C., & Silva, T. I. (2012). Dam construction and loss of geodiversity in the araguari river basin, brazil. *Land Degradation and Development*, *23*(4), 419–426. https://doi.org/10.1002/ldr.2157

Sala, O. E., Chapin, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H. A., Oesterheld, M., Poff, N. L. R., Sykes, M. T., Walker, B. H., Walker, M., & Wall, D. H. (2000). Global Biodiversity Scenarios for the Year 2100. *Science*, *287*(5459), 1770–1774. https://doi.org/10.1126/SCIENCE.287.5459.1770

Sant'Anna, B. S., Takahashi, E. L. H., & Hattori, G. Y. (2015). Cultivo experimental do caranguejo de água doce *Dilocarcinus pagei*: Efeito da densidade no crescimento. *Boletim Do Instituto de Pesca*, *41*(3), 645–653. https://www.pesca.sp.gov.br/boletim/index.php/bip/article/view/41_3_645-653

Santiago do Vale, V., Raymundo, D., Afonso do Prado Júnior, J., Cristina da Silva Santos, L., Paulo Costa, J., Eugênio Alves Macedo Oliveira, P., Gabriele Vaz Souza, A., & Júnior, P. (2021). Impacts on seasonal dry forests located for several years near dams in the Araguari River Basin. *Scientia Forestalis*, *49*, 130. https://doi.org/10.18671/scifor.v49n130.25

Sethi, S., Ram, N., & Venkatesan, V. (2013). Food and feeding habits of *Macrobrachium lar* (Decapoda, Palaemonidae) from Andaman and Nicobar islands, India. *Indian Journal of Fisheries*, *60*(4), 131–135. http://eprints.cmfri.org.in/9819/

Sichieri, G., Lopes, B., Moura, P., Faciole, F., Costa, F., & Nunes, I. (2021). Predation on leptodactylid and hylid frogs by the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda, Trichodactylidae) in the Brazilian Pantanal. *Herpetology Notes*, *14*, 1133–1136. https://www.biotaxa.org/hn/article/view/68371/68184Soares, M. P., Jesus, F., Almeida, A. R., Zlabek, V., Grabic, R., Domingues, I., & Hayd, L. (2017). Endemic shrimp *Macrobrachium pantanalense* as a test species to assess potential contamination by pesticides in Pantanal (Brazil). *Chemosphere*, *168*, 1082–1092. https://doi.org/10.1016/j.chemosphere.2016.10.100

Strayer, D. L., & Dudgeon, D. (2010). Freshwater biodiversity conservation: recent progress and future challenges. *Journal of the North American Benthological Society*, *29*(1), 344–358. https://doi.org/10.1899/08-171.1

Stanford, J. A., & Ward, J. V. (2001). Revisiting the serial discontinuity concept. *Regulated Rivers: Research & Management*, *17*(4–5), 303–310. https://doi.org/10.1002/RRR.659

Taddei, F. G., Davanso, T. M., Castiglioni, L., Herrera, D. R., Fransozo, A., & Da Costa, R. C. (2015). Population structure, recruitment, and mortality of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Brachyura, trichodactylidae) in Southeastern Brazil. *Invertebrate Reproduction & Development*, *59*(4), 189–199. https://doi.org/10.1080/07924259.2015.1081638

Taddei, F., & Herrera, D. (2010). Crescimento do caranguejo *Dilocarcinus pagei* Stimpson, 1861 (Crustacea, Brachyura, Trichodactylidae) na represa Barra Mansa, Mendonça, SP. *Boletim Do Instituto de Pesca*, *36*(2), 99–110. https://www.pesca.agricultura.sp.gov.br/boletim/index.php/bip/article/view/906

Thomaz, S. M., Kovalenko, K. E., Havel, J. E., & Kats, L. B. (2014). Aquatic invasive species: general trends in the literature and introduction to the special issue. *Hydrobiologia*, *746*(1), 1–12. https://doi.org/10.1007/s10750-014-2150-8

Torres, M. V., Giri, F., & Williner, V. (2012). Size selective predation on an invasive bivalve, *Limnoperna fortunei* (Mytilidae), by a freshwater crab, *Zilchiopsis collastinensis* (Trichodactylidae). *Journal of Crustacean Biology*, *32*(5), 698–710. https://doi.org/10.1163/193724012X649444

Viana, C. R. S., Junior, E. S. O., Santos, M. F. dos, Lázaro, W. L., Lizieri, C., & Muniz, C. C. (2023). Among macrophytes and microplastics: diet of Crustacea Decapoda *Dilocarcinus pagei* (Stimpson, 1861) and *Trichodactylus petropolitanus* (Göldi, 1886) in the Pantanal region of Cáceres - MT. *Research, Society and Development*, *12*(2), e29012240148–e29012240148. https://doi.org/10.33448/RSD-V12I2.40148

Viana, M. L. P. (2019). Preferência Alimentar e o Efeito de Abrigos Naturais no Cultivo do Caranguejo Vermelho *Dilocarcinus pagei* Stimpson, 1861. *Universidade Estadual Paulista (Unesp)*, Botucatu-SP. https://tede.ufam.edu.br/handle/tede/7453

Viozzi, M. F., Cabrera, J. M., Giri, F., Carvalho, D. de A., & Williner, V. (2021). Ontogenetic shifts in natural diet, chelae, and mandibles of the omnivorous freshwater crab aegla uruguayana: Linking morphology and function. *Canadian Journal of Zoology*, *99*(8), 625–641. https://doi.org/10.1139/CJZ-2020-0290/ASSET/IMAGES/LARGE/CJZ-2020-0290CON1.JPEG

Vogt, G. (2013). Abbreviation of larval development and extension of brood care as key features of the evolution of freshwater Decapoda. *Biological Reviews*, *88*(1), 81–116. https://doi.org/10.1111/J.1469-185X.2012.00241.X

Wang, J., Chen, L., Tang, W., Heino, J., & Jiang, X. (2021). Effects of dam construction and fish invasion on the species, functional and phylogenetic diversity of fish assemblages in the Yellow River Basin. *Journal of Environmental Management*, *293*, 112863. https://doi.org/10.1016/j.jenvman.2021.112863

Williner, V., & Collins, P. A. (2002). Daily Rhythm of Feeding Activity of the Freshwater Crab *Dilocarcinus Pagei* in the Rio Pilcomayo National Park, Formosa, Argentina. In *Modern Approaches to the Study of Crustacea* (pp. 171–178). Springer US. https://doi.org/10.1007/978-1-4615-0761-1_27

Yeo, D. C. J., Ng, P. K. L., Cumberlidge, N., Magalhães, C., Daniels, S. R., & Campos, M. R. (2008). Global diversity of crabs (Crustacea: Decapoda: Brachyura) in freshwater. *Freshwater Animal Diversity Assessment*, 275–286. https://doi.org/10.1007/978-1-4020-8259-7_30

Capítulo 1

Population biology of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) in the Araguari River, south-eastern Brazil

A. C. G. Barboza[a], C. S. Nogueira[b], M. Calixto-Cunha[a], B. P. Londe[a], & G. B. Jacobucci[a]

[a]Laboratory of Ecology of Aquatic Ecosystems (LEEA), Institute of Biology, Federal University of Uberlândia (UFU), Uberlândia, Brazil; [b]Laboratory of Biology of Marine and Freshwater Shrimps (LABCAM), Department of Biological Sciences, Faculty of Sciences, São Paulo State University (UNESP), Bauru, Brazil

CONTACT A. C. G. Barboza ana.barboza1@ufu.br

Declaração de Direitos Autorais

O Capítulo 1 desta tese foi previamente publicado no periódico Journal of Natural History, conforme a seguinte referência:

Barboza, A. C. G., Nogueira, C. S., Calixto-Cunha, M., Londe, B. P., & Jacobucci, G. B. (2023). Population biology of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) in the Araguari River, south-eastern Brazil. Journal of Natural History, 57(5–8), 427–444. DOI: https://doi.org/10.1080/00222933.2023.2190547

Abstract

Dilocarcinus pagei is a freshwater crab that has a wide distribution in South America, occurring in the main river basins of Brazil. Our study analysed some aspects of the population biology of *D. pagei* in a population that occurs in the Araguari River, in south-eastern Brazil. Crabs were sampled monthly between September 2020 and November 2021. The population structure was analysed according to the organisms' size, sex and life stage. The frequency of demographic groups (adults and juveniles) over months was assessed using an environmental gradient analysis and a canonical correspondence analysis (CCA). A total of 392 crabs were collected, 282 males and 110 females. Male crabs were more abundant during most of the sampling period. Thus, the sex ratio in general and for most months was biased towards males. Gradient and CCA analyses showed seasonality in the occurrence of ovigerous females. This demographic group was more frequently sampled when the local rainfall increased. Our study provides relevant information about the population and reproductive biology of *D. pagei*, which may contribute to the understanding of the reproductive traits of freshwater crabs and the ecological role of this species in the environments it inhabits.

Keywords: Brachyura; Minas Gerais; population dynamics; reproductive biology; seasonality.

Resumo

Dilocarcinus pagei é um caranguejo de água doce que possui ampla distribuição na América do Sul, ocorrendo nas principais bacias hidrográficas do Brasil. Nosso estudo analisou alguns aspectos da biologia populacional de *D. pagei* em uma população que ocorre no rio Araguari, no sudeste do Brasil. Os caranguejos foram amostrados mensalmente entre setembro de 2020 e novembro de 2021. A estrutura populacional foi analisada de acordo com o tamanho, sexo e estágio de vida dos organismos. A frequência dos grupos demográficos (adultos e juvenis) ao longo dos meses foi avaliada utilizando uma análise de gradiente ambiental e uma análise de correspondência canónica (CCA). Foram coletados 392 caranguejos, sendo 282 machos e 110 fêmeas. Os caranguejos machos foram mais abundantes durante a maior parte do período de amostragem. Assim, a proporção entre os sexos em geral e durante a maioria dos meses foi tendenciosa em favor dos machos. As análises de gradiente e CCA mostraram sazonalidade na ocorrência de fêmeas ovígeras. Este grupo demográfico foi amostrado com mais frequência quando a precipitação local aumentou. Nosso estudo fornece informações relevantes sobre a população e a biologia reprodutiva de *D. pagei*, que podem contribuir para a compreensão das características reprodutivas dos caranguejos de água doce e do papel ecológico desta espécie nos ambientes que habita.

Palavras chaves: Brachyura; Minas Gerais; dinâmica populacional; biologia reprodutiva e sazonalidade.

Capítulo 2

Natural feeding of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) in the floodplain of the Araguari River, southeastern Brazil

Abstract

Freshwater decapods, such as the crabs in the family Trichodactylidae, are key components of benthic food webs, but research on their trophic ecology is limited. This study aimed to investigate variations in the natural diet of the freshwater crab *Dilocarcinus pagei* in the Araguari River, Brazil. We analyzed demographic groups and seasonal differences in stomach fullness, volume, and frequency of occurrence of various dietary items. Our results revealed that stomach fullness varied among demographic groups, with adult females showing lower levels and juvenile females showing higher levels. Analysis of stomach contents identified 12 types of items, including unidentified animals, detritus, sand, plastic filaments, and mollusks. Juvenile females showed a higher consumption of plant tissue, while only adult males and juveniles showed a consumption of mollusks. Plant tissue and detritus (digested material) were the most frequent items. These findings reveal the feeding habits of *D. pagei* in the sampling area, highlighting the influence of demographic groups and seasonal variations on their diet, including the consumption of plant tissue, predation on mollusks, and ingestion of microplastics.

Keywords: Brachyura; Feeding ecology; Trophic ecology; Aquatic invasions; Cerrado

Resumo

Os decápodes de água doce, como os caranguejos da família Trichodactylidae, são componentes-chave das cadeias alimentares bentônicas, mas a pesquisa sobre sua ecologia trófica é limitada. Este estudo teve como objetivo investigar variações na dieta natural do caranguejo de água doce *Dilocarcinus pagei* no Rio Araguari, Brasil. Analisamos grupos demográficos e diferenças sazonais na plenitude estomacal, volume e frequência de ocorrência de vários itens dietéticos. Nossos resultados revelaram que a plenitude estomacal variou entre os grupos demográficos, com as fêmeas adultas apresentando níveis mais baixos e as fêmeas juvenis apresentando níveis mais elevados. A análise do conteúdo estomacal identificou 12 tipos de itens, incluindo animais não identificados, detritos, areia, filamentos de plástico e moluscos. As fêmeas juvenis apresentaram maior consumo de tecido vegetal, enquanto apenas machos adultos e juvenis apresentaram consumo de moluscos. Tecido vegetal e detritos (material digerido) foram os itens mais frequentes. Estas descobertas revelam os hábitos alimentares de *D. pagei* na área de amostragem, destacando a influência de grupos demográficos e variações sazonais na sua dieta, incluindo o consumo de tecidos vegetais, predação de moluscos e ingestão de microplásticos.

Palavras chaves: Brachyura; Ecologia alimentar; Ecologia trófica; Invasões aquáticas; Cerrado

Introduction

Freshwater decapods are a diverse group of aquatic animals found in various freshwater environments, such as rivers, streams, lakes, and ponds (Cumberlidge 2014; Magalhães et al. 2016). These animals are adaptable and can change their habitat and nutritional requirements, with the microbiota potentially playing an important role in digestion and nutrient absorption, as observed in various decapod crustaceans (Foysal, 2023), depending on several factors, such as life phases (e.g., juvenile and adult), and seasonal cycles (Collins et al. 2007; Carvalho et al. 2013). Feeding is a significant aspect of the lives of decapods, as they occupy different trophic levels ranging from herbivores to top predators, making them key players in food webs. However, their position in the food web varies depending on the environment and the species present (Cumberlidge et al. 2009).

Studies of freshwater crustacean decapods in the context of trophic ecology are an important approach to understanding their food requirements, trophic relationships with other species, and interactions with the environment (Collins et al. 2007; Toh et al. 2022). Moreover, as the trophic interactions between producers, primary consumers, secondary consumers, and higher-order consumers are the main drivers of energy and nutrient cycling through ecosystems, this approach can provide valuable insights into the functioning of aquatic ecosystems (van der Putten et al. 2004).

Trichodactylidae crabs are fully adapted to freshwater environments, and some species of this freshwater crab group can also be found in semi-terrestrial environments (Yeo et al. 2008). These true freshwater crabs are endemic to the Neotropical region (Bond-Buckup et al. 2008; Magalhães and Turkay 2008; Fernandes et al. 2020) and are important components of the littoral fauna as consumers in benthic food webs, exhibiting an omnivorous and opportunistic diet that includes plant detritus and benthic invertebrates (Williner and Collins 2002; Collins et al. 2007, 2012), and occasionally feeding on vertebrates such as frogs (Affonso and Signorelli 2011). Additionally, they play a crucial role as shredders in freshwater habitats and are subject to predation by a diverse range of organisms, including fishes, amphibians, reptiles, birds, and mammals (Pardin 1998; Magalhães 2005), serving as an important link between aquatic and terrestrial food chains.

Among the trichodactylid crabs, *Dilocarcinus pagei* Stimpson, 1861, is one of the most widespread species, occurring in various South American countries, primarily distributed in the Amazon, lower Paraná, and Paraguay river basins (Magalhães 2005; Davanso et al. 2013; Herrera et al. 2013). It occurs mainly in lowlands above 100 m above sea level, although there are some records at altitudes above 900 m (Cumberlidge et al. 2009; Cumberlidge 2016). *Dilocarcinus pagei* is a medium-sized crab (up to 60 mm in carapace width) that lives associated with aquatic vegetation (Pinheiro & Taddei 2005a; Davanso et al. 2013; Herrera et al. 2013; Davanso et al. 2016). These crabs are cryptic and nocturnal, with direct embryonic development, where juveniles hatch from eggs with morphology similar to that of adults (Magalhães and Turkay 2008; Williner et al. 2014).

In the context of the expanding distribution of *D. pagei* in the reservoirs of southeastern Brazil (Upper Paraná basin) and its potential link to accidental or deliberate introductions—possibly related to its use as bait in sport fishing (Magalhães et al. 2005)—it becomes crucial to explore the trophic ecology of this species. This crab is becoming increasingly common in the basins of the Grande and Paranaíba Rivers (Taddei and Herrera 2010; Garcia et al. 2021), as well as in some of their principal tributaries, including the Araguari River (Barboza et al. 2023). Moreover, the presence of many large hydroelectric dams in this region is altering aquatic ecosystems (Rodrigues and Silva 2012), potentially facilitating the invasion of alien species (Havel et al. 2005; Rodrigues and Silva 2012; Daga et al. 2014; Coelho et al. 2018; Linares et al. 2019; Alho 2020; Elton 2020).

The Araguari River harbors invasive mollusk species such as *Limnoperna fortunei* Dunker, 1857 (Bivalvia: Mytilidae), *Corbicula fluminea* Müller, 1774 (Bivalvia: Corbiculidae), and *Melanoides tuberculata* Müller, 1774 (Gastropoda: Thiaridae) (Linares et al. 2017). Although there is no definitive confirmation that these molluscs make new connections within the Araguari River food web, it is possible that they do so, as has been observed in other environments (Boltovskoy & Cataldo, 2009; Sylvester et al., 2007). Studies suggest that invasive mollusk species may create new trophic links that potentially alter energy and nutrient transfer in native ecosystems (Jackson et al. 2017; Boltovskoy et al., 2022). One notable species among them is the golden mussel *L. fortunei*, which has become a substantial part of the diet of fishes, including crabs, as already documented in the Upper Paraná basin (Cantanhêde et al. 2008) and other regions (Williner and Collins 2002; Sylvester et al. 2007; Torres et al. 2012). Additionally, the golden mussel has been responsible for significant economic losses in various sectors related to water, such as public water supply, power generation, industry, and navigation (Boltovskoy and Cataldo 1999; Darrigran 2002; Oliveira et al. 2006; Sylvester et al. 2007; Darrigran and Damborenea 2011; Barbosa et al. 2018; Boltovskoy et al. 2022; Fortunato et al. 2022).

Studies on *D. pagei* have mainly focused on its population biology, including growth, reproduction, and population structure (Taddei and Herrera 2010; Davanso et al. 2013; Herrera et al. 2013; Davanso et al. 2016; Barboza et al. 2023). Furthermore, investigations into the cultivation of the species have been conducted due to its economic potential in aquaculture (Sant'Anna et al., 2015; Viana, 2019) and as live bait in sport fishing (Taddei & Herrera, 2010; Mussato et al., 2019; Garcia et al., 2021). Despite these efforts, little attention has been paid to its trophic ecology, with only two studies conducted on its natural diet, one in the Lower Paraná basin in Argentina (Williner and Collins 2002) and another in the Paraguay basin in Brazil (Viana et al. 2023). Therefore, further research is crucial to gain a more comprehensive understanding of the trophic ecology of the species and its role in the ecosystem.

Addressing this knowledge gap, the present study aims to evaluate the natural diet of the freshwater crab *D. pagei* in the Araguari River, Minas Gerais, Brazil. Different demographic groups (adult females and males, juvenile females and males) were considered to predict variations in stomach fullness, volume, and frequency of food items consumed. These demographic groups may have distinct dietary requirements influenced by seasonal changes in food resource availability. Moreover, we expect *D. pagei* to have a diverse diet comprising both plant and animal material, including invasive mollusk species, similar to other freshwater crabs.

Materials and methods

Study Area

The study was conducted in a section of the Araguari River, 30 km upstream of its confluence with the Paranaíba River and 50 km downstream of the Amador Aguiar II (AA II) dam in Minas Gerais, Brazil (Figure 1A). The Araguari River is an important tributary of the Paraná River, which ranks as the second largest river in South America (Bonetto et al. 1986). Additionally, the Araguari River flows through the Cerrado biome, recognized as one of the world's most important biodiversity hotspots (Myers et al. 2000).

The Araguari River basin covers approximately 22.000 km² (Salla et al. 2014) and spans 20 municipalities in western Minas Gerais, southeastern Brazil. This river features a system of cascading reservoirs, including several hydroelectric power plants such as Nova Ponte, Miranda, Amador Aguiar I (AAI), and Amador Aguiar II (AAII), arranged in sequence from upstream to downstream (Loures and Pompeu 2019). The presence of these reservoirs has led to changes in water levels and flow velocity, resulting in flooding during the rainy season. These alterations have had a significant impact on both the hydrological regime of the river and the biogeochemical cycles, sediment retention, and biota of the riparian zones (Rodrigues and Silva 2012).

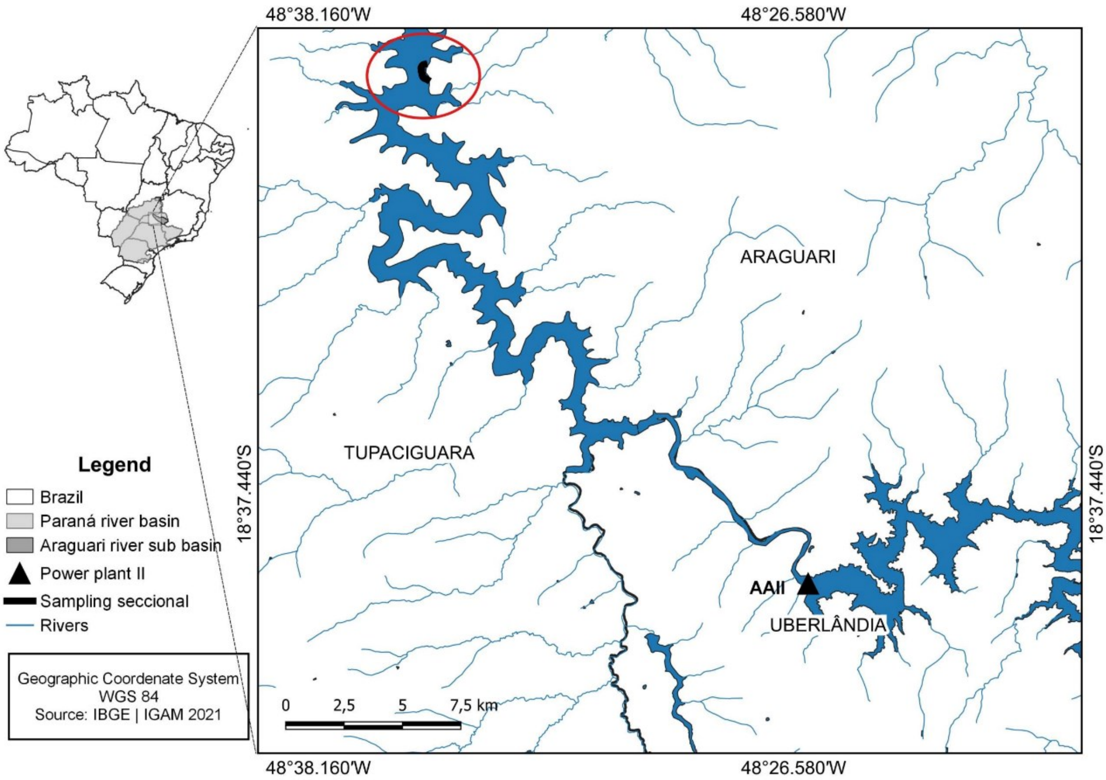

Figure 1. Location of the study area in the Araguari River, Minas Gerais, Brazil (between coordinates -18.4544°S, -48.5925°W and -18.4497°S, -48.5916°W). The sampled section is indicated by the red circle.

In the analyzed section of the river, small fragments of dry forests are present in the elevated regions of the floodplain (Vale et al. 2021). However, the riparian vegetation in the lower areas was likely displaced due to bank flooding caused by the construction of the Itumbiara/Furnas hydroelectric plant on the Paranaíba River in the 1980s, as well as the impact of the four upstream cascading dams on the Araguari River. Currently, the land-water interface is dominated by angiosperms such as grasses (Poaceae) and pteridophytes (*Salvinia* sp.), along with macrophytes such as *Eichhornia crassipes* (Mart.) Solms ("aguapé") and others, which exhibit rapid changes as water level fluctuates. Additionally, we have observed the presence of invasive bivalve species in this area, including *L. fortunei*, *C. fluminea*, and *M. tuberculata*.

The climate classification of the study area, based on the Köppen system, is Aw, indicating a tropical climate with two distinct seasons: dry (April–September) and rainy (October–March) (Alvares et al. 2013; Beck et al. 2018). The average annual temperature in the area ranges between 18°C and 21.5°C (Novais et al. 2018). Rainfall data were obtained from the digital platform 'HidroWeb' of the Sistema Nacional de Recursos Hídricos (SNIRH), collected from a weather station near the sampling site. Rainfall affects water levels, so access to this data is crucial for monitoring changes in water resources.

Sampling and Measurements

Over a one-year period from September 2020 to August 2021, approximately 30 crabs were collected each month. Collections were made at night, by actively searching a 900-meter section of the riverbank for one hour. Sampling was done randomly, without controlling for sex or age class, with the aim of obtaining a representative sample of the total population. Two sampling methods were employed: manual collection of crabs found along the land-water interface, and the use of a sieve (mesh size of 3 mm), which was handled within the aquatic vegetation present in the area. The entire sampling process lasted one hour. Subsequently, crustaceans were individually placed in labeled plastic bags, anesthetized by cooling, and frozen to avoid the negative effects of digestion after death.

We identified the specimens following taxonomic literature (Melo 2003). Sex was determined by assessing the morphology of the abdomen, including its shape and size (Pinheiro and Taddei 2005a). All specimens had their carapace width (CW) measured, and in males, the right propodus length was also measured using a digital caliper with 0.01 mm accuracy. The measurements of carapace width and right propodus length in males were used to define demographic groups (adults and juveniles), while for females, the smallest ovigerous female was used as the reference to determine adult females, following the methodology employed by Barboza et al. (2023).

Stomach Content Analysis

Each animal was thawed and dissected to remove the stomach. Subsequently, we promptly determined the relative degree of stomach fullness (in percentage terms) by assigning a score according to six classes (Table 1), as proposed by Hyslop (1980) and Williams (1981). This visual assessment was feasible due to the translucent, thin-walled nature of the stomach in *D. pagei* (Collins et al. 2007). Individuals with empty stomachs were excluded from all subsequent calculations and statistical analyses.

Table 1. Relative degree of fullness scaled.

Fullness	Classes (Degree of Fullness – score)
0% (empty)	0
0% < stomach's fullness ≤ 5%	0.02
5% < stomach's fullness ≤35%	0.25
35% < stomach's fullness ≤ 65%	0.5
65% < stomach's fullness ≤ 95%	0.75
stomach's fullness > 95% (full)	1

Following this analysis, the entire stomach contents were mounted in a Petri dish covered with millimeter paper containing 1 x 1 mm squares for quantification under a stereomicroscope. We identified all dietary components to the lowest feasible taxonomic level, utilizing partially digested remnants as the basis for identification. Dietary items consisting of macroinvertebrates were identified using taxonomic keys obtained from specialized literature (Mugnai et al. 2010; Hamada et al. 2014), or expert support was sought when necessary. The presence of small leaf fragments indicated macrophyte remains or plant tissue.

Food items were categorized into 12 groups in total: Ant, Coleoptera, Ephemeroptera, Hemiptera, Mollusca (mantle tissues or shell), shrimp (pieces of mouth appendages, chelae, rostrum, cephalothorax, telson, uropods, exuviae from recent molts, and setae), plant tissue (stems, branches, leaves, seeds, flowers, fruits, and roots) or macrophyte, detritus (fragmented or partially digested organic material), sponge spicules, plastic filaments, sand, and unidentified animal. Animal remains that could not be clearly identified (e.g., egg-like structures and exoskeletons) were grouped into an unidentified category.

Additionally, we determined the volume of each item in the stomach, utilizing either the absolute point frequency or the method of points (MP) in a scale form. To achieve this, we quantified the area of each dietary item using 1 mm² squares and calculated the individual dietary proportion for each item by dividing its area by the total area covered by all items. Subsequently, a score was assigned to each item based on five ranking categories (Table 2), following the approach proposed by Williams (1981).

Table 2. Scales that were considered for the application of the Method of Points (MP). These scales vary according to the area occupied by each food item.

Volume by item	Category (Methods of Points – score)
$\leq 5\%$	2.5
$5< \text{volume} \leq 35\%$	25
$35< \text{volume} \leq 65\%$	50
$65< \text{volume} \leq 95\%$	75
$> 95\%$	100

The number of points for each item is determined by multiplying the number of points by the value dependent on the degree of stomach fullness, as defined by the equation $MP_i = (\sum_{j=1}^{n} a_{ij} / A).100$, where a_{ij} is the number of points of item i found in stomach j, A is the total number of points for all items, and n is the total number of stomachs (Williams 1981). Subsequently, we evaluate the frequency of occurrence (FO) of each food item using the equation: $FO = \left(\frac{bi}{n}\right).100$, where bi is the number of stomachs that have item i.

Data Analysis

To compare the fullness degree (FD), absolute frequency of points (MP), and frequency of occurrence (FO) among different seasons (Dry vs. Rainy), demographic groups including adult females (AF), juvenile females (JF), adult males (AM), and juvenile males (JM), as well as different types of food items, we employed a Generalized Linear Model (GLM). Additionally, when necessary, we performed Tukey's Test to compare all possible pairs of means between the groups. FD was modeled using a Gaussian distribution with an "identity" link, while MP was modeled using a Gamma distribution with a "log" link. Furthermore, for FO, we used a binomial distribution with a "logit" link. The analysis was conducted using the GLM package (Brooks et al. 2017), and the significance of variance was assessed using the Wald chi-squared test from the car package (Fox and Weisberg 2011). All statistical analyses were performed in RStudio 3.5.1 software (R Core Team 2018) at a significant level of 5%. To ensure the validity of our results, we tested for the assumptions of normality, heteroscedasticity, and overdispersion of the data.

Results

Throughout the analyzed period, there was notable variation in precipitation, ranging from a complete absence of rainfall, represented by an accumulation of 0 mm in the driest month (July), to a total of 174 mm in the rainiest month (November). A total of 333 crabs were examined, comprising 96 (29%) females and 237 (71%) males. Among the females, 61 (18.32%) were adults, and 35 (10.51%) were juveniles. Among the males, 71 (21.32%)

were adults, and 166 (49.85%) were juveniles. The carapace width (CW) exhibited average values of 39.37 ± 9.57 mm for females and 40.28 ± 7.63 mm for males (Table 3).

Table 3. Carapace width (mm) of *Dilocarcinus pagei* Stimpson, 1861 across different demographic groups, including adult females (AF), juvenile females (JF), adult males (AM), and juvenile males (JM), during both the dry and rainy seasons in Araguari River, Minas Gerais, Brazil.

Season	Demographic groups	N	Mean ± SD	Minimum	Maximum
Dry	AF	20	43.74 ± 3.63	38.21	50.22
	JF	19	28.18 ± 4.68	20	37.12
	AM	66	47.67 ± 2.01	44.74	53.24
	JM	97	37.72 ± 7.12	12.7	44.54
Rainy	AF	41	46.63 ± 4.72	37.44	53.84
	JF	16	28.62 ± 5.17	18.82	36.12
	AM	5	46.84 ± 1.98	44.99	50.20
	JM	69	36.34 ± 6.71	19.62	44.36

Stomach Content Analysis: Seasons and Demographic Groups

Regarding stomach contents, a total of 191 (57.36%) had some food in their stomachs, while 142 (42.64%) were completely empty. Among the crabs with food in their stomachs, the distribution across demographic groups was as follows: 17 (8.90%) adult females, 33 (17.28%) juvenile females, 45 (23.56%) adult males, and 96 (50.26%) juvenile males (Table 4). These percentages are based on the subset of individuals with food in their stomachs, not the total sample, which is why the values do not add up to 100%.

Table 4. Absolute and relative frequency (%) of *Dilocarcinus pagei* (Stimpson, 1861) across different demographic groups, including adult females (AF), juvenile females (JF), adult males (AM), and juvenile males (JM), during both the dry and rainy seasons in Araguari River, Minas Gerais, Brazil.

Season	Demographic groups	Empty stomach		Stomach with contents	
		N	%	N	%
Dry	AF	14	9.86	6	3.14
	JF	0	0.00	19	9.95
	AM	23	16.20	43	22.51
	JM	38	26.76	59	30.89
Rainy	AF	30	21.13	11	5.76
	JF	2	1.41	14	7.33
	AM	3	2.11	2	1.05
	JM	32	22.54	37	19.37
	Total	142	100	191	100

The degree of stomach fullness exhibited a significant difference among demographic groups (GLM, $\chi2 = 39.748$, df = 3, $p < 0.001$), but no difference was observed between seasons (GLM, $\chi2 = 0.111$, df = 1, $p = 0.739$). Moreover, the interaction between the factors was not significant, indicating that the variation in stomach fullness among demographic groups was not affected by the season (GLM, $\chi2 = 3.734$, df = 3, $p = 0.291$). Thus, based on the comparison between pairs of demographic groups, we can infer those adult females exhibited the lowest level of stomach fullness, while juvenile females consistently showed significantly higher levels of stomach fullness compared to the other groups, approximately 4.5 times higher than adult females (Tukey's Test, $p < 0.05$; Table S1; see supplementary material). On the other hand, adult and juvenile males did not differ significantly in terms of stomach fullness, regardless of the season (Tukey's Test, $p > 0.05$, Table S1; see supplementary material) (Figure 2).

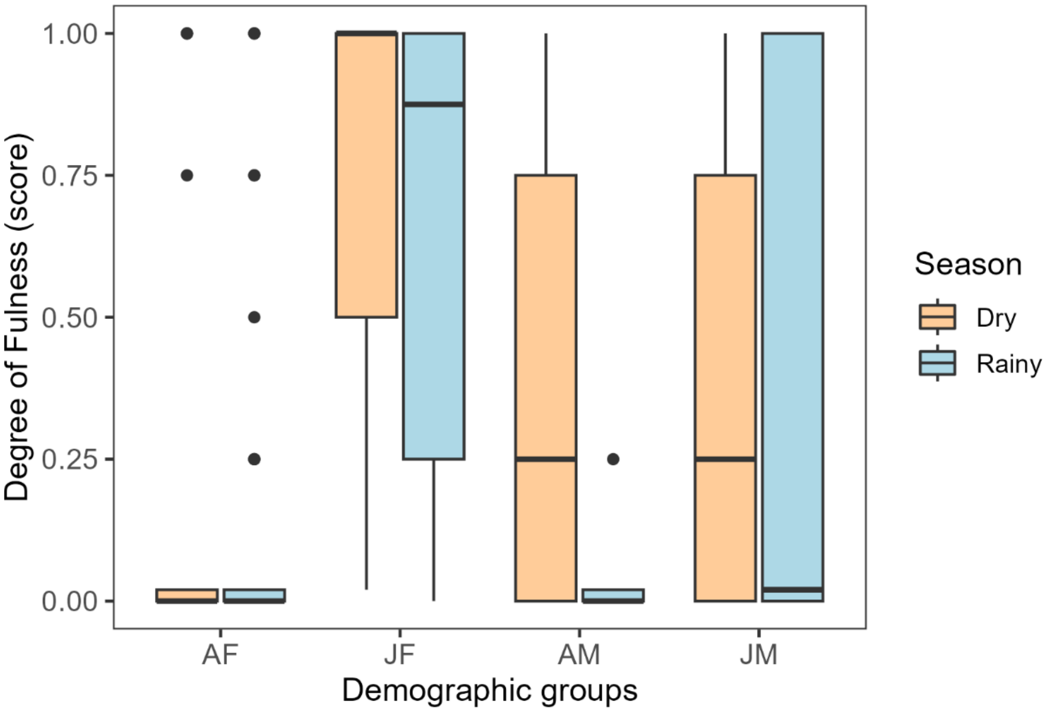

Figure 2. Boxplot with median (trace), minimum and maximum values, representing the degree of fullness observed in the stomachs of *Dilocarcinus pagei* Stimpson, 1861 among different demographic groups, including adult females (AF), juvenile females (JF), adult males (AM), and juvenile males (JM), during both the dry and rainy seasons in Araguari River, Minas Gerais, Brazil. The black circles indicate outliers, which fall outside the interquartile range (IQR).

Based on the absolute and relative frequency of points (%), the proportion of food consumed during the dry season was approximately 63%, while the rainy season accounted for 37%. Notably, during the dry season, the most consumed items were plant tissue (58.08%), followed by detritus (29.35%), unidentified animal matter (4.31%), mollusks (4.04%), and sand (3.23%) (Table 5). During the rainy season, the dominant items were plant tissue (66.78%), detritus (23.25%), unidentified animal matter (3.94%), and mollusks (2.81%) (Table 5).

Table 5. Absolute frequency of points (MP) and relative frequency (%) of the items found in the stomachs of *Dilocarcinus pagei* (Stimpson, 1861) among different demographic groups, including adult females (AF), juvenile females (JF), adult males (AM), and juvenile males (JM), during both the dry and rainy seasons in Araguari River, Minas Gerais, Brazil. The items include Coleoptera (Col), Detritus (Det), Ephemeroptera (Eph), Mollusca (Mol), Plant tissue (Plan), Plastic filaments (Plas), Sand, Shrimp (Shr), Sponge spicules (Spi), and Unidentified animal (Ua).

Season	Item	AF	%	JF	%	AM	%	JM	%
Dry	Ant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Col	0.00	0.00	0.00	0.00	1.88	0.09	0.00	0.00
	Det	189.00	53.23	369.75	28.16	600.25	28.92	813.13	27.31
	Eph	0.00	0.00	0.00	0.00	25.00	1.20	0.63	0.02
	Hem	0.00	0.00	1.50	0.11	0.00	0.00	0.00	0.00
	Mol	0.00	0.00	0.00	0.00	256.25	12.35	15.00	0.50
	Plant	147.30	41.49	916.80	69.82	1033.13	49.78	1805.65	60.66

	Plas	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.02
	Sand	0.00	0.00	25.00	1.90	41.88	2.02	150.50	5.06
	Shr	0.00	0.00	0.00	0.00	0.00	0.00	18.75	0.63
	Spi	0.00	0.00	0.00	0.00	0.00	0.00	18.75	0.63
	Ua	18.75	5.28	0.00	0.00	116.88	5.63	153.88	5.17
	Subtotal	355.05	100.00	1313.05	100.00	2075.25	100.00	2976.90	100.00
Rainy	Ant	0.50	0.09	0.00	0.00	0.00	0.00	0.00	0.00
	Col	1.25	0.24	0.00	0.00	0.00	0.00	50.00	2.02
	Det	111.25	21.03	307.50	31.16	6.25	43.10	506.13	20.46
	Eph	0.00	0.00	0.00	0.00	0.00	0.00	28.50	1.15
	Hem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mol	0.00	0.00	0.00	0.00	0.00	0.00	112.50	4.55
	Plant	364.13	68.82	677.00	68.59	8.25	56.90	1624.85	65.67
	Plas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sand	18.75	3.54	2.50	0.25	0.00	0.00	27.50	1.11
	Shr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Spi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ua	33.25	6.28	0.00	0.00	0.00	0.00	124.63	5.04
	Subtotal	529.13	100.00	987.00	100.00	14.50	100.00	2474.10	100.00

Our findings indicate that while there may be apparent differences in consumption percentages between seasons, these visual distinctions do not lead to significant variations in the overall volume consumed (GLM, $\chi2$ = 0.699, df = 1, p = 0.403). However, we observed variation among demographic groups (GLM, $\chi2$ = 11.256, df = 3, p = 0.010), as well as among different food item types (GLM, $\chi2$ = 83.054, df = 11, p < 0.001). Furthermore, significant differences were observed between seasons and demographic groups when examining their interaction (GLM, $\chi2$ = 9.399, df = 3, p = 0.024), indicating that the impact of the season on food consumption varied among different demographic groups. For example, during the rainy season, adult females, juvenile females, and juvenile males exhibited higher levels of resource consumption compared to adult males (Tukey's Test, p < 0.05, Table S2; see supplementary material). Particularly, juvenile females demonstrated a food consumption volume that was 2.26 times greater than that of adult males, representing an approximate difference of 127%. Conversely, during the dry season, no variations in consumption were detected among the groups (Tukey's Test, p > 0.05, Table S2; see supplementary material). When comparing consumption between seasons and the corresponding demographic groups (e.g., AF vs AF, JF vs JF), no significant variations were observed (Tukey's Test, p > 0.05, Table S2; see supplemental material).

We observed a significant interaction between season and food types (GLM, $\chi2$ = 11.871, df = 5, p = 0.036), indicating that the volume of food consumed varied between different food types in both seasons. Plastic filaments, sponge spicules, and shrimp were only observed in the stomachs of animals sampled during the dry season, while ants (although appearing only once throughout the sampling) were found during the rainy season (Tukey’s Test, p < 0.05, Table S3; see supplementary material).

The significant interaction observed between demographic groups and food types (GLM, $\chi2$ = 25.074, df = 11, p = 0.008) indicates that the volume of food consumed varied among different demographic groups, particularly in relation to different food types. For example, all groups had higher proportions of plant tissues in their diet, but juvenile females consumed at a rate 1.23 times higher than adult males (Tukey's Test, $p < 0.05$, Table S4; see supplementary material).

However, no significant interaction was found between season, demographic groups, and food types regarding the volume of food consumed (GLM, $\chi2 = 6.134$, df = 5, p = 0.293). Although the season had varying effects on food consumption among demographic groups, the impact of food type on the combined interaction between season and demographic groups was not evident.

The frequency of occurrence of the most representative items reveals that during the dry season, plant tissue accounted for 46.64%, detritus for 36.19%, sand for 6.72%, and unidentified animals for 4.85% (Table 6). In the rainy season, plant tissue represented 46.56%, detritus accounted for 37.40%, unidentified animals were observed at 6.87%, and sand at 3.05% (Table 6) (Figure 3).

Table 6. Frequency of occurrence (FO) of the items found in the stomachs of *Dilocarcinus pagei* (Stimpson, 1861) among different demographic groups, adult females (AF), juvenile females (JF), adult males (AM), and juvenile males (JM), during both the dry and rainy seasons in Araguari River, Minas Gerais, Brazil. The items include Ant, Coleoptera (Col), Detritus (Det), Ephemeroptera (Eph), Hemiptera (Hem), Mollusca (Mol), Plant tissue (Plan), Plastic filaments (Plas), Sand, Shrimp (Shr), Sponge spicules (Spi), and Unidentified animal (Ua).

Season	Item	AF	%	JF	%	AM	%	JM	%
Dry	Col	0.00	0.00	0.00	0.00	1.00	1.08	0.00	0.00
	Det	5.00	41.67	15.00	41.67	32.00	34.41	45.00	35.43

	Eph	0.00	0.00	0.00	0.00	1.00	1.08	1.00	0.79
	Hem	0.00	0.00	1.00	2.78	0.00	0.00	0.00	0.00
	Mol	0.00	0.00	0.00	0.00	5.00	5.38	2.00	1.57
	Plan	6.00	50.00	19.00	52.78	43.00	46.24	57.00	44.88
	Plas	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.79
	Sand	0.00	0.00	1.00	2.78	6.00	6.45	11.00	8.66
	Shr	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.79
	Spi	0.00	0.00	0.00	0.00	0.00	0.00	2.00	1.57
	Ua	1.00	8.33	0.00	0.00	5.00	5.38	7.00	5.51
	Subtotal	12.00	100.00	36.00	100.00	93.00	100.00	127.00	100.00
Rainy	Ant	1.00	4.17	0.00	0.00	0.00	0.00	0.00	0.00
	Col	1.00	4.17	0.00	0.00	0.00	0.00	1.00	1.32
	Det	8.00	33.33	13.00	46.43	1.00	33.33	27.00	35.53
	Eph	0.00	0.00	0.00	0.00	0.00	0.00	3.00	3.95
	Mol	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.63
	Plan	10.00	41.67	14.00	50.00	2.00	66.67	35.00	46.05
	Sand	1.00	4.17	1.00	3.57	0.00	0.00	2.00	2.63
	Ua	3.00	12.50	0.00	0.00	0.00	0.00	6.00	7.89
	Subtotal	24.00	100.00	28.00	100.00	3.00	100.00	76.00	100.00
	Total	36.00	9.02	64.00	16.04	96.00	24.06	203.00	50.88

Our results showed significant variations in the frequency of occurrence among the different items studied (GLM, $\chi2 = 1133.33$, df = 11, $p < 0.001$) (Figure 4). Plant tissue, followed by detritus, was found to occur most frequently, while shrimp and plastic filaments were the least frequent (Tukey's Test, $p < 0.05$; Table S5; see supplementary material). However, we did not observe significant differences in the frequency of occurrence of items based on season (GLM, $\chi2 = 12.56$, df = 11, $p = 0.323$). On the other hand, significant differences were found in the frequency of occurrence of items between demographic groups (GLM, $\chi2 = 60.56$, df = 33, $p = 0.002$).

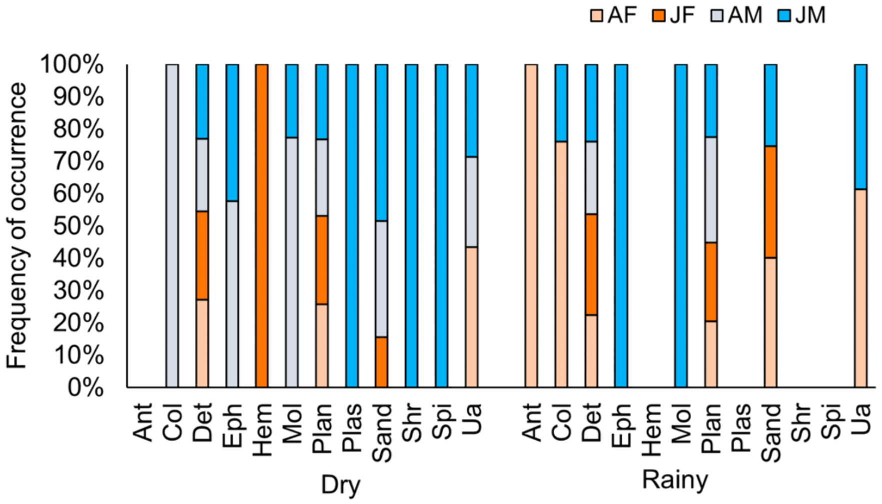

Figure 3. Plot representing the frequency of occurrence of the items found in the stomachs of *Dilocarcinus pagei* Stimpson, 1861 among different demographic groups, including adult females (AF), juvenile females (JF), adult males (AM), and juvenile males (JM), during both the dry and rainy seasons in Araguari River, Minas Gerais, Brazil. The items include Ant, Coleoptera (Col), Detritus (Det), Ephemeroptera (Eph), Hemiptera (Hem), Mollusca (Mol), Plant tissue (Plan), Plastic filaments (Plas), Sand, Shrimp (Shr), Sponge spicules (Spi), and Unidentified animal (Ua).

Although plant tissues and detritus were present in all demographic groups, plants were more frequent in juvenile females, adult males, and juvenile males, while detritus was more frequent in adult females. Certain items, such as mollusks, were found exclusively in adult and juvenile males (Tukey's Test, $p < 0.05$; Table S6; see supplementary material). When exploring interactions between factors such as items, seasons, and demographic groups, no significant differences were observed (GLM, $\chi2 = 7.39$, df = 33, $p = 0.999$). These results indicate that the combined effects do not lead to noticeable variations in the observed patterns.

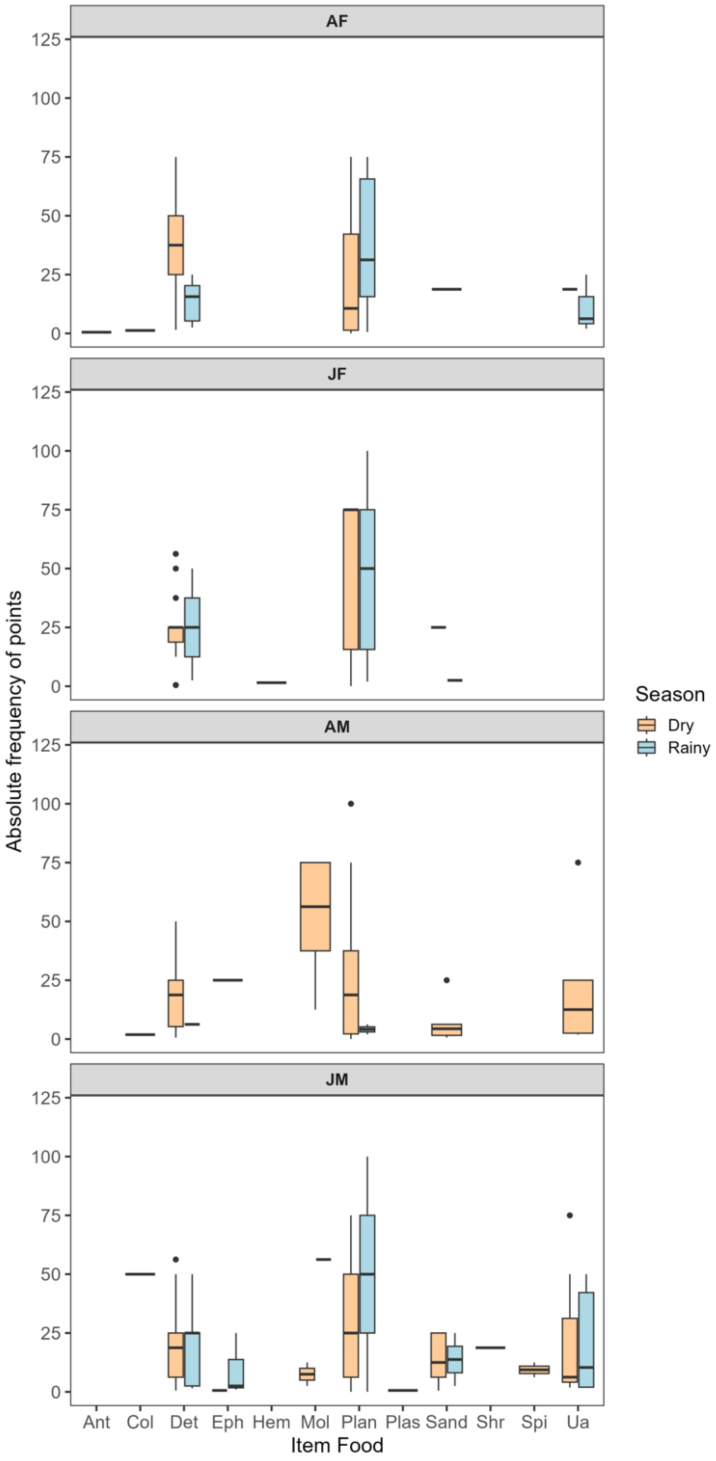

Figure 4. Boxplot with median (trace), minimum and maximum values, representing the absolute frequency of points of the items found in the stomachs of *Dilocarcinus pagei* Stimpson, 1861 among different demographic groups, including adult females (AF), juvenile females (JF), adult males (AM), and juvenile males (JM), during both the dry and rainy seasons in Araguari River, Minas Gerais, Brazil. The items include Ant, Coleoptera (Col), Detritus (Det), Ephemeroptera (Eph), Hemiptera (Hem), Mollusca (Mol), Plant tissue (Plan), Plastic filaments (Plas), Sand, Shrimp (Shr), Sponge spicules (Spi), and Unidentified animal (Ua).

Discussion

The analysis of the stomach contents in *Dilocarcinus pagei* crabs unveiled nuanced feeding patterns influenced by demographic groups and seasonal dynamics. Additionally, our findings indicate that the dietary habits of *D. pagei* align with those of conspecific populations and other trichodactylid crabs, showing a predilection for plant tissue consumption. However, we also noted occasional consumption of animal-derived items, such as mollusks, albeit in lesser proportions. These results provide support for the hypotheses posited in this study. The ability of *D. pagei* to efficiently digest plant tissue may be related to the microbiota in its digestive tract, which facilitates the breakdown of complex polysaccharides such as cellulose. Although there are few specific studies on D. pagei, research on other crustaceans, including marine species, suggests that the presence of microbial symbionts in the digestive tract plays an important role in the digestion of plant material (Harris, 1993; Zhang et al., 2020).

Regarding the degree of stomach fullness, encompassing both empty and filled stomachs, we observed a relatively constant level throughout the year, regardless of whether it was the dry or rainy season. In contrast, a study by Williner et al. (2013) on *Trichodactylus borellianus* Nobili, 1896 (Trichodactylidae) in the La Plata basin, Argentina, characterized by a temperate climate, reported a lower stomach fullness index in winter and a higher index in spring. These findings suggest that feeding patterns and stomach fullness may be influenced by distinct climatic and seasonal factors compared to other regions, such as the tropical Cerrado biome in Brazil. Alternatively, when considering all stomachs combined in our analysis of fullness, the seasonal difference may not be readily apparent. This discrepancy could arise from the presence of empty stomachs during the rainy season, albeit in a lower proportion, potentially equalizing the overall average and masking the seasonal variation.

In terms of stomach fullness across groups, juvenile females exhibited a higher degree compared to adult females, even surpassing adult and juvenile males. This suggests that the increased food consumption by juvenile females may be directly related to accelerated body growth during this life phase to attain morphological maturity and gonadal development. This observation is further supported by the fact that females reach morphological sexual maturity at a carapace width (CW) of 37.44 mm, while males attain sexual maturity at a larger size, 44.74 mm CW (Barboza et al., 2023). The higher stomach fullness in juvenile females likely reflects the increased energy requirements necessary for reaching reproductive maturity, a process that occurs earlier in females compared to males, potentially driving this differential feeding behavior.

Previous studies on *D. pagei* have shown that females have faster growth rates than males, a phenomenon associated with their reproductive strategy (Pinheiro & Taddei, 2005b; Taddei & Herrera, 2010). However, adult females of this species may reduce their activity patterns during certain reproductive processes, thereby decreasing the frequency at which this group ingests food (Herrera et al. 2013; Marciano et al. 2020). The observation of ovigerous females of *D. pagei* in natural environments is rare, as noted in previous studies (Mansur and Hebling 2002; Davanso et al. 2013; Taddei et al. 2015; Barboza et al. 2023). It is believed that reproductively active or ovigerous females of *D. pagei* exhibit highly cryptic behaviors (Davanso et al. 2013), remaining sheltered after mating as a strategy to avoid predators and ensure the development of embryos and early juvenile stages (which remain attached inside the females' abdomen). Consequently, due to this behavior, these organisms may refrain from feeding, thus justifying the differences found in the present study.

In the method of points, only stomachs with contents were considered, revealing a more pronounced difference in the volume consumed among items, with variations depending on the specific demographic group. This observation likely arises from the direct correlation between food availability and crab consumption, reflecting the crabs’ response to seasonal fluctuations in food resources. Higher consumption rates were observed during the rainy season, particularly among juvenile females. The increased consumption by juvenile females suggests a heightened demand to support body growth and the development of reproductive structures, as evidenced by stomach fullness. These findings highlight distinct patterns of food consumption across different life stages during both the dry and rainy seasons. The rainy season, characterized by increased prey availability and nutrient content in the water, may stimulate heightened food intake by juvenile females (Kennish, 1997).

Furthermore, we noted variations in the volume of consumed items across different demographic groups. Plant tissue, particularly macrophytes, comprised a substantial portion of the diet for all demographic groups compared to other food types. Macrophytes are widely acknowledged as the preferred food source for trichodactylid crabs. Studies indicate that both crabs, *Trichodactylus petropolitanus* (Goeldi, 1886), and *D. pagei*, consume a significant proportion of macrophytes, with reported values exceeding 35% (Viana et al., 2023). Adult and juvenile males exhibited a more diverse diet, including the consumption of mollusks, whereas adult and juvenile females did not display this behavior. During our field observations, we documented the presence of *Pomacea* sp. gastropod and invasive bivalves such as *L. fortunei* (golden mussel), *C. fluminea*, and *M. tuberculata*. Although it was challenging to distinguish them in the crab's stomach contents, we directly observed *D. pagei* primarily feeding on *Pomacea* sp. and *L. fortunei*. This observation suggests that these mollusk species, as documented for other decapods, may represent significant dietary components for *D. pagei* crabs. The presence of these specific prey items may contribute to the observed differences in diet among sexes or life stages, as discussed earlier. These findings highlight the potential existence of distinct food preferences or foraging behaviors among various demographic groups of the studied species.

Variations in diet composition among demographic groups can be influenced by several factors, including food resource availability, prey structure in the sampling area, foraging behavior, and claw morphology, which varies according to life phase. Ontogenetic changes may lead to shifts in crab food preferences (Viozzi et al., 2021). It is plausible that differences in claw morphology and the capacity to manipulate mollusks contribute to more efficient consumption of these items by males, as observed in certain marine brachyuran crabs (Schenk and Wainwright, 2001). In the case of *D. pagei*, previous studies have suggested that both adult males and females possess robust claws, potentially broadening their dietary repertoire (da Silva & Nogueira, 2023). However, sexual dimorphism in claw morphology is primarily evident in males (Davanso et al., 2016; da Silva & Nogueira, 2023), indicating potential disparities in feeding behavior and resource utilization between sexes. This could elucidate the findings of our study, where only male crabs (juveniles and adults) were seen consuming mollusks. However, a study in Argentina found no significant difference in the general composition of the diet between juveniles and adults or between males and females (Williner and Collins, 2002). These outcomes imply that dietary variations may be population-specific or influenced by environmental factors and resource availability in the studied region. Furthermore, another factor potentially influencing the dietary repertoire of this *D. pagei* population in Argentina is the size of individuals. Williner and Collins (2002) investigated relatively small individuals compared to *D. pagei* populations in Brazil, with crabs ranging from 4.4 to 39.4 mm CW, and the majority falling between 7.5 and 17.5-mm CW (see figure 3 in Williner and Collins, 2002). Consequently, these individuals likely possessed smaller and less dimorphic claws, potentially limiting access to certain food resources.

Additionally, plastic filaments were found in one of the examined stomachs, indicating the ingestion of microplastics. It is well-documented that microplastics are ingested by various benthic invertebrates, including decapods (Browne et al., 2008; Devriese et al., 2015; Windsor et al., 2019; Villagran et al., 2020; Wang et al., 2021; Viana et al., 2023). This ingestion can occur through diverse mechanisms, such as accidental consumption during foraging (e.g., filtering or detritivory), opportunistic feeding, or bioturbation activities. Notably, a study on the crab *Minuca rapax* (Smith, 1870) revealed that bioturbation activity within burrows can influence the distribution of microplastics in sediments (Capparelli et al., 2022). These results underscore the potential impacts of microplastic pollution on decapod crustaceans and emphasize the necessity for further research to comprehend the ecological implications in aquatic environments.

Conclusion

This study offers valuable insights into the feeding habits of *D. pagei* crabs within the Cerrado biome. Our findings highlight the influence of demographic groups and seasonal variations on their dietary preferences. Understanding these variations in diet composition among different groups sheds light on the ecological and behavioral adaptations of these animals across various environmental conditions. Moreover, it provides insight into the potential impacts of invasive species and microplastic pollution on decapod crustaceans. Further research is imperative to deepen our comprehension of the ecological implications of these feeding patterns and the consequences of microplastic ingestion in the freshwater environment. Such knowledge is essential for formulating effective conservation and management strategies aimed at preserving the health and functionality of aquatic ecosystems.

Acknowledgments

ACGB acknowledges the doctoral scholarship provided by the Coordination for the Improvement of Higher Education Personnel (CAPES). CSN acknowledges the postdoctoral scholarship provided by the São Paulo State Research Support Foundation (2023/01445-8). The authors thank all colleagues at the Aquatic Ecosystems Ecology Laboratory and F.L.M. Barboza for their extensive help with fieldwork, and E.F. Dantas for kindly allowing access to the study area through his property.

References

Affonso ID, Signorelli L (2011) Predation on frogs by the introduced crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda, Trichodactylidae) on a Neotropical floodplain. Crustaceana 84:1653-1657. https://doi.org/10.1163/156854011X605701

Alho CJ (2020) Hydropower dams and reservoirs and their impacts on Brazil's biodiversity and natural habitats: a review. World J Adv Res Rev 6:205-215. https://doi.org/10.30574/wjarr.2020.6.3.0197

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JDM, Sparovek G (2013) Köppen's climate classification map for Brazil. Meteorol Z 22:711-728. https://doi.org/10.1127/0941-2948/2013/0507

Barbosa NP, Ferreira JA, Nascimento CA, Silva FA, Carvalho VA, Xavier ER, Ramon L, Almeida AC, Carvalho MD, Cardoso AV (2018) Prediction of future risk of invasion by *Limnoperna fortunei* (Dunker, 1857) (Mollusca, Bivalvia, Mytilidae) in Brazil with cellular automata. Ecol Indic 92:30-39. https://doi.org/10.1016/j.ecolind.2018.01.005

Barboza ACG, Nogueira CS, Calixto-Cunha M, Londe BP, Jacobucci GB (2023) Population biology of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) in the Araguari River, south-eastern Brazil. J Nat Hist 57:427-444. https://doi.org/10.1080/00222933.2023.2190547

Beck HE, Zimmermann NE, McVicar TR, Vergopolan N, Berg A, Wood EF (2018) Present and future Köppen-Geiger climate classification maps at 1-km resolution. Sci. Data 5:1-12. https://doi.org/10.1038/sdata.2018.214

Boltovskoy D, Cataldo DH (1999) Population dynamics of *Limnoperna fortunei*, an invasive fouling mollusc, in the lower Paraná River (Argentina). Biofouling 14:255-263. https://doi.org/10.1080/08927019909378417

Boltovskoy D, Paolucci E, MacIsaac HJ, Zhan A, Xia Z, Correa N (2022) What we know and don't know about the invasive golden mussel *Limnoperna fortunei*. Hydrobiologia 1-48. https://doi.org/10.1007/s10750-022-04988-5

Bond-Buckup G, Jara CG, Pérez-Losada M, Buckup L, Crandall KA (2008) Global diversity of crabs (Aeglidae: Anomura: Decapoda) in freshwater. Freshwater Anim Divers Assess 595:267-273. http://doi.org/10.1007/978-1-4020-8259-7_29

Bonetto AA, Neiff JJ, Di Persia DH (1986) The Paraná river system. In: Davies BR, Walker, KF (eds) The ecology of river systems. Springer. Dordrecht, pp 541-598. https://doi.org/10.1007/978-94-017-3290-1_11

Brooks ME, Kristensen K, Van Benthem KJ, Magnusson A, Berg CW, Nielsen A, Skaug HJ, Machler M, Bolker BM (2017) glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. R Journal 9:378-400. https://doi.org/10.3929/ethz-b-000240890

Browne MA, Dissanayake A, Galloway TS, Lowe DM, Thompson RC (2008) Ingested microscopic plastic translocates to the circulatory system of the mussel, *Mytilus edulis* (L.). Environ Sci Tech 42:5026-5031. https://doi.org/10.1021/es800249a

Cantanhêde G, Hahn NS, Gubiani EA, Fugi R (2008) Invasive molluscs in the diet of *Pterodoras granulosus* (Valenciennes, 1821) (Pisces, Doradidae) in the Upper Paraná River floodplain, Brazil. Ecol Freshw Fish 17:47-53. https://doi.org/10.1111/j.1600-0633.2007.00258.x

Capparelli MV, Martínez-Colón M, Lucas-Solis O, Valencia-Castañeda G, Celis-Hernández O, Ávila E, Moulatlet GM (2022) Can the bioturbation activity of the fiddler crab *Minuca rapax* modify the distribution of microplastics in sediments?. Mar Pollut Bull 180:113798. https://doi.org/10.1016/j.marpolbul.2022.113798

Carvalho DA, Collins PA, De Bonis, CJ (2013) Predation ability of freshwater crabs: age and prey-specific differences in *Trichodactylus borellianus* (Brachyura: Trichodactylidae). J Freshw Ecol 28:573-584. https://doi.org/10.1080/02705060.2013.80 6273

Coelho PN, Fernandez MA, Cesar DAS, Ruocco AMC, Henry R (2018) Updated distribution and range expansion of the gastropod invader *Melanoides tuberculata* (Müller, 1774) in Brazilian waters. Bioinvasions Rec 7:405–409 https://doi.org/10.3391/bir.2018.7.4.08

Collins P, Williner V, Giri F (2007) Trophic relationships in crustacean decapods of a river with a floodplain. In: Elewa AMT (ed) Predation in organisms: a distinct phenomenon. Springer, Heidelberg, pp 59-86. https://doi.org/10.1007/978-3-540-46046-6_5

Cumberlidge N (2014) Freshwater decapod conservation: recent progress and future challenges. In: Yeo D, Cumberlidge N, Klaus S (eds) Advances in freshwater decapod systematics and biology. Brill, Leiden, pp 53-69. https://doi.org/10.1163/978900 4207615_005

Cumberlidge N (2016) Global diversity and conservation of freshwater crabs (Crustacea: Decapoda: Brachyura). In: Kawai T, Cumberlidge N (eds) A global overview of the conservation of freshwater decapod crustaceans. Springer, Cham, pp 1-22. https://doi.org/10.1007/978-3-319-42527-6_1

Cumberlidge N, Ng PK, Yeo DC, et al (2009). Freshwater crabs and the biodiversity crisis: importance, threats, status, and conservation challenges. Biol Conserv 142:1665-1673. https://doi.org/10.1016/j.biocon.2009.02.038

da Silva AR, Nogueira CS (2023) From color to shape: ontogenetic shifts in traits of the freshwater crab *Dilocarcinus pagei* (Brachyura: Trichodactylidae). Can J Zool 101:658-671. https://doi.org/10.1139/cjz-2023-0039

Daga VS, Skóra F, Padial AA, Abilhoa V, Gubiani EA, Vitule JRS (2015) Homogenization dynamics of the fish assemblages in Neotropical reservoirs: comparing the roles of introduced species and their vectors. Hydrobiologia 746:327-347. http://doi.org/10.1007/s10750-014-2032-0.

Darrigran G (2002) Potential impact of filter-feeding invaders on temperate inland freshwater environments. Biol Invasions 4:145-156. https://doi.org/10.1023/A:10205218 11416

Darrigran G, Damborenea C (2011) Ecosystem engineering impact of *Limnoperna fortunei* in South America. Zool Sci 28:1-7. https://doi.org/10.2108/zsj.28.1

Davanso TM, Taddei FG, Hirose GL, Costa RC (2016) Sexual maturity, handedness and sexual dimorphism of the freshwater crab *Dilocarcinus pagei* in Southeastern Brazil. Bol Inst Pesca, 42:269-279. https://doi.org/10.20950/1678-2305.2016v42n2p269

Davanso TM, Taddei FG, Simões SM, Fransozo A, Costa RC (2013) Population dynamics of the freshwater crab *Dilocarcinus pagei* in tropical waters in southeastern Brazil. J Crust Biol 33:235-243. https://doi.org/10.1163/1937240X-00002129

De Grave S, Smith KG, Adeler NA, et al (2015). Dead shrimp blues: a global assessment of extinction risk in freshwater shrimps (Crustacea: Decapoda: Caridea). PLoS One 10:e0120198. https://doi.org/10.1371/journal.pone.0120198

Devriese LI, Van der Meulen MD, Maes T, Bekaert K, Paul-Pont I, Frère L, Robbens J, Vethaak AD (2015) Microplastic contamination in brown shrimp (*Crangon crangon*, Linnaeus 1758) from coastal waters of the Southern North Sea and Channel area. Mar Pollut Bull 98:179-187. https://doi.org/10.1016/j.marpolbul.2015.06.051

Elton CS (2020) The ecology of invasions by animals and plants. Springer, Cham. https://doi.org/10.1007/978-3-030-34721-5

Fernandes LS, Sant'Anna BS, Hattori GY (2020) Amazon freshwater crab *Dilocarcinus pagei* (Decapoda: Trichodactylidae): a view about burrow construction behavior. Lat Am J Aquat Res 48:85-93. https://doi.org/10.3856/vol48-issue1-fulltext-2 325

Fortunato HFM, Figueira RMA (2022) Freshwater sponges overgrow the invasive golden mussel *Limnoperna fortunei* in the upper Paraná river, Brazil. Mar Freshwater Res 73:1393-1398. https://doi.org/10.1071/MF22023

Garcia DAZ, Casimiro ACR, Geller IV, Ferraz JD, Jarduli LR, Orsi ML (2021) Live bait trade as a pathway for the introduction of non-native species: The first record of *Dilocarcinus pagei* in the Paranapanema river basin. Oecol Aust 25:775-785. https://doi.org/10.4257/oeco.2021.2503.14

Hamada N, Nessimian JL, Querino RB (2014) Insetos aquáticos na Amazônia brasileira: taxonomia, biologia e ecologia. Editora INPA, Manaus.

Harris, JM (1993) Widespread occurrence of extensive epimural rod bacteria in the hindguts of marine Thalassinidae and Brachyura (Crustacea: Decapoda). *Marine Biology*, *116*, 615-629.

Havel JE, Lee CE, Vander Zanden JM (2005) Do reservoirs facilitate invasions into landscapes?. BioScience 55:518-525. https://doi.org/10.1641/0006-3568(2005)055[0518:DRFIIL]2.0.CO;2

Herrera DR, Davanso TM, Costa RC, Taddei FG (2013) The relative growth and sexual maturity of the freshwater crab *Dilocarcinus pagei* (Brachyura, Trichodactylidae) in the northwestern region of the state of São Paulo. Iheringia Sér Zool 103:232-239. https://doi.org/10.1590/S0073-47212013000300004

Hyslop EJ (1980) Stomach contents analysis—a review of methods and their application. J Fish Biol 17:411-429. https://doi.org/10.1111/j.1095-8649.1980.tb02775.x

Jackson MC, Wasserman RJ, Grey J, Ricciardi A, Dick JTA, Alexander ME (2017) Novel and disrupted trophic links following invasion in freshwater ecosystems. In: Bohan DA, Dumbrell AJ, Massol F (eds) Advances in Ecological Research. Academic Press, Oxford, pp 55-97. https://doi.org/10.1016/bs.aecr.2016.10.006

Kennish R (1997) Seasonal patterns of food availability: influences on the reproductive output and body condition of the herbivorous crab *Grapsus albolineatus*. Oecologia 109:209-218. https://doi.org/10.1007/s004420050075

Linares MS, Assis W, de Castro Solar RR, Leitão RP, Hughes RM, Callisto M (2019) Small hydropower dam alters the taxonomic composition of benthic macroinvertebrate assemblages in a neotropical river. River Res Appl 35:725-735. https://doi.org/10.1002/rra.3442

Linares MS, Callisto M, Marques JC (2017) Invasive bivalves increase benthic communities' complexity in neotropical reservoirs. Ecol Indic 75:279-285. https://doi.org/10.1016/j.ecolind.2016.12.046

Loures RC, Pompeu PS (2019) Temporal changes in fish diversity in lotic and lentic environments along a reservoir cascade. Fresh Biol 64:1806-1820. https://doi.org/10.1111/fwb.13372

Magalhães C, Bueno SLS, Bond-Buckup G, Valenti WC, Silva HLM, Kiyohara F, Mossolin EC, Rocha SS (2005) Exotic species of freshwater decapod crustaceans in the state of São Paulo, Brazil: records and possible causes of their introduction. Biodivers Conserv 14:1929-1945. https://doi.org/10.1007/s10531-004-2123-8

Magalhães C, Campos MR, Collins PA, Mantelatto FL (2016) Diversity, distribution and conservation of freshwater crabs and shrimps in South America. In: Kawai T, Cumberlidge N (eds) A global overview of the conservation of freshwater decapod crustaceans. Springer, Cham, pp 303-322. https://doi.org/10.1007/978-3-319-42527-6_10

Marciano A, López Greco LS, Colpo KD (2021) Reproductive patterns and energy management strategies of females of the fiddler crab *Leptuca uruguayensis* with short reproductive seasons. Can J Zool, 99:149-159. https://doi.org/10.1139/cjz-2020-0129

Melo GAS (2003) Manual de identificação dos Crustacea Decapoda de água doce do Brasil. Edições Loyola, São Paulo.

Mugnai R, Nessimian JL, Baptista DF (2010) Manual de identificação de macroinvertebrados aquáticos do Estado do Rio de Janeiro. Technical Books Editora, Rio de Janeiro.

Mussato JHM, Vercesi K, & Hayd LA (2019) Mortality reduction of *Dilocarcinus pagei* during the in loco storage, in Pantanal of Porto Murtinho, Brazil. Oecol Aust 23: 1091-1099. https://doi.org/10.4257/oeco.2019.2304.29

Myers N, Mittermeier RA, Mittermeier CG, Fonseca GA, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853-858. https://doi.org/10.1038/35002501

Novais GT, Brito JLS, Sanches FO (2018) Unidades climáticas do Triângulo Mineiro/Alto Paranaíba. Rev Bras Climatol 23:223-243. http://dx.doi.org/10.5380/abclima.v23i0.58520

Oliveira MD, Takeda AM, Barros LF, Barbosa DS, Resende EK (2006) Invasion by *Limnoperna fortunei* (Dunker, 1857) (Bivalvia, Mytilidae) of the Pantanal wetland, Brazil. Biol Inv 8:97-104. https://doi.org/10.1007/s10530-005-0331-0

Pinheiro MA, Taddei FG (2005a) Weight/carapace width relationship and condition factor in *Dilocarcinus pagei* Stimpson (Crustacea, Trichodactylidae) in São José do Rio Preto, São Paulo, Brazil. Rev Bras Zool 22:825-829. https://doi.org/10.1590/S0101-81752005000400002

Pinheiro MA, Taddei FG (2005b) Crescimento do caranguejo de água doce, *Dilocarcinus pagei* Stimpson (Crustacea, Brachyura, Trichodactylidae). Rev Bras Zool 22:522-528. https://doi.org/10.1590/S0101-81752005000300002

Rodrigues SC, Silva TI (2012) Dam construction and loss of geodiversity in the Araguari river basin, Brazil. Land Degrad Dev 23:419-426. https://doi.org/10.1002/ldr.2157

Salla MR, Paredes-Arquiola J, Solera A, Álvarez JA, Pereira CE, Alamy Filho JE, Oliveira AL (2014) Integrated modeling of water quantity and quality in the Araguari River basin, Brazil. Lat Am J Aquat Res 42:224-257. http://dx.doi.org/103856/vol42-issue1-fulltext-19

Schenk SC, Wainwright PC (2001) Dimorphism and the functional basis of claw strength in six brachyuran crabs. J Zool 255:105-119. https://doi.org/10.1017/S0952836901001157

Sylvester F, Boltovskoy D, Cataldo DH (2007) Fast response of freshwater consumers to a new trophic resource: predation on the recently introduced Asian bivalve *Limnoperna fortunei* in the lower Paraná River, South America. Austral Ecol 32:403-415. https://doi.org/10.1111/j.1442-9993.2007.01707.x

Taddei FG, Herrera DR (2010) Growth of the crab *Dilocarcinus pagei* Stimpson, 1861 (Crustacea, Brachyura, Trichodactylidae) in the Barra Mansa dam, Mendonca, SP. Bol Inst Pesca 36:99-110.

Toh EX, Gan LX, Yeo DC (2022) A global overview of climate change impacts on freshwater decapods: Substantial research gaps across taxa and biogeographic regions. J Crust Biol 42:ruab088. https://doi.org/10.1093/jcbiol/ruab088

Torres MV, Giri F, Williner V (2012) Size selective predation on an invasive bivalve, *Limnoperna fortunei* (Mytilidae), by a freshwater crab, *Zilchiopsis collastinensis* (Trichodactylidae). J Crust Biol 32:698-710. https://doi.org/10.1163/193724012X649444

Vale VS, Raymundo D, Prado Júnior JA, Santos LCS, Costa JP, Oliveira PEAM, Souza AGV (2021) Impacts on seasonal dry forests located for several years near dams in the Araguari River Basin. Sci For 49:e3542. https://doi.org/10.18671/scifor.v49n130.25

van der Putten WH, Ruiter PC, Bezemer TM, Harvey JA, Wassen M, Wolters V (2004) Trophic interactions in a changing world. Basic Appl Ecol 5:487-494. https://doi.org/10.1016/j.baae.2004.09.003

Viana CRS, Junior ESO, Santos MF, Lázaro WL, Lizieri C, Muniz CC (2023) Among macrophytes and microplastics: diet of Crustacea Decapoda *Dilocarcinus pagei* (Stimpson, 1861) and *Trichodactylus petropolitanus* (Göldi, 1886) in the Pantanal region of Cáceres – MT. Res Soc Dev 12:e29012240148. https://doi.org/10.33448/rsd-v12i2.40148

Villagran DM, Truchet DM, Buzzi NS, Lopez ADF, Severini MDF (2020) A baseline study of microplastics in the burrowing crab (*Neohelice granulata*) from a temperate southwestern Atlantic estuary. Mar Pollut Bull 150:110686. https://doi.org/10.1016/j.marpolbul.2019.110686

Viozzi MF, Cabrera JM, Giri F, Carvalho DA, Williner V (2021) Ontogenetic shifts in natural diet, chelae, and mandibles of the omnivorous freshwater crab *Aegla uruguayana*: linking morphology and function. Can J Zool 99:625-641. https://doi.org/10.1139/cjz-2020-0290

Yeo DC, Ng PK, Cumberlidge N, Magalhaes C, Daniels SR, Campos MR (2008) Global diversity of crabs (Crustacea: Decapoda: Brachyura) in freshwater. In: Balian EV, Lévêque C, Segers H, Martens K (eds) Freshwater Animal Diversity Assessment. Springer, Dordrecht, pp 275-286. https://doi.org/10.1007/978-1-4020-8259-7_30

Wang T, Hu M, Xu G, Shi H, Leung JY, Wang Y (2021) Microplastic accumulation via trophic transfer: can a predatory crab counter the adverse effects of microplastics by body defence? Sci Total Environ 754:142099. https://doi.org/10.1016/j.scitotenv.2020.142099

Williams MJ (1981) Methods for analysis of natural diet in portunid crabs (Crustacea: Decapoda: Portunidae). J Exp Mar Bio Ecol 52:103-113. https://doi.org/10.1016/0022-0981(81)90174-X

Williner V, Carvalho DA, Collins PA (2014) Feeding spectra and activity of the freshwater crab *Trichodactylus kensleyi* (Decapoda: Brachyura: Trichodactylidae) at La Plata basin. Zool Stud 53:1-9. https://doi.org/10.1186/s40555-014-0071-x

Williner V, Collins PA (2002) Daily rhythm of feeding activity of the freshwater crab *Dilocarcinus pagei pagei* in the Río Pilcomayo National Park, Formosa, Argentina. In: Escobar-Briones E, Alvarez F (eds) Modern approaches to the study of Crustacea. Springer, New York, pp 171-178. https://doi.org/10.1007/978-1-4615-0761-1_27

Williner V, Collins PA (2013) Feeding ecology of the freshwater crab *Trichodactylus borellianus* (Decapoda: Trichodactylidae) in the floodplain of the Paraná River, southern South America. Lat Am J Aquat Res 41:781-792. http://dx.doi.org/103856/vol41-issue4-fulltext-15

Windsor FM, Tilley RM, Tyler CR, Ormerod SJ (2019) Microplastic ingestion by riverine macroinvertebrates. Sci Total Environ 646:68-74. https://doi.org/10.1016/j.scitotenv.2018.07.271

Zhang X, Zhang M, Zheng H, Ye H, Zhang X, & Li S (2020) Source of hemolymph microbiota and their roles in the immune system of mud crab. *Developmental & Comparative Immunology*, *102*, 103470. https://doi.org/10.1016/j.dci.2019.103470

Supplementary material

Article title: Natural feeding of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) in the floodplain of the Araguari River, southeastern Brazil

Journal name: Animal Biology

Author names: Ana Cláudia Garcia Barboza, Caio Santos Nogueira, Alessandra Angélica Pádua Bueno and Giuliano Buzá Jacobucci

Affiliation: Federal University of Uberlândia (UFU), São Paulo State University “Júliode Mesquita Filho” (UNESP) and Federal University of Lavras (UFLA)

Email address (corresponding author): ana.barboza1@ufu.br

Table captions

cat = demographic groups, AF = adult female, JF = juvenile female, AM = adult male, JM = juvenile male, Col = coleoptera, Det = detritus, Eph = Ephemeroptera, Mol = Mollusca, Plan = plant tissue, Plas = plastic filaments, Shr = shrimp, Spi = sponge spicules, Ua = unidentified animal.

Table S1. Tukey test comparing the degree of stomach fullness among the different demographic categories. Different letters indicate different means among the compared categories.

emmean	SE	df	lower.CL	upper.CL	group	diferences
AF	0.157	0.0504	329	0.0578	0.256	a
AM	0.336	0.0468	329	0.2445	0.428	b
JM	0.357	0.0306	329	0.2967	0.417	b
JF	0.688	0.0666	329	0.5570	0.819	c

Table S2. Tukey test comparing the volume of food consumed by each demographic category across different seasons (season*cat). Different letters indicate different means among the compared categories.

emmean	SE	df	lower.CL	upper.CL	group	diferences
Rainy_AF	3.09	0.191	391	2.718	3.47	b
Rainy_JF	3.56	0.177	391	3.215	3.91	b
Rainy_AM	1.58	0.540	391	0.513	2.64	a
Rainy_JM	3.48	0.107	391	3.272	3.69	b
Dry_AF	3.39	0.270	391	2.856	3.92	ab
Dry_JF	3.60	0.156	391	3.290	3.90	b
Dry_AM	3.11	0.097	391	2.914	3.30	ab
Dry_JM	3.15	0.083	391	2.991	3.32	ab

Table S3. Tukey test comparing the volume of items consumed across each season (season*item). Different letters indicate different means among the compared categories.

emmean	SE	df	lower.CL	upper.CL	.group	diferences
RainyAnt	-0.693	0.8512	380	-2.37	0.98	a
DryPlas	-0.470	0.8512	380	-2.14	1.20	ab
DryHem	0.405	0.8512	380	-1.27	2.08	abc
DryCol	0.629	0.8512	380	-1.04	2.30	abcde
DrySpi	2.238	0.6019	380	1.05	3.42	abcdef
RainyEph	2.251	0.4914	380	1.29	3.22	abcdef
DrySand	2.491	0.2006	380	2.10	2.89	bcd
RainySand	2.500	0.4256	380	1.66	3.34	abcdef
DryEph	2.550	0.6019	380	1.37	3.73	abcdef
RainyUa	2.865	0.2837	380	2.31	3.42	cdef
DryShr	2.931	0.8512	380	1.26	4.60	abcdef
RainyDet	2.945	0.1216	380	2.71	3.18	cde
DryDet	3.012	0.0864	380	2.84	3.18	cd
DryUa	3.103	0.2361	380	2.64	3.57	cdef
RainyCol	3.244	0.6019	380	2.06	4.43	cdef
DryPlan	3.441	0.0761	380	3.29	3.59	ef
DryMol	3.657	0.3217	380	3.02	4.29	def
RainyPlan	3.781	0.1090	380	3.57	3.99	f
RainyMol	4.030	0.6019	380	2.85	5.21	cdef

Table S4. Tukey test comparing the volume of items consumed by different demographic categories (cat*item). Different letters indicate different means among the compared categories.

emmean	SE	df	lower.CL	upper.CL	.group	diferences
AF_Ant	-0.693	0.8565	372	-2.38	0.991	a
JM_Plas	-0.470	0.8565	372	-2.15	1.214	ab
AF_Col	0.223	0.8565	372	-1.46	1.907	abc
JF_Hem	0.405	0.8565	372	-1.28	2.090	abc
AM_Col	0.629	0.8565	372	-1.06	2.313	abcde
AM_Sand	1.943	0.3497	372	1.26	2.630	abc
JM_Eph	1.985	0.4282	372	1.14	2.827	abcd
JM_Spi	2.238	0.6056	372	1.05	3.429	abcdef
AF_Ua	2.565	0.4282	372	1.72	3.407	abcdef
JM_Sand	2.617	0.2375	372	2.15	3.084	abcd
JF_Sand	2.621	0.6056	372	1.43	3.812	abcdef
JM_Det	2.908	0.1009	372	2.71	3.107	cd
AM_Det	2.911	0.1491	372	2.62	3.204	cd
JM_Shr	2.931	0.8565	372	1.25	4.615	abcdef
AF_Sand	2.931	0.8565	372	1.25	4.615	abcdef
JM_Ua	3.064	0.2375	372	2.60	3.532	cdef
AF_Det	3.140	0.2375	372	2.67	3.607	cdef
AM_Plan	3.142	0.1277	372	2.89	3.393	cde
AM_Ua	3.152	0.3830	372	2.40	3.905	cdef
JF_Det	3.186	0.1619	372	2.87	3.504	cdef
AM_Eph	3.219	0.8565	372	1.53	4.903	Abcdef

JM_Mol	3.462	0.4282	372	2.62	4.304	Cdef
AF_Plan	3.465	0.2141	372	3.04	3.886	Cdef
JM_Plan	3.619	0.0893	372	3.44	3.794	Ef
JF_Plan	3.877	0.1491	372	3.58	4.171	F
JM_Col	3.912	0.8565	372	2.23	5.596	Bcdef
AM_Mol	3.937	0.3830	372	3.18	4.690	Def

Table S5. Tukey test comparing the frequency of occurrence of different food items. Different letters indicate different means among the compared categories.

emmean	SE	Df	asymp.LCL	asymp.UCL	.group	diferences
Ant	-5.805	1.001	Inf	-7.768	-3.842	ab
Plas	-5.805	1.001	Inf	-7.768	-3.842	ab
Shr	-5.805	1.001	Inf	-7.768	-3.842	ab
Hem	-5.805	1.001	Inf	-7.768	-3.842	ab
Spi	-5.109	0.709	Inf	-6.499	-3.719	a
Col	-4.700	0.580	Inf	-5.837	-3.564	a
Eph	-4.184	0.451	Inf	-5.067	-3.300	ab
Mol	-3.584	0.338	Inf	-4.246	-2.921	ab
Sand	-2.649	0.221	Inf	-3.081	-2.216	b
Ua	-2.649	0.221	Inf	-3.081	-2.216	b
Det	-0.248	0.110	Inf	-0.464	-0.031	c
Plan	0.235	0.110	Inf	0.019	0.452	c

Table S6. Tukey test comparing the frequency of occurrence of each food item among different demographic categories (cat*item). Different letters indicate different means among the compared categories.

emmean	SE	Df	asymp.LCL	asymp.UCL	.group	diferences
JF_Ant	-20.566	2.996.979	Inf	-5.894.538	5.853.406	abcdefg
JF_Plas	-20.566	2.996.979	Inf	-5.894.538	5.853.406	abcdefg
JF_Col	-20.566	2.996.979	Inf	-5.894.538	5.853.406	abcdefg
JF_Eph	-20.566	2.996.979	Inf	-5.894.538	5.853.406	abcdefg
AF_Eph	-20.566	2.270.141	Inf	-4.469.961	4.428.829	abcdefg
JM_Hem	-20.566	1.376.144	Inf	-2.717.758	2.676.626	abcdefg
AM_Spi	-20.566	2.104.208	Inf	-4.144.738	4.103.605	abcdefg
AM_Hem	-20.566	2.104.208	Inf	-4.144.738	4.103.605	abcdefg
AF_Shr	-20.566	2.270.141	Inf	-4.469.961	4.428.829	abcdefg
AF_Plas	-20.566	2.270.141	Inf	-4.469.961	4.428.829	abcdefg
AF_Spi	-20.566	2.270.141	Inf	-4.469.961	4.428.829	abcdefg
JM_Ant	-20.566	1.376.144	Inf	-2.717.758	2.676.626	abcdefg
JF_Mol	-20.566	2.996.979	Inf	-5.894.538	5.853.406	abcdefg
JF_Shr	-20.566	2.996.979	Inf	-5.894.538	5.853.406	abcdefg
AM_Shr	-20.566	2.104.208	Inf	-4.144.738	4.103.605	abcdefg
JF_Ua	-20.566	2.996.979	Inf	-5.894.538	5.853.406	abcdefg
AM_Plas	-20.566	2.104.208	Inf	-4.144.738	4.103.605	abcdefg
AF_Hem	-20.566	2.270.141	Inf	-4.469.961	4.428.829	abcdefg
JF_Spi	-20.566	2.996.979	Inf	-5.894.538	5.853.406	abcdefg
AM_Ant	-20.566	2.104.208	Inf	-4.144.738	4.103.605	abcdefg
AF_Mol	-20.566	2.270.141	Inf	-4.469.961	4.428.829	abcdefg

JM_Plas	-5.106	1.003	Inf	-7.072	-3.140	ab
JM_Shr	-5.106	1.003	Inf	-7.072	-3.140	ab
JM_Col	-5.106	1.003	Inf	-7.072	-3.140	ab
JM_Spi	-4.407	0.711	Inf	-5.801	-3.012	a
AM_Eph	-4.248	1.007	Inf	-6.222	-2.275	abc
AM_Col	-4.248	1.007	Inf	-6.222	-2.275	abc
AF_Sand	-4.094	1.008	Inf	-6.071	-2.118	abc
AF_Col	-4.094	1.008	Inf	-6.071	-2.118	abc
AF_Ant	-4.094	1.008	Inf	-6.071	-2.118	abc
JM_Mol	-3.701	0.506	Inf	-4.693	-2.709	a
JM_Eph	-3.701	0.506	Inf	-4.693	-2.709	a
JF_Hem	-3.526	1.015	Inf	-5.515	-1.538	abcde
JF_Sand	-2.803	0.728	Inf	-4.231	-1.376	abc
AF_Ua	-2.657	0.517	Inf	-3.671	-1.643	ab
AM_Ua	-2.580	0.464	Inf	-3.489	-1.671	ab
AM_Mol	-2.580	0.464	Inf	-3.489	-1.671	ab
JM_Ua	-2.465	0.289	Inf	-3.032	-1.899	ab
JM_Sand	-2.465	0.289	Inf	-3.032	-1.899	ab
AM_Sand	-2.383	0.427	Inf	-3.219	-1.546	ab
AF_Det	-1,306	0.313	Inf	-1,919	-0.693	bc
AF_Plan	-1,034	0.291	Inf	-1,605	-0.464	bcd
JM_Det	-0.267	0.157	Inf	-0.574	0.040	cdef
AM_Det	-0.141	0.238	Inf	-0.607	0.325	cdefg
JM_Plan	0.218	0.156	Inf	-0.088	0.524	defg
AM_Plan	0.549	0.246	Inf	0.066	1.031	Efg

JF_Det	1.386	0.423	Inf	0.558	2.215	fg
JF_Plan	2.803	0.728	Inf	1.376	4.231	g

Capítulo 3

Niche differentiation between two sympatric decapod species: insights from carbon and nitrogen stable isotopes

Abstract

Decapods are abundant and diverse, playing significant ecological roles in freshwater ecosystems. Further, additional research on their trophic ecology and interactions is crucial. Stable isotopes, especially carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$), offer valuable insights into their food consumption, ecological niches, trophic positions, and interspecific interactions. The aim of this study was to investigate isotopic signatures, niche overlap, and trophic interactions between crab *Dilocarcinus pagei* (Trichodactylidae) and shrimp *Macrobrachium pantanalense* (Palaemonidae), in the Araguari River in the Brazilian Cerrado. Sampling was carried out during the dry season (June 2022) and included potential food sources for decapods. The samples were dried and homogenized, and isotopic ratios were determined using Continuous Flow Isotope Ratio Mass Spectrometry for stable isotope analysis. Carbon and nitrogen isotopic compositions were plotted on a bi-plot graph to evaluate the trophic structure and interactions between the decapod species and their resources. Additionally, the isotopic niche (evaluated through the Standard Ellipse Area - SEA) was calculated to assess niche size and overlap among species, while the trophic position was determined to identify the trophic levels of each species. *Dilocarcinus pagei* exhibited a greater variation in δ13C values, resulting in a larger isotopic niche (SEA = 12.91) than *M. pantanalense* (SEA = 3.55). This outcome implies that *D. pagei* exploits a broader range of resources within the ecosystem. In addition, the niche overlap between the two species was relatively low, suggesting that *D. pagei* and *M. pantanalense* feed differently and likely utilize different habitats or carbon sources. The enriched δ15N values observed in *M. pantanalense* compared to *D. pagei* indicate significant differences in trophic hierarchy, indicating that *M. pantanalense* feeds at higher trophic levels and may consume more nitrogen-rich prey. These findings enhance our understanding of the trophic ecology and interactions between these two species, highlighting the importance of niche differentiation for their coexistence.

Keywords: Stable isotopes; food web; aquatic environments; crustacean; diets

Resumo

Os decápodes são abundantes e diversos, desempenhando papéis ecológicos significativos nos ecossistemas de água doce. Além disso, pesquisas adicionais sobre sua ecologia trófica e interações são cruciais. Isótopos estáveis, especialmente carbono ($\delta^{13}C$) e nitrogênio ($\delta^{15}N$), oferecem informações valiosas sobre seu consumo alimentar, nichos ecológicos, posições tróficas e interações interespecíficas. O objetivo deste estudo foi investigar assinaturas isotópicas, sobreposição de nichos e interações tróficas entre o caranguejo *Dilocarcinus pagei* (Trichodactylidae) e o camarão *Macrobrachium pantanalense* (Palaemonidae), no rio Araguari, no Cerrado brasileiro. A amostragem foi realizada durante a estação seca (junho de 2022) e incluiu potenciais fontes de alimento para decápodes. As amostras foram secas e homogeneizadas, e as razões isotópicas foram determinadas usando espectrometria de massa de razão isotópica de fluxo contínuo para análise de isótopos estáveis. As composições isotópicas de carbono e nitrogênio foram plotadas em um gráfico bi-plot para avaliar a estrutura trófica e as interações entre as espécies de decápodes e seus recursos. Adicionalmente, o nicho isotópico (avaliado através da Standard Ellipse Area - SEA) foi calculado para avaliar o tamanho do nicho e a sobreposição entre as espécies**.** *Dilocarcinus pagei* exibiu uma maior variação nos valores de δ13C, resultando em um nicho isotópico (SEA = 12.91) maior do que o de *M. pantanalense* (SEA = 3.55). Esse resultado sugere que *D. pagei* explora uma gama mais ampla de recursos dentro do ecossistema. Além disso, a sobreposição de nicho entre as duas espécies foi relativamente baixa, sugerindo que *D. pagei* e *M. pantanalense* possuem estratégias alimentares distintas e provavelmente utilizam habitats ou fontes de carbono diferentes. Os valores enriquecidos de δ15N observados em *M. pantanalense* em comparação com *D. pagei* indicam diferenças significativas em suas hierarquias tróficas, sugerindo que *M. pantanalense* se alimenta em níveis tróficos mais altos e pode consumir presas mais ricas em nitrogênio. Esses achados ampliam nossa compreensão sobre a ecologia trófica e as interações entre essas duas espécies, destacando a importância da diferenciação de nicho para sua coexistência.

Palavras chaves: Isótopos estáveis; rede alimentar; ambientes aquáticos; crustáceos; dietas

Introduction

In tropical rivers, decapod crustaceans, such as crabs and shrimps, are numerically dominant and play a crucial role in aquatic food webs, contributing to the trophic ecology of these environments (Collins et al., 2007; Wantzen et al., 2016). These organisms are typically found in floodplains rich in aquatic vegetation, which serve as essential refuges and primary food sources (Burns & Walker, 2000). Acting as detritivores, primary and secondary consumers, and occasionally as predators or prey, decapods are vital in transferring energy and nutrients along the food chain (Collins et al., 2007). Through these roles, decapods can regulate the availability of resources across different trophic levels, influencing the structure and function of aquatic ecosystems (Cumberlidge, 2014; Mao et al., 2016; Toh et al., 2022).

In South America, the decapod families Trichodactylidae and Palaemonidae are well represented and are known for their high densities and significant contribution to the trophic structure of local aquatic habitats (Collins et al., 2012). Among the species in these families are the crab *Dilocarcinus pagei* Stimpson, 1861 (Trichodactylidae) and the shrimp *Macrobrachium pantanalense* (Palaemonidae). *Dilocarcinus pagei* is native to the Amazon basin, Paraguay and the lower Paraná (Magalhães, 2003; Herrera et al., 2013), while *M. pantanalense* is originally found in the upper Paraguay basin, particularly in the Pantanal region (Dos Santos et al., 2013; Soares et al., 2017).

Demonstrating considerable ecological adaptability, *D. pagei* has established itself in various Brazilian river basins, including the Upper Paraná Basin (Pinheiro & Taddei, 2005; Darim et al., 2007; Azevedo-Santos & Lima-Stripari, 2010; Taddei & Herrera, 2010; Davanso et al., 2013, 2016; Herrera et al., 2013; Taddei et al., 2015; Garcia et al., 2021; Barboza et al., 2023; da Silva & Nogueira, 2023), where it may have been introduced through sport fishing activities or accidentally transported with the roots of aquatic macrophytes or by other anthropogenic actions (Magalhães, 2003; Magalhães et al., 2005, 2016; Silva-Junior et al., 2017).

Dilocarcinus pagei and *M. pantanalense* have significant economic value. *Dilocarcinus pagei* has an optimal potential for aquaculture and is used as a fishery resource in the Amazon region (Sant'Anna et al., 2015; Viana, 2019). In the same way, *M. pantanalense* is widely used in commercial fishing, aquaculture, and aquarism (David et al., 2021; Hooper et al., 2023). Additionally, it is recognized as an important environmental indicator because of its sensitivity to anthropogenic changes and its role in the food chain (Freitas et al., 2021).

Recently, *D. pagei* and *M. pantanalense* were reported in the Araguari River, in the upper Paraná basin, by Barboza et al. (2023) and Calixto-Cunha et al. (2021), respectively. The Araguari River has a significant history of cascade dams, which have led to the formation of reservoirs and various environmental impacts, such as flooding of areas, suppression of riparian and aquatic vegetation, changes in hydrodynamics and increased nutrient availability (Santiago do Vale et al., 2021). These changes have created opportunities for invasive species from the Asian continent, such as the golden mussel *Limnoperna fortunei* Dunker, 1856 (Linares et al., 2017), the Asian clam *Corbicula fluminea* Müller, 1774 (Maroneze et al., 2011; Linares et al., 2017) and *Melanoides tuberculata* Müller, 1774 (Maroneze et al., 2011; Martins et al., 2015), which have established populations in the river. Mussels, *L. fortunei,* readily encrust in the pipelines of hydropower plants, leading to significant socio-economic impacts (Mansur et al., 2004; Darrigran et al., 2020). In addition, these organisms, including Asian clam, cause significant ecological impacts, including changes in substrate composition, where they act as ecosystem engineers, and changes in nutrient availability and water quality, which in turn affect the biological communities that depend on these habitats (Robinson &

Wellborn, 1988; Voelz et al., 1998; Ricciardi, 1998; Cataldo & Boltovskoy, 1998; De Oliveira et al., 2006; Pimpão & Martins, 2008; Boltovskoy & Cataldo, 2009; Darrigran & Damborenea, 2011; Lucy et al., 2012; Barbosa et al., 2018; Fortunato et al., 2022; Linares et al., 2019).

These molluscs are known to be part of the diet of various predators, including decapods (Dudgeon & Catherine, 1990; Torres et al., 2012; Carvalho et al., 2013; Quinn, 2020). For instance*,* *D. pagei* feeds primarily on plant material and organic detritus, but occasionally also on small invertebrates (Williner & Collins, 2002; Viana et al., 2023; author's personal observation - unpublished data), and potentially invasive molluscs (author's personal observation - unpublished data), as has also been observed in other freshwater crabs (Rudnick, 2005; Sylvester et al., 2007). Experimental studies have demonstrated the importance of *L. fortunei* as a food source for various species of freshwater crabs. Torres et al. (2012), showed that *L. fortunei* was selected in different sizes and included in the diet of the crab *Zilchiopsis collastinensis* Pretzmann, 1968. Complementing these results, Carvalho et al. (2013) confirmed the same for *Trichodactylus borellianus* Nobili 1896.

In contrast, the natural diet of *M. pantanalense* was still unknown at the time of this study. It is expected that it does not differ significantly from that of its close relative, *Macrobrachium amazonicum* Heller 1862, due to the close phylogenetic relationship (Calixto-Cunha et al., 2021). This species is known for their varied diet, reflecting an adaptation to the available resources in the aquatic environment. *Macrobrachium amazonicum* consumes a higher proportion of aquatic invertebrates, such as insect larvae, depending on their availability in the habitat (da Cruz et al., 2023).

Omnivorous benthic decapods facilitate the flow of energy between different trophic levels by occupying multiple trophic levels and integrating into the food web

(Simon et al., 2019) and contribute to the regulation of prey populations by avoiding outbreaks that could destabilize the ecosystem (Collins et al., 2012). The coexistence of species such as the decapods in the Araguari River and their dietary adaptations provides an opportunity to study niche overlap and competition for resources in this ecosystem (Lawlor, 1980; Siqueira et al., 2009; Hill et al., 2015; De Castro et al., 2016; Galvez et al., 2022). Niche overlap, including the trophic positions species occupy, within the food web is an important aspect of community structure and can be studied using stable isotope analysis (Lawlor, 1980; Wada et al., 1991; Rudnick & Resh, 2005; Jackson et al., 2011). This method provides information on the isotopic signatures of species, reflecting their diet and habitat use, by examining differences in the isotopic ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) (Wada et al., 1991).

Therefore, the aim of this study was to investigate the trophic ecology of decapod species in the Araguari River, Minas Gerais, Brazil, by analyzing stable isotopes of carbon and nitrogen. Specifically, our study analyzed the stable isotope signatures of two decapod species to understand how differences in their diets are reflected in their isotopic compositions, and what this reveal about their niche differentiation and trophic position. To answer these questions, we tested the following hypotheses: i) *Dilocarcinus pagei* and *M. pantanalense* exhibit differences in $\delta^{13}C$ signatures that reflect their different food sources. It is expected that the $\delta^{13}C$ signatures of *D. pagei*, which consumes more plant material, reflect aquatic plant sources, while the $\delta^{13}C$ signatures of *M. pantanalense,* which eats more invertebrates, are closer to those of aquatic consumers. ii) We expect a low niche overlap between these two decapod species due to their different diets; iii) We hypothesize that if *D. pagei* consumes mainly plant material, exhibiting lower $\delta^{15}N$ ratios indicating a lower trophic position in the Araguari River ecosystem. In contrast, if *M. pantanalense* relies more on animal resources than *D. pagei*, it will present higher $\delta^{15}N$

ratios, reflecting its higher trophic level; iv) If *D. pagei* eats invasive mussels and gastropods, its $\delta^{13}C$ signature will match that of the mussels, indicating a similarity in $\delta^{13}C$ values.

Materials and methods

Study area

The study area is located along the lower Araguari River, 30 km upstream of its confluence with the Paranaíba River and 50 km downstream of the Amador Aguiar II (AA II) dam in Minas Gerais, Brazil (Figure 1). The Araguari River has its headwaters in the heights of the Serra da Canastra National Park, situated within the Brazilian Cerrado biome and the Paraná basin (Alvares et al., 2013; Beck et al., 2018). The area is characterized by a Köppen Cw climate, which is described as semi-humid tropical with an average temperature of 23°C. There are dry months from April to September, followed by humid months from October to March (Rodrigues & Silva, 2012).

The Araguari River is influenced by four cascade dams (Amador Aguiar I, Amador Aguiar II, Nova Ponte and Miranda) built for hydroelectric power generation, which have altered its hydrological system. These structures regulate water flow, influence the dynamics of floods and droughts, and define the characteristics of the wetland area within the floodplain.

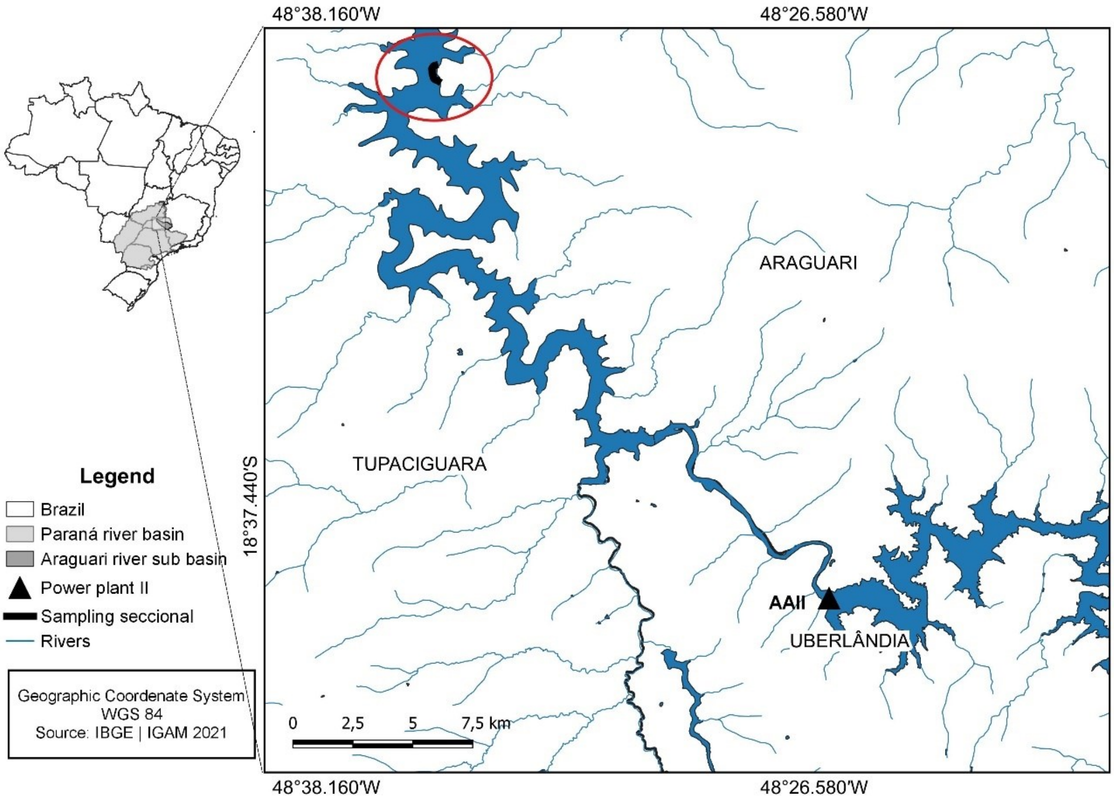

Figure 1. The red circle shows the sampled section in the Araguari River, Minas Gerais, Brazil, which marks the study area between -18.4544°S, -48.5925°W and -18.4497°S, -48.5916°W.

In this area there are remnants of Cerrado biome forests in the upper floodplain, but the riparian vegetation in the lower areas has been displaced by the flooding of the Itumbiara/Furnas hydroelectric plant on the Paranaíba River in the 1980s (Santiago do Vale et al., 2021) and also, by the impact of four cascade dams upstream on the Araguari River. The land is mainly used for grazing and shows signs of degradation such as exposed soils and contraction fissures during river water recession. Various angiosperms dominate the land-water interface (author's personal observation), including grasses (Poaceae family), pteridophytes such as *Salvinia* sp. (Salviniaceae family) and macrophytes such as *Eichhornia crassipes* (Pontederiaceae family), which respond to water level changes. Non-native mollusc species such as *Limnoperna fortunei* (golden mussel), *Corbicula fluminea* (Asian clam) and *Melanoides tuberculata* were also observed in the area.

Sampling

Sampling was conducted once during the dry season (June) in 2022. Our sampling for isotopic analysis included organisms that could represent potential resources in the decapod crustacean food web, such as benthic insects, molluscs, aquatic plants, and terrestrial plants (see Table 1). This method allowed us to focus on the decapods while considering the broader context of their food chain and sources from aquatic and terrestrial environments. Availability of food resources was sampled simultaneously with the collection of decapods (see supplementary material Table S1).

Table 1. Number of samples collected for isotopic analysis ($\delta^{13}C$ and $\delta^{15}N$) during the dry season (June 2022) in the Araguari River, Minas Gerais, Brazil.

Category	N sample ($\delta^{13}C$ and $\delta^{15}N$)
Decapoda	
Dilocarcinus pagei Stimpson, 1861	7
Macrobrachium pantanalense Dos Santos, Hayd & Anger, 2013	7
Food Resources	
Benthic insect larvae (Mixing: Aeshnidae+Libellulidae+Hemiptera)	5
Corbicula fluminea Müller, 1774	5
Limnoperna fortunei Dunker, 1857	5
Melanoides tuberculata Müller, 1774	5
Aquatic plant (Mixing: *Eichhornia crassipes+Salvinia sp.*)	5
Terrestrial plant (Mixing: *Alberta edulis+Annona crassfolia+Hirtela gracilpes*)	5

For decapods, such as the crab *Dilocarcinus pagei*, we used manual collection methods and a sieve (3 mm mesh size) for both *D. pagei* and *M. pantanalense*, targeting individuals hidden in aquatic vegetation or under leaf litter in the riverbed. All collected decapods were adults

Benthic insects and molluscs were sampled with a D-frame (30 cm opening, 250 µm mash) and an area of 0.09 m² (Peck et al., 2006). Sampling occurred from downstream to upstream, following a zigzag route along the substrate and among aquatic plants where these organisms are commonly found (Castro et al., 2017). Both terrestrial and aquatic plants (fresh leaves) were collected by hand, and the species were placed in plastic bags individually. Subsequently, all captured invertebrates were stored in a thermal container with ice and transported together with the plants to the Laboratory of Aquatic Ecosystem Ecology (LEEA/UFU). For the taxonomic identification of organisms, we relied on specific literature, including Melo (2003) for crustaceans and taxonomic keys for benthic invertebrates (Hamada et al., 2014; Mugnai et al., 2010). Molluscs were sent to the Zoological Museum of the USP (MZUSP) for identification, and plants were identified with the help of specialists from the Department of Botany of the Federal University of Uberlândia.

Stable isotope analysis

For isotope analysis, we extract at least 2-5 mg of animal tissue (muscle tissue), and 5-10 mg of aquatic and terrestrial plant samples, which were dried for 48 hours at 50°C (de Carvalho et al., 2019). Subsequently, the samples were stored in Eppendorf tubes and sent to the Stable Isotopes Center (CEI) at Paulista State University (UNESP) in Botucatu, São Paulo. At the CEI, the samples were homogenized using a cryogenic mill (Geno/Grinder 2010 – SPEX SamplePrep, USA), and a 0.800 to 1.200 mg aliquot was weighed into 5.0 x 8.0 mm tin capsules using a balance with a 0.001 mg resolution

(XP6 – Mettler Toledo, Switzerland). The drying and homogenization of the samples were necessary to obtain representative aliquots of dry mass in the capsules.

To determine the stable isotope ratio, encapsulated samples were analyzed using a continuous-flow isotope ratio mass spectrometry system (CF-IRMS) comprising an IRMS (Delta V, Thermo Scientific, Germany) coupled to an elemental analyzer EA (Flash 2000, Thermo Scientific, Germany) through a gas interface (ConFlo IV, Thermo Scientific, Germany). The CF-IRMS determined the isotopic ratios of stable nitrogen R(^{15}N/^{14}N) and carbon R (^{13}C/^{12}C), which were expressed as relative differences in isotopic ratios (δ^{15}N and δ^{13}C) based on international standards PeeDeeBelemnite (VPDB) e Air (atmosfheric Nitrogen), as per equations 1 and 2, respectively (Coplen, 2011). For each element, CF-IRMS also determined the levels of total nitrogen (TN) and total organic carbon (TOC), expressed in relation to dry mass, as per equations 3 and 4.

$$(1)\ \delta^{15}N_{(\text{‰})} = \frac{R\left({}_{\square}^{15}N/{}_{\square}^{14}N\right)_{sample}}{R\left({}_{\square}^{15}N/{}_{\square}^{14}N\right)_{Air}} - 1 \qquad (2)\ \delta^{13}C_{(\text{‰})} = \frac{R\left({}_{\square}^{13}C/{}_{\square}^{12}C\right)_{sample}}{R\left({}_{\square}^{13}C/{}_{\square}^{12}C\right)_{VPDB}} - 1$$

$$(3)\ TN_{(\%)} = \frac{nitrogen\ mass}{dry\ mass} \qquad (4)\ TOC_{(\%)} = \frac{organic\ carbon\ mass}{dry\ mass}$$

The results were standardized using the NBS-22 and IAEA-N1 standards. The standard uncertainty of the IRMS for δ^{15}N or δ^{13}C is ±0.15‰, and for TN or TOC, it is ±0.30‰. Each isotope value represents a specific measurement of a single.

Data analysis

To investigate the trophic structure of *D. pagei* and *M. pantanalense*, we utilized a four-step approach. **Step 1:** We performed a t-test to determine if there were significant differences in the isotopic compositions of $\delta^{13}C$ and $\delta^{15}N$ between the decapod species. This test helped us to determine whether the two species utilize different food resources or occupy different positions within the food chain. **Step 2:** Next, the isotopic compositions of carbon (x-axis) and nitrogen (y-axis) were plotted in a bi-plot graph to assess the trophic structure and interactions between the decapod species and their resources. These plots show the decapod samples along with the means and standard deviations of the potential food resources and provide a clear visualization of the isotopic relationships between sources and consumers. This method helps to identify key food resources, determine species' positions in the food web and distinguish between species with similar or different diets, providing information on their trophic interactions and food consumption (Wada et al., 1991; McCutchan et al., 2003; Vander Zanden et al., 2015).

Step 3: We calculated the isotopic niche of *D. pagei* and *M. pantanalense* using the Standard Ellipse Area (SEA - expressed in ‰^{2}) to assess niche size and overlap between species. This analysis was performed using the Stable Isotope Bayesian Ellipses in R (SIBER) package (Jackson, 2011). The application of SEAc (corrected for differences in sample size) improves the accuracy of comparisons by facilitating the assessment of niche differences between species, even when sample sizes vary. The SEAc metric allows us to calculate the degree of niche overlap (as a percentage, where 100% represents complete overlap) and serves as a quantitative measure of dietary similarity between different species (Hill et al., 2015).

Step 4: Finally, we then calculated the trophic position (T_p) occupied by *D. pagei* and *M. pantanalense* , using the formula described by Vander Zanden et al. (1997): $T_p = [(\delta^{15}N_{decapod} - \delta^{15}N_{resources}) \div 3.0] + 1$, where $\delta^{15}N_{decapod}$ = $\delta^{15}N$ values of decapod, $\delta^{15}N_{resources}$ = mean values of $\delta^{15}N$ of basal resources (aquatic plant), 3.0 represents the fractionation per trophic level (McCutchan et al., 2003), and 1 is the position of producers within the food chain. This allows us to compare whether each species feeds at the same trophic levels at the sampling site. To determine if there were significant differences in the trophic levels occupied by the decapods, we performed a t-test.

Results

The isotopic compositions varied between decapods for both carbon ($t = 2.429$, $p = 0.038$) and nitrogen ($t = -2.679$, $p = 0.0218$) (Fig. 2a,b). Stable isotope values of $\delta^{13}C$ were more enriched for *D. pagei* than for *M. pantanalense*. In contrast, values of $\delta^{15}N$ were more enriched for *M. pantanalense* than for *D. pagei*.

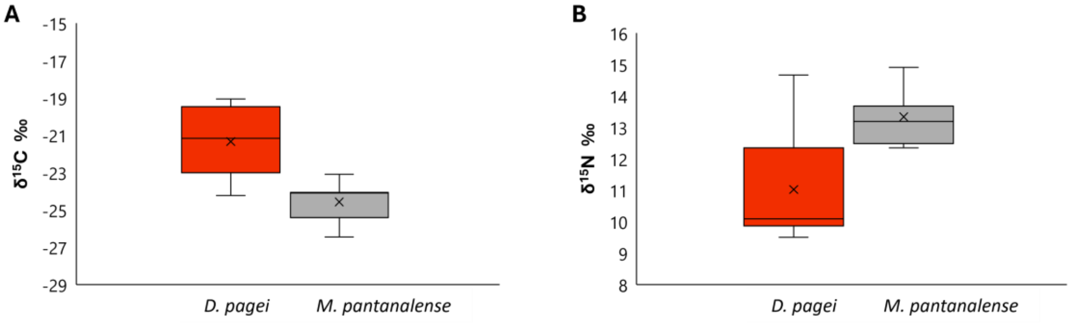

Figure 2. Variation in $\delta^{13}C$ **(a)** and $\delta^{15}N$ **(b)** values of *D. pagei* and *M. pantanalense* in the Araguari River, Minas Gerais, Brazil. The central line represents the median, the box represents the interquartile range (IQR), the whiskers represent the minimum and maximum values, and "X" represents the mean.

Differences between decapod resource utilization were further reflected by their distributions in carbon-nitrogen bi-plot space (Fig. 3), in the amplitude of the isotopic niche (Fig. 4a) and in its trophic position (Fig. 4b).

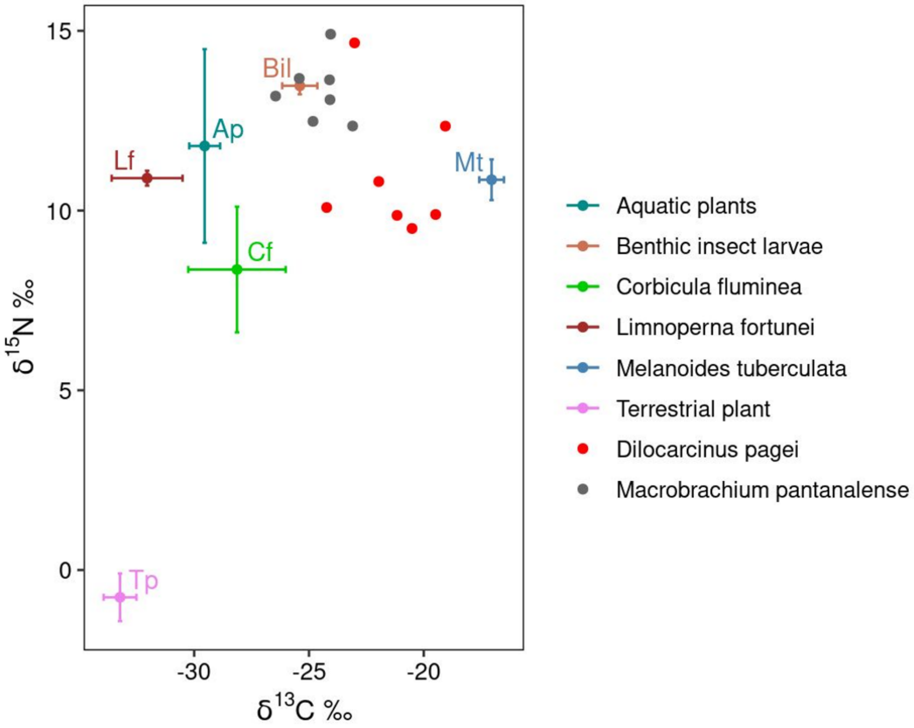

Figure 3. Stable isotope signatures ($\delta^{13}C$ and $\delta^{15}N$, mean ± SD) and food web representation (bi-plot space) for decapod species (red and gray symbols) and their potential basal food resources sampled from the Rio Araguari, Minas Gerais, Brazil. (AP = Aquatic plants; Bil = Benthic Insect larvae; Cf = *Corbicula fluminea*; Lf = *Limnoperna fortunei*; Mt = *Melanoides tuberculata*; Tp = Terrestrial plant).

The isotopic niche was wider for *D. pagei* (TA = 17.37; SEA = 10.76; SEAc = 12.91), than for *M. pantanalense* (TA = 4.39; SEA = 2.96; SEAc = 3.56) (Fig. 4a). The niche overlap between the two species was relatively low, with only 20% overlap observed, indicating distinct diets. Regarding trophic hierarchy, *M. pantanalense* displayed higher trophic positions than *D. pagei* (F = 8.83, p = 0.01) (Fig. 4b).

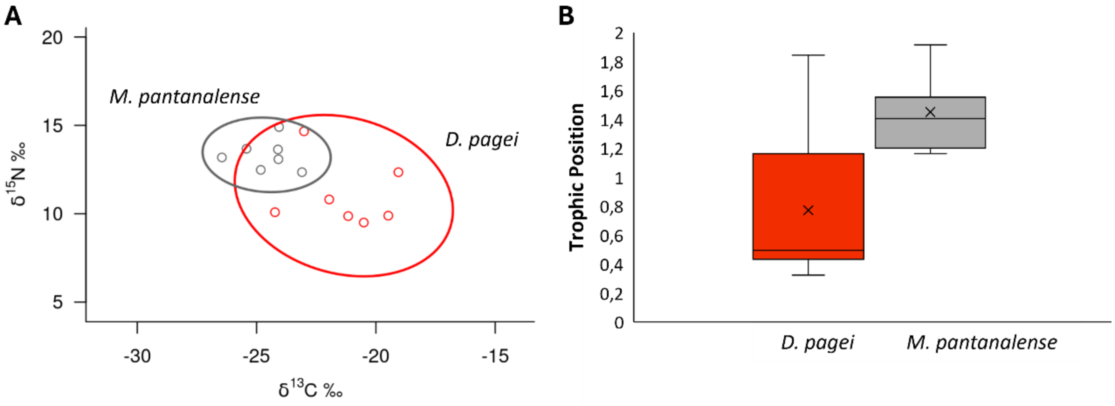

Figure 4. Isotopic niche **(a)** (evaluated by the ellipse area with 95% confidence interval) and trophic position **(b)** of *Dilocarcinus pagei* (red color) and *Macrobrachium pantanalense* (gray color) in the Araguari River, Minas Gerais, Brazil. In **(b)**, the central line represents the median, the box represents the interquartile range (IQR), the whiskers represent the minimum and maximum values, and "X" represents the mean.

Discussion

Differences in the $\delta^{13}C$ isotope signatures

Our first hypothesis that *M. pantanalen*se and *D. pagei* would exhibit distinct $\delta^{13}C$ isotopic signatures reflecting their different food sources was supported. Our results show that *M. pantanalense* has a $\delta^{13}C$ signature closer to aquatic organisms, with a narrower isotopic range compared to *D. pagei*. Similar to *M. pantanalense*, other species in the genus *Macrobrachium* may have a more specialized diet, with less variation in carbon sources, suggesting a more consistent and specific feeding behavior. Supporting this idea, studies on *M. amazonicum* and *Macrobrachium brasiliense* Heller, 1862 in natural environments highlight the crucial role of aquatic invertebrates in the diet of these species (da Cruz et al., 2021). In particular, *M. brasiliense* shows a notable increase in insect consumption as the shrimp matures suggests an adaptive shift in food sources during growth. Similarly, an experimental study on *M. amazonicum* found that aquatic invertebrates made a significant contribution to biomass growth, as estimated using stable isotope techniques (Heldt et al., 2019). Other examples, in species like *Macrobrachium hainanense* Parisi, 1919, $\delta^{13}C$ and $\delta^{15}N$ isotopic analyses confirm its predatory trophic status, with all life stages exhibiting higher isotopic signatures compared to other sympatric predatory invertebrates (Mantel & Dudgeon, 2004). *Macrobrachium borelli* Nobili, 1896 also displays a varied diet, with a marked tendency towards larger, protein-rich prey, reflecting a distinctly predatory behavior (Collins & Paggi, 1997). *Macrobrachium nipponense* De Haan 1849 in the Anzali Wetland (Iran) has a diet primarily composed of aquatic invertebrates, occupying a high trophic position (TL = 3.38), which reinforces its specialized diet (Mirzajani et al., 2020).

In contrast, *D. pagei* exhibits more enriched $\delta^{13}C$ isotopic signatures and a broader niche, reflecting a diet composed of a greater diversity of carbon sources. This suggests that *D. pagei* feeds on both aquatic plants and carbon sources derived from lower trophic level aquatic organisms. This interpretation is supported by the significant volume of macrophytes found in the stomachs of *D. pagei* crabs compared to other food items, such as aquatic insects (Chapter 2 of this thesis; Williner & Collins, 2002; Viana et al., 2023). Furthermore, a similar pattern is observed in other members of the Trichodactilidae family, indicating an adaptation to exploit the available plant resources in their environment. Although the isotopic analysis in this study focused on a mixture of two aquatic macrophyte species (*Eichhornia crassipes* and *Salvinia sp.*), whose isotopic signatures do not directly correspond to those observed in *D. pagei*, this discrepancy does not rule out the possibility that *D. pagei* may be utilizing other aquatic plants that were not sampled and analyzed in our study. Alternatively, there may be significant variation within the populations of these macrophytes or in specific parts of the plants that were not represented in the collected samples. Indeed, the literature indicates that aquatic plants can exhibit considerable isotopic variability, even within a single population, due to differences in microhabitats, access to dissolved inorganic carbon in the water, plant types (C3, C4, CAM), and the influence of environmental factors such as light, temperature, and the presence of organic matter (Osmond et al., 1981; Farquhar et al., 1989). Moreover, isotopic variation observed within the same plant species can exceed 10‰ within a single frond of algae, indicating that plants of the same type and location can contribute to a wide range of $\delta^{13}C$ values (Osmond et al., 1981; LaZerte & Szalados, 1982).

The broad range of $\delta^{13}C$ values observed in aquatic plants highlights the complexity of carbon sources available in aquatic environments. In the case of *D. pagei*, this variation suggests that its diet may include a mixture of these plants, each contributing differently to the final isotopic signature observed, resulting in an average signature that does not directly correspond to any specific species. This preference may be related to the abundance or accessibility of these plants in the crab's environment, or perhaps to the ease of processing and digesting these plant sources compared to more complex foods. It is relevant to mention that crustaceans have evolved to host specific endosymbiotic organisms in their digestive tracts, which may facilitate the digestion of plant materials (Štrus et al., 2019; Williner et al., 2013).

In addition to plants, *D. pagei* may include mollusks in its diet, which also contributes to the complexity of its isotopic signature. Filter-feeding mollusks, such as mussels, exhibit a wide range of $\delta^{13}C$ values that vary significantly depending on the organic particles they filter (Riera et al., 1999). Including these organisms in *D. pagei's* diet may enrich $\delta^{13}C$ values, bringing them closer to those of aquatic plants, but with additional variation that could explain the lack of a direct match with the macrophytes and mussels. Thus, the presence of a diverse range of aquatic plants, each with different isotopic signatures, along with the inclusion of mollusks and aquatic insects in the diet, could explain part of the broad range of $\delta^{13}C$ values observed in *D. pagei*. These factors emphasize the complexity of its diet and its ability to exploit different ecological niches, characterizing it as an opportunistic omnivorous species.

Isotopic Niche Overlap

The second hypothesis predicted a low isotopic niche overlap between the two decapod species due to expected dietary differences. The results support this, showing a 20% overlap in isotopic space, indicating that the species utilize different trophic niches. *Dilocarcinus pagei* exhibits a broader niche breadth, likely due to its consumption of a diverse range of food resources, including plant material, invertebrates, and detritus, as indicated in Chapter 2. In contrast, *M. pantanalense* shows a more specialized diet, reflected in its narrower isotopic niche breadth. The higher consumption of aquatic plants by *D. pagei* and the greater reliance on insects by *M. pantanalense* (Barboza et al., 2023) further support these dietary distinctions, with *M. pantanalense* demonstrating a stronger dependence on animal-derived resources in the Araguari River.

Trophic level and $\delta^{15}N$ isotope signatures

The third hypothesis predicted that *M. pantanalense* would exhibit higher $\delta^{15}N$ isotope ratios than *D. pagei*, reflecting a higher trophic position due to its greater dependence on animal resources. The data confirmed this, with *M. pantanalense* having elevated $\delta^{15}N$ values, indicating its superior trophic niche. This is consistent with the stomach content analysis, where *D. pagei* had a higher frequency of occurrence (FO) of aquatic plants (46.61%), while *M. pantanalense* was more dependent on insects, similar to *M. brasiliense*, which had the highest FO of insects (40.42%) compared to other species (Barboza et al., 2023). These results emphasize the dietary differences between the species, with *M. pantanalense* occupying a higher trophic level due to its consumption of animal resources, while *D. pagei* is more dependent on plant material.

Additional studies by da Cruz et al. (2021, 2023) also investigated the diets of *M. brasiliense* and *M. amazonicum*, highlighting the importance of insects in the diet of these species, particularly in habitats where animal resources are abundant. These studies underscore that an omnivorous diet, with a strong inclination toward animal resources, is a critical factor for the elevated trophic position of these species in aquatic ecosystems. Furthermore, stable isotope analysis of *M. amazonicum* revealed that this species occupies a higher trophic position within tropical stream ecosystems (Heldt et al., 2019; Winemiller et al., 2011). These findings corroborate the notion that species within the genus *Macrobrachium*, despite having variations in their diets, including *M. pantanalense*, can play crucial roles as predators and processors of organic matter in their natural habitats, occupying elevated trophic levels.

Consumption of invasive molluscs by D. pagei

Finally, the fourth hypothesis states that if *D. pagei* consumed invasive molluscs, its $\delta^{13}C$ signatures would reflect these food sources. Although the specific consumption of invasive molluscs was not directly associated with the items (prey) collected, the broad isotopic spectrum of $\delta^{13}C$ observed in *D. pagei* could indicate the ingestion of various carbon sources, possibly including molluscs. This possibility is supported by evidence of molluscan feeding by other species in the family Trichodactylidae. For example, *Zilchiopsis collastinensis* and *Trichodactylus borellianus* have been documented as a selective predator of the invasive bivalve *Limnoperna fortunei* (Torres et al., 2012;

Carvalho et al., 2013). In addition, *T. borellianus* was found to be an epibiont of this mussel, suggesting a complex interaction between these species (Molina & Williner, 2014).

In our study on the diet of *D. pagei* (Chapter 2 of this thesis), we observed the presence of shell fragments from the golden mussel *Limnoperna fortunei* in the stomach contents of some individuals, particularly during the dry season (early June). Our sampling of organisms for isotope analysis also took place during the dry season. According to Viozzi, et al. (2021) the isotopic incorporation rate of carbon (τ) for $\delta^{13}C$ in the muscles of shrimps (*Macrobrachium borellii*), is about 75.8 days. This means that the muscles primarily reflect what the organism has metabolized over a long period, especially in ectotherms like crustaceans (Vander Zanden et al., 2015). Although this test was performed in shrimp, given the physiological similarities between decapod crustaceans, this rate of incorporation may be a useful reference for interpreting the results in crabs (Peterson & Fry, 1987; Fry & Sherr, 1989).

Considering this, it is likely that the carbon signature observed in *D. pagei* reflects feeding during the rainy season (March), when more plant material is available for *D. pagei* to consume in higher quantities (Williner & Collins, 2002; unpublished data by the author). The isotopic composition could therefore represent an average value for the crab's diet during this period, reflecting the most abundant and consistent food sources. However, further specific studies on the isotopic incorporation rate in crabs would be necessary to confirm whether this estimate based on shrimp can be directly applied to *D. pagei*.

Conclusion

The results presented confirm many of the hypotheses formulated and illustrate the complexity of trophic interactions for *M. pantanalense* and *D. pagei*. The marked difference in trophic levels and niche breadth suggests that these two species coexist by minimizing direct competition and exploiting different food resources in the Araguari River ecosystem. These results contribute to a better understanding of the trophic ecology of decapod species in tropical aquatic systems and may inform management and conservation strategies, particularly in contexts where invasive species introductions and habitat modification have significant impacts.

Limitations and future directions

This study encountered some limitations that may have affected the ability to establish clear relationships between decapod species and their food resources. One of the main limitations was the scale of sampling, which may not have been comprehensive enough to capture the full range of potential food sources (or proper prey collection) in the ecosystem. In addition, the methods used in this study to infer trophic interactions between species (such as isotope signature analysis) provide valuable information but may not be sufficient to capture the full complexity of feeding relationships within the ecosystem. Future research could consider expanding sampling and applying complementary approaches, such as refining direct stomach content analysis, using molecular techniques to identify specific food sources more accurately, or conducting laboratory and field experiments to better understand the trophic ecology of species in the Araguari River ecosystem.

Acknowledgments

ACGB gives thanks for the doctoral scholarship provided by the Coordination for the Improvement of Higher Education Personnel (CAPES). CSN acknowledges the doctoral scholarship provided by the São Paulo State Research Support Foundation. We thank F.L.M. Barboza for extensive help during fieldwork and E.F. Dantas for kindly allowing access to the study area through their property, and the Museu de Zoologia da USP (MZUSP) for confirming the mollusk species.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico/Programa de Pesquisa Ecológica de Longa Duração [441142/2020-6]; Fundação de Amparo à Pesquisa do Estado de Minas Gerais [APQ-03372-21]; Fundação de Amparo à Pesquisa do Estado de São Paulo [2019/00661-3].

References

Albertoni, E. F., Palma-Silva, C., & Esteves, F. D. A. (2003). Natural diet of three species of shrimp in a tropical coastal lagoon. *Brazilian Archives of Biology and Technology*, *46*(3), 395–403. https://doi.org/10.1590/S1516-89132003000300011

Alho, C. J. R. (2020). Hydropower dams and reservoirs and their impacts on Brazil's biodiversity and natural habitats: A Review. *World Journal of Advanced Research and Reviews*, *6*(3), 205–215. https://doi.org/10.30574/WJARR.2020.6.3.0197

Alvares, C. A., Stape, J. L., Sentelhas, P. C., De Moraes Gonçalves, J. L., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*(6), 711–728. https://doi.org/10.1127/0941-2948/2013/0507

Alves, D. F. R., Martinez, P. A., Magalhães, C., Barros-Alves, S. de P., de Almeida, A. C., & Amado, T. F. (2024). Global patterns and predictors of primary freshwater crab richness across taxa and realms. *Hydrobiologia 2024 851:17*, *851*(17), 4149–4165. https://doi.org/10.1007/S10750-024-05572-9

Anacléto, M. J. P., Ligeiro, R., Barbosa, J. E. L., Molozzi, J., & Callisto, M. (2018). Effects of an atypical drought on the benthic macroinvertebrate community in a tropical reservoir. *Biota Neotropica*, *18*(2), e20170352. https://doi.org/10.1590/1676-0611-BN-2017-0352

Aragon, M., & Marinho-Filho, J. (2009). História natural e biologia reprodutiva de marsupiais no pantanal, Mato Grosso, Brasil. *Zoologia*, *26*(2), 220–230. https://doi.org/10.1590/S1984-46702009000200004

Azevedo-Santos, V. M., & Lima-Stripari, N. (2010). Primeiro registro de *Dilocarcinus pagei* Stimpson, 1861 (Decapoda, Trichodactylidae) no estado de Minas Gerais. *Biotemas*, *23*(2), 199–202. https://doi.org/10.5007/2175-7925.2010V23N2P199

Barbosa, N. P. U., Ferreira, J. A., Nascimento, C. A. R., Silva, F. A., Carvalho, V. A., Xavier, E. R. S., Ramon, L., Almeida, A. C., Carvalho, M. D., & Cardoso, A. V. (2018). Prediction of future risk of invasion by Limnoperna fortunei (Dunker, 1857) (Mollusca, Bivalvia, Mytilidae) in Brazil with cellular automata. *Ecological Indicators*, *92*, 30–39. https://doi.org/10.1016/J.ECOLIND.2018.01.005

Barboza, A. C. G., Nogueira, C. S., Calixto-Cunha, M., Londe, B. P., & Jacobucci, G. B. (2023). Population biology of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Trichodactylidae) in the Araguari River, south-eastern Brazil. *Journal of Natural History*, *57*(5–8), 427–444. https://doi.org/10.1080/00222933.2023.2190547

Bauer, R. T. (2004). *Remarkable shrimps: adaptations and natural history of the carideans*. University of Oklahoma Press.

Bauer, R. T. (2023). The Shrimps: An Overview. In *Shrimps: Their diversity, intriguing adaptations and varied lifestyles* (Vol. 42, pp. 1–17). Springer Nature. https://doi.org/10.1007/978-3-031-20966-6_1

Baxter, R. M. (2003). Environmental Effects of Dams and Impoundments. *Annual Review of Ecology and Systematics*, *8*(1), 255–283. https://doi.org/10.1146/ANNUREV.ES.08.110177.001351

Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., & Wood, E. F. (2018). Present and future köppen-geiger climate classification maps at 1-km resolution. *Scientific Data*, *5*, 1–12. https://doi.org/10.1038/sdata.2018.214

Benstead, J. P., March, J. G., & Pringle, C. M. (2000). Estuarine larval development and upstream post-larval migration of freshwater shrimps in two tropical rivers of Puerto Rico. *Biotropica*, *32*(3), 545–548. https://doi.org/10.1111/j.1744-7429.2000.tb00500.x

Bobeldyk, A. M., & Ramírez, A. (2007). Leaf breakdown in a tropical headwater stream (Puerto Rico): The role of freshwater shrimps and detritivorous insects. *Journal of Freshwater Ecology*, *22*(4), 581–590. https://doi.org/10.1080/02705060.2007.9664819

Boltovskoy, D., & Cataldo, D. H. (2009). Population dynamics of Limnoperna fortunei, an invasive fouling mollusc, in the lower Parana river (Argentina). *The Journal of Biodhesion and Biolfim Research*, *14*(3), 255–263. https://doi.org/10.1080/08927019909378417

Boltovskoy, D., Paolucci, E., MacIsaac, H. J., Zhan, A., Xia, Z., & Correa, N. (2022). What we know and don't know about the invasive golden mussel *Limnoperna fortunei*. *Hydrobiologia*, 1–48. https://doi.org/10.1007/s10750-022-04988-5

Burns, A., & Walker, K. F. (2000). Biofilms as food for decapods (Atyidae, Palaemonidae) in the River Murray, South Australia. *Hydrobiologia*, *437*(1), 83–90. https://doi.org/10.1023/A:1026555501638/METRICS

Calixto-Cunha, M., Rodrigues, T. S., Ueira-Vieira, C., Rodrigues Alves, D. F., & Almeida, A. C. de. (2021). Genetic and phenotypic variability in populations of the *Macrobrachium amazonicum* complex: New findings to the upper Paraná Hydrographic Basin. *Zoologischer Anzeiger*, *293*, 26–36. https://doi.org/10.1016/J.JCZ.2021.05.006

Calvo, N. S., Reynoso, C. M., Resnik, S., Cortés-Jacinto, E., & Collins, P. (2020). Thermal stability of astaxanthin in oils for its use in fish food technology. *Animal Feed Science and Technology*, *270*, 114668. https://doi.org/10.1016/J.ANIFEEDSCI.2020.114668

Carvalho, D. A., Collins, P. A., & De Bonis, C. J. (2013). Predation ability of freshwater crabs: Age and prey-specific differences in *Trichodactylus borellianus* (Brachyura: Trichodactylidae). *Journal of Freshwater Ecology*, *28*(4), 573–584. https://doi.org/10.1080/02705060.2013.806273

Castro, D. M. P., Dolédec, S., & Callisto, M. (2017). Landscape variables influence taxonomic and trait composition of insect assemblages in Neotropical savanna streams. *Freshwater Biology*, *62*(8), 1472–1486. https://doi.org/10.1111/fwb.12961

Cataldo, D., & Boltovskoy, D. (1998). Population dynamics of Corbicula fluminea (Bivalvia) in the Paraná River Delta (Argentina). *Hydrobiologia*, *380*(1–3), 153–163. https://doi.org/10.1023/A:1003428728693

Chace, F. A., & Hobbs, H. H. (1969). The freshwater and terrestrial decapod crustaceans of the West Indies with special reference to Dominica. *United States National Museum Bulletin*, *292*, 1–258. https://doi.org/10.5479/si.03629236.292.1

Collins, P. A., Carnevali, R. P., Carvalho, D., & Williner, V. (2012). Dynamics of decapod crustaceans in a trophic web of continental aquatic environments in Southern south America. In *Advances in environmental research* (Vol. 21, pp. 159–185).

Collins, P. A., & Paggi, J. C. (1997). Feeding ecology of Macrobrachium borelli (Nobili) (Decapoda: Palaemonidae) in the flood valley of the River Parana, Argentina. *Hydrobiologia*, *362*(1), 21–30. https://doi.org/10.1023/A:1003166116086/METRICS

Collins, P., Williner, V., & Giri, F. (2007). Trophic relationships in crustacean decapods of a river with a floodplain. In *Predation in Organisms: A Distinct Phenomenon* (pp. 59–86). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-46046-6_5

Coplen, T. B. (2011). Guidelines and recommended terms for expression of stable-isotope-ratio and gas-ratio measurement results. *Rapid Communications in Mass Spectrometry*, *25*(17), 2538–2560. https://doi.org/10.1002/RCM.5129

Crowl, T., McDowell, W., Covich, A., & Johnson, S. (2001). Freshwater shrimp effects on detrital processing and nutrients in a tropical headwater stream. *Ecology*, *82*(3), 775–783. https://doi.org/10.1890/0012-9658(2001)082[0775:FSEODP]2.0.CO;2

Cumberlidge, N. (2014). Freshwater decapod conservation: recent progress and future challenges. In *Crustaceana Monographs* (Vol. 19, pp. 53–69). Brill. https://doi.org/10.1163/9789004207615_005

Cumberlidge, N. (2016). Global diversity and conservation of freshwater crabs (Crustacea: Decapoda: Brachyura). In *A Global Overview of the Conservation of Freshwater Decapod Crustaceans* (pp. 1–22). Springer International Publishing. https://doi.org/10.1007/978-3-319-42527-6_1

da Cruz, B. R. F., Cunha, M. C., Bueno, A. A. P., & Jacobucci, G. B. (2021). Natural diet of *Macrobrachium brasiliense* (Crustacea, decapoda) in a cerrado stream. *Iheringia - Serie Zoologia*, *111*, 1–11. https://doi.org/10.1590/1678-4766e2021003

da Cruz, B. R. F., Nogueira, C. S., Bueno, A. A. P., & Jacobucci, G. B. (2023). Natural diet of the freshwater prawn *Macrobrachium amazonicum* (Heller, 1862) in the Rio Grande, southeastern Brazil. *Studies on Neotropical Fauna and Environment*. https://doi.org/10.1080/01650521.2023.2286677

da Silva, A. R., & Nogueira, C. S. (2023). From color to shape: ontogenetic shifts in traits of the freshwater crab *Dilocarcinus pagei* (Brachyura: Trichodactylidae). *Canadian Journal of Zoology*, 1–14. https://doi.org/10.1139/CJZ-2023-0039

Darim, M. F., David, F. S., Davanso, T. M., & Taddei, F. G. (2007). Maturidade morfológica do caranguejo de água doce *Dilocarcinus pagei* Stimpson, 1861 (Decapoda: Brachyura: Trichodactylidae) encontrado na represa de Furnas, Marimbondo, Icém-SP. *Ecologia*, *1861*. http://www.seb-ecologia.org.br/revistas/indexar/anais/viiiceb/pdf/683.pdf

Darrigran, G., Agudo-Padrón, I., Baez, P., Belz, C., Cardoso, F., Carranza, A., Collado, G., Correoso, M., Cuezzo, M. G., Fabres, A., Gutiérrez Gregoric, D. E., Letelier, S., Ludwig, S., Mansur, M. C., Pastorino, G., Penchaszadeh, P., Peralta, C., Rebolledo, A., Rumi, A., … Damborenea, C. (2020). Non-native mollusks throughout South America: emergent patterns in an understudied continent. *Biological Invasions*, *22*(3), 853–871. https://doi.org/10.1007/S10530-019-02178-4

Darrigran, G., & Damborenea, C. (2011). Ecosystem Engineering Impact of Limnoperna fortunei in South America. *Zoological Science*, *28*(1), 1–7. https://doi.org/10.2108/ZSJ.28.1

Davanso, T. M., Taddei, F. G., Hirose, G. L., & da Costa, R. C. (2016). Maturidade sexual, lateralidade e dimorfismo sexual do caranguejo dulcícola *Dilocarcinus pagei* no Sudeste do Brasil. *Boletim Do Instituto de Pesca*, *42*(2), 269–279. https://doi.org/10.20950/1678-2305.2016v42n2p269

Davanso, T. M., Taddei, F. G., Simões, S. M., Fransozo, A., & Da Costa, R. C. (2013). Population dynamics of the freshwater crab *Dilocarcinus pagei* in tropical waters in southeastern Brazil. *Journal of Crustacean Biology*, *33*(2), 235–243. https://doi.org/10.1163/1937240X-00002129

David, F. S., Proença, D. C., Flickinger, D. L., Wolff Bueno, G., & Valenti, W. C. (2021). Carbon budget in integrated aquaculture systems with Nile tilapia (*Oreochromis niloticus*) and Amazon river prawn (*Macrobrachium amazonicum*). *Aquaculture Research*, *52*(11), 5155–5167. https://doi.org/10.1111/are.15384

de Carvalho, D. R., de Castro, D. M. P., Callisto, M., Chaves, A. J. de M., Moreira, M. Z., & Pompeu, P. S. (2019). Stable isotopes and stomach content analyses indicate omnivorous habits and opportunistic feeding behavior of an invasive fish. *Aquatic Ecology*, *53*(3), 365–381. https://doi.org/10.1007/s10452-019-09695-3

De Castro, D. M. P., De Carvalho, D. R., Pompeu, P. D. S., Moreira, M. Z., Nardoto, G. B., & Callisto, M. (2016). Land use influences niche size and the assimilation of resources by benthic macroinvertebrates in tropical headwater streams. *PLoS ONE*, *11*(3), 1–19. https://doi.org/10.1371/journal.pone.0150527

De Grave, S., Cai, Y., & Anker, A. (2008). Global diversity of shrimps (Crustacea: Decapoda: Caridea) in freshwater. *Hydrobiologia*, *595*(1), 287–293. https://doi.org/10.1007/s10750-007-9024-2

De Oliveira, M. D., Takeda, A. M., De Barros, L. F., Barbosa, D. S., & De Resende, E. K. (2006). Invasion by Limnoperna fortunei (Dunker, 1857) (Bivalvia, Mytilidae) of the Pantanal Wetland, Brazil. *Biological Invasions*, *8*(1), 97–104. https://doi.org/10.1007/S10530-005-0331-0/METRICS

Dos Santos, A., Hayd, L., & Anger, K. (2013). A new species of *Macrobrachium* Spence Bate, 1868 (Decapoda, Palaemonidae), *M. pantanalense*, from the Pantanal, Brazil. *Zootaxa*, *3700*(4), 534–546. https://doi.org/10.11646/zootaxa.3700.4.2

Dudgeon, D., & Catherine, C. P. S. (1990). Selection of gastropod prey by a tropical freshwater crab. *Journal of Zoology*, *220*(1), 147–155. https://doi.org/10.1111/J.1469-7998.1990.TB04299.X

Emery-Butcher, H. E., Beatty, S. J., & Robson, B. J. (2020). The impacts of invasive ecosystem engineers in freshwaters: A review. *Freshwater Biology*, *65*(5), 999–1015. https://doi.org/10.1111/FWB.13479

Esteves, F. de A. (1988). Fundamentos de Limnologia. In *Interciência* (2a. ed.). https://doi.org/10.1515/znc-1987-0514

Farquhar, G. D., Ehleringer, J. R., & Hubick, K. T. (1989). Carbon Isotope Discrimination and Photosynthesis. *Annual Review of Plant Physiology and Plant*

Molecular Biology, *40*(1), 503–537. https://doi.org/10.1146/ANNUREV.PP.40.060189.002443

Fortunato, H. F. de M., Figueira, R. M. A., Fortunato, H. F. de M., & Figueira, R. M. A. (2022). Freshwater sponges overgrow the invasive golden mussel Limnoperna fortunei in the Upper Paraná River, Brazil. *Marine and Freshwater Research*, *73*(11), 1393–1398. https://doi.org/10.1071/MF22023

Foysal, M. J. (2023). Host habitat shapes the core gut bacteria of decapod crustaceans: A meta-analysis. *Heliyon*, *9*(6). https://doi.org/10.1016/j.heliyon.2023.e16511

Freitas, E., Hayd, L., & Calado, R. (2021). Effects of salinity, stocking density and feeding in *Macrobrachium pantanalense* larviculture. *Aquaculture Reports*, *20*, 100706. https://doi.org/10.1016/J.AQREP.2021.100706

Fry, B., & Sherr, E. B. (1989). *δ13C Measurements as Indicators of Carbon Flow in Marine and Freshwater Ecosystems*. 196–229. https://doi.org/10.1007/978-1-4612-3498-2_12

Galvez, J. R., St. John, M. E., McLean, K., Dening Touokong, C., Gonwouo, L. N., & Martin, C. H. (2022). Trophic Specialization on unique resources despite limited niche divergence in a celebrated example of sympatric speciation. *Ecology of Freshwater Fish*, *31*(4), 675–692. https://doi.org/10.1111/eff.12661

Garcia, D. A. Z., Casimiro, A. C. R., Geller, I. V., Ferraz, J. D., Jarduli, L. R., & Orsi, M. L. (2021). Live bait trade as a pathway for the introduction of non-native species: The first record of *Dilocarcinus pagei* in the paranapanema river basin. *Oecologia Australis*, *25*(3), 775–785. https://doi.org/10.4257/oeco.2021.2503.14

Gomes, A. F. T., Mossolin, E. C., & Mantelatto, F. L. (2012). Populational and reproductive aspects of Southern *Macrobrachium acanthurus* (Wiegmann, 1836) (Crustacea: Palaemonidae), Brazil. *Brazilian Journal of Aquatic Science and Technology*, *16*(1), 9. https://doi.org/10.14210/bjast.v16n1.p9-18

Gonçalves-Silva, M., Luduvice, J. S. V., Gomes, M. V. T., Rosa, D. C. O., & Brito, M. F. G. (2022). Influence of ontogenetic stages and seasonality on the diet of the longtail knifefish *Sternopygus macrurus* (Gymnotiformes, Sternopygidae) in a large Neotropical river. *Studies on Neotropical Fauna and Environment*, *57*(1), 11–17. https://doi.org/10.1080/01650521.2020.1806007

Hamada, N., Nessimian, J. L., & Querino, R. B. (2014). *Insetos aquáticos na Amazônia brasileira: taxonomia, biologia e ecologia*. Editora do INPA.

Hamid, A., & Wardiatno, Y. (2018). Diversity of Decapod Crustaceans in Lasongko Bay, South-east Sulawesi, Indonesia. *Biodiversity Journal*, *9*(3), 303–311. https://doi.org/10.31396/Biodiv.Jour.2018.9.3.303.311

Havel, J., Lee, C., & Vander Zanden, M. J. (2005). Do reservoirs facilitate invasions into landscapes? *BioScience*, *55*(6), 518–525. https://academic.oup.com/bioscience/article-abstract/55/6/518/363697

Hawkins, B. A., Field, R., Cornell, H. V., Currie, D. J., Guégan, J. F., Kaufman, D. M., Kerr, J. T., Mittelbach, G. G., Oberdorff, T., O'Brien, E. M., Porter, E. E., & Turner, J. R. G. (2003). ENERGY, WATER, AND BROAD-SCALE GEOGRAPHIC PATTERNS OF SPECIES RICHNESS. *Ecology*, *84*(12), 3105–3117. https://doi.org/10.1890/03-8006

Heldt, A., Suita, S., Dutra, F. M., Pereira, A. L., Ballester, E., Heldt, A., Suita, S., Dutra, F. M., Pereira, A. L., & Ballester, E. (2019a). Stable isotopes as a method for analysis of the contribution of different dietary sources in the production of <:/>Macrobrachium amazonicum</>. *Latin American Journal of Aquatic Research*, *47*(2), 282–291. https://doi.org/10.3856/VOL47-ISSUE2-FULLTEXT-8

Heldt, A., Suita, S., Dutra, F. M., Pereira, A. L., Ballester, E., Heldt, A., Suita, S., Dutra, F. M., Pereira, A. L., & Ballester, E. (2019b). Stable isotopes as a method for analysis of the contribution of different dietary sources in the production of Macrobrachium amazonicum. *Latin American Journal of Aquatic Research*, *47*(2), 282–291. https://doi.org/10.3856/VOL47-ISSUE2-FULLTEXT-8

Herrera, D. R., Davanso, T. M., Costa, R. C., & Taddei, F. G. (2013). The relative growth and sexual maturity of the freshwater crab *Dilocarcinus pagei* (Brachyura, Trichodactylidae) in the northwestern region of the state of São Paulo. *Iheringia. Série Zoologia*, *103*(3), 232–239. https://doi.org/10.1590/s0073-47212013000300004

Hill, J. M., Jones, R. W., Hill, M. P., & Weyl, O. L. F. (2015). Comparisons of isotopic niche widths of some invasive and indigenous fauna in a South African river. *Freshwater Biology*, *60*(5), 893–902. https://doi.org/10.1111/FWB.12542

Hooper, C., Debnath, P. P., Stentiford, G. D., Bateman, K. S., Salin, K. R., & Bass, D. (2023). Diseases of the giant river prawn *Macrobrachium rosenbergii*: A review for a growing industry. In *Reviews in Aquaculture* (Vol. 15, Issue 2, pp. 738–758). John Wiley & Sons, Ltd. https://doi.org/10.1111/raq.12754

Hudson, D. M., Phillips, G., Lasso, C. A., & Campos, M. R. (2021). Threats to Endemic Colombian Freshwater Crabs (Decapoda: Pseudothelphusidae, Trichodactylidae) Associated with Climate Change and Human-Mediated Activities. *Recent Advances in Freshwater Crustacean Biodiversity and Conservation*, 425–444. https://doi.org/10.1201/9781003139560-14

Jackson, A. L., Inger, R., Parnell, A. C., & Bearhop, S. (2011). Comparing isotopic niche widths among and within communities: SIBER-Stable Isotope Bayesian Ellipses in R. *Journal of Animal Ecology*, *80*, 595–602. https://doi.org/10.1111/j.1365-2656.2011.01806.x

Jackson, C. H. (2011). Multi-State Models for Panel Data: The msm Package for R. *Journal of Statistical Software*, *38*(8), 1–28. https://doi.org/10.18637/JSS.V038.I08

Jackson, M. C., Wasserman, R. J., Grey, J., Ricciardi, A., Dick, J. T. A., & Alexander, M. E. (2017). Novel and Disrupted Trophic Links Following Invasion in Freshwater Ecosystems. In *Advances in Ecological Research* (Vol. 57, pp. 55–97). Academic Press. https://doi.org/10.1016/BS.AECR.2016.10.006

Latini, A. O., Resende, D. C., Pombo, V. B., & Coradin, L. (2016). *Espécies Exóticas Invasoras de Águas Continentais no Brasil: Vol. Biodiversidade 39*. Ministério do Meio Ambiente.

Lavajoo, F., Biuki, N. A., Khanipour, A. A., Mirzajani, A., Fruitos, J. G., & Akbarzadeh, A. (2019). Natural diet of macrobrachium nipponense shrimp from three habitats in anzali wetland, iran. *Caspian Journal of Environmental Sciences*, *17*(2), 101–111. https://doi.org/10.22124/cjes.2019.3404

Lawlor, L. R. (1980). Overlap, Similarity, and Competition Coefficients. *Ecology*, *61*(2), 245–251. https://doi.org/10.2307/1935181

LaZerte, B. D., & Szalados, J. E. (1982). Stable carbon isotope ratio of submerged freshwater macrophytes1,1. *Limnology and Oceanography*, *27*(3), 413–418. https://doi.org/10.4319/LO.1982.27.3.0413

Linares, M. S., Assis, W., de Castro Solar, R. R., Leitão, R. P., Hughes, R. M., & Callisto, M. (2019). Small hydropower dam alters the taxonomic composition of benthic macroinvertebrate assemblages in a neotropical river. *River Research and Applications*, *35*(6), 725–735. https://doi.org/10.1002/RRA.3442

Linares, M. S., Callisto, M., & Marques, J. C. (2017). Invasive bivalves increase benthic communities complexity in neotropical reservoirs. *Ecological Indicators*, *75*, 279–285. https://doi.org/10.1016/j.ecolind.2016.12.046

Linares, M. S., Macedo, D. R., Massara, R. L., & Callisto, M. (2020). Why are they here? Local variables explain the distribution of invasive mollusk species in neotropical hydropower reservoirs. *Ecological Indicators*, *117*, 106674. https://doi.org/10.1016/J.ECOLIND.2020.106674

Loures, R. C., & Pompeu, P. S. (2019). Temporal changes in fish diversity in lotic and lentic environments along a reservoir cascade. *Freshwater Biology*, *64*(10), 1806–1820. https://doi.org/10.1111/FWB.13372

Lucy, F. E., Karatayev, A. Y., & Burlakova, L. E. (2012). Predictions for the spread, population density, and impacts of corbicula fluminea in Ireland. *Aquatic Invasions*, *7*(4), 465–474. https://doi.org/10.3391/ai.2012.7.4.003

Magalhães, C. (2000). Diversity and Abundance of Decapod Crustaceans in the Rio Negro Basin, Pantanal, Mato Grosso Do Sul, Brasil. *Rap Bulletin of Biological Assessment*, *18*, 56–62. http://decapoda.nhm.org/pdfs/31285/31285.pdf

Magalhães, C. (2003). Famílias Pseudothelphusidae e Trichodactylidae. In *Manual de Identificação dos Crustacea Decapoda de Água doce do Brasil* (pp. 143–287). https://www.researchgate.net/profile/Gustavo-Melo-4/publication/267849392_MANUAL_DE_IDENTIFICACAO_DOS_CRUSTACEA_DECAPODA_DE_AGUA_DOCE_DO_BRASIL/links/5666f9c908ae34c89a01fd89/MANUAL-DE-IDENTIFICACAO-DOS-CRUSTACEA-DECAPODA-DE-AGUA-DOCE-DO-BRASIL.pdf

Magalhães, C., Bueno, S. L. S., Bond-Buckup, G., Valenti, W. C., Melo Da Silva, H. L., Kiyohara, F., Mossolin, E. C., & Rocha, S. S. (2005). Exotic species of freshwater decapod crustaceans in the state of São Paulo, Brazil: Records and possible causes of their introduction. *Biodiversity and Conservation*, *14*(8), 1929–1945. https://doi.org/10.1007/s10531-004-2123-8

Magalhães, C., Campos, M. R., Collins, P. A., & Mantelatto, F. L. (2016). Diversity, distribution and conservation of freshwater crabs and shrimps in South America. *A Global Overview of the Conservation of Freshwater Decapod Crustaceans*, 303–322. https://doi.org/10.1007/978-3-319-42527-6_10

Mancinelli, G., Sangiorgio, F., & Scalzo, A. (2013). The effects of decapod crustacean macroconsumers on leaf detritus processing and colonization by invertebrates in stream habitats: A meta-analysis. *International Review of Hydrobiology*, *98*(4), 206–216. https://doi.org/10.1002/iroh.201301539

Mansur, M., Callil, C., Cardoso, F., & Ibara, J. (2004). Uma retrospectiva e mapeamento da invasão de espécies de *Corbicula* (Mollusca, Bivalvia, Veneroida, Corbiculidae) oriundas do sudeste asiático, na América do Sul, Brasil. In J. SILVA & R. SOUZA (Eds.), *Água de Lastro e Bioinvasão* (pp. 39–58). Interciência.

Mantel, S. K., & Dudgeon, D. (2004). Dietary variation in a predatory shrimp Macrobrachium hainanense (Palaemonidae) in Hong Kong forest streams. *Archiv Fur Hydrobiologie*, *160*(3), 305–328. https://doi.org/10.1127/0003-9136/2004/0160-0305

Mao, Z., Gu, X., & Zeng, Q. (2016). Food sources and trophic relationships of three decapod crustaceans: insights from gut contents and stable isotope analyses. *Aquaculture Research*, *47*(9), 2888–2898. https://doi.org/10.1111/are.12739

Maroneze, D. M., Coscarelli, D., Vidigal, T. H. D. A., & Callisto, M. (2011). First record of Corbicula fluminea (Müller, 1774) in the drainage basin of the Araguari River, Minas Gerais, Brazil. *Brazilian Journal of Biology*, *71*(1), 221–222. https://doi.org/10.1590/S1519-69842011000100033

Martins, I., Sanches, B., Kaufmann, P. R., Hughes, R. M., Santos, G. B., Molozzi, J., & Callisto, M. (2015). Ecological assessment of a southeastern Brazil reservoir. *Biota Neotropica*, *15*(1), e20140061. https://doi.org/10.1590/1676-06032015006114

McCutchan, J. H., Lewis, W. M., Kendall, C., & McGrath, C. C. (2003). Variation in trophic shift for stable isotope ratios of carbon, nitrogen, and sulfur. *Oikos*, *102*(2), 378–390. https://doi.org/10.1034/J.1600-0706.2003.12098.X

Melo, M. S. de, & Nakagaki, J. M. (2013). Evaluation of the feeding habits of *Macrobrachium brasiliense* (Heller, 1862) in the Curral de Arame stream (Dourados/Mato Grosso do Sul, Brazil). *Nauplius*, *21*(1), 25–33. https://doi.org/10.1590/s0104-64972013000100004

Melo, G. (2003). *Manual de identificação dos Crustacea Decapoda de água doce do Brasil* (Edições Loyola). São Paulo: Museu de Zoologia USP. https://books.google.com.br/books?hl=pt-BR&lr=&id=By-q9Gd-2kYC&oi=fnd&pg=PA21&dq=Manual+de+identifica%C3%A7%C3%A3o+dos+crustacea+decapoda+de+%C3%A1gua+doce+do+Brasil.+S%C3%A3o+Paulo:+Mu

seu+de+Zoologia+USP&ots=WEKYY1KVlW&sig=ND9hRGHuFY0O5NwRWg0aXv5DPeE

Milardi, M., Gavioli, A., Soininen, J., & Castaldelli, G. (2019). Exotic species invasions undermine regional functional diversity of freshwater fish. *Scientific Reports*, *9*(1), 1–10. https://doi.org/10.1038/s41598-019-54210-1

Molina, F. R., & Williner, V. (2014). First record of the non-indigenous mussel Limnoperna fortunei (Bivalvia, Mytilidae) as an epibiont of the crab Trichodactylus borellianus (Decapoda, Trichodactylidae). *Crustaceana*, *86*(6), 682–692. https://doi.org/10.1163/15685403-00003183

Mugnai, R., Nessimian, J. L., & Baptista, D. F. (2010). *Manual de identificação de macroinvertebrados aquáticos do Estado do Rio de Janeiro: para atividades técnicas, de ensino e treinamento em programas de avaliação da qualidade ecológica dos ecossistemas lóticos* (1a ed.). Technical Books Editora.

Mussato, J. H. M., Vercesi, K., & Hayd, L. (2019). Redução da mortalidade de *Dilocarcinus Pagei* durante o armazenamento in loco no Pantanal de Porto Murtinho, Brasil. *Oecologia Australis*, *23*(04), 1091–1099. https://doi.org/10.4257/oeco.2019.2304.29

Nilsson, C., Reidy, C. A., Dynesius, M., & Revenga, C. (2005). Fragmentation and flow regulation of the world's large river systems. *Science*, *308*(5720), 405–408. https://doi.org/10.1126/SCIENCE.1107887

Olmos, F., Pacheco, J. F., Luís, E., & Silveira, F. (2006). Notas sobre aves de rapina (Cathartidae, Acciptridae e Falconidae) brasileiras. *Revista Brasileira de Ornitologia*, *14*(4), 401–404.

Osmond, C. B., Valaane, N., Haslam, S. M., Uotila, P., & Roksandic, Z. (1981). Comparisons of δ13C values in leaves of aquatic macrophytes from different habitats in Britain and Finland; some implications for photosynthetic processes in aquatic plants. *Oecologia*, *50*(1), 117–124. https://doi.org/10.1007/BF00378804/METRICS

Ozga, A. V., Castro, V. da S. de, & Castiglioni, D. da S. (2018). Population structure of two freshwater amphipods (Crustacea: Peracarida: Hyalellidae) from southern Brazil. *Nauplius*, *26*, e2018025. https://doi.org/10.1590/2358-2936E2018025

Peck, D. V., Lazorchak, J. M., & Klemm, D. J. (2006). Environmental monitoring and assessment program - surface waters: Western pilot study field operations manual for wadeable streams. In *EPA/620/R-06/003.Washington, DC.* https://www.researchgate.net/publication/235943200_Environmental_Monitoring_and_Assessment_Program-Surface_Waters_Western_Pilot_Study_Field_Operations_Manual_for_Wadeable_Streams

Peixer, J., & Petrere Jr, M. (2007). Hook selectivity of the Pacu *Piaractus mesopotamicus* (Holmberg, 1887) in the Pantanal, the state of Mato Grosso do Sul, Brazil. *Brazilian Journal of Biology*, *67*(2), 339–345.

Peterson, B. J., & Fry, B. (1987). Stable isotopes in ecosystem studies. *Annual Review of Ecology and Systematics. Vol. 18*, *18*(Volume 18, 1987), 293–320. https://doi.org/10.1146/ANNUREV.ES.18.110187.001453/CITE/REFWORKS

Pimpão, D. M., & Martins, D. D. S. (2008). Ocorrência do molusco asiático Corbicula fluminea (Müller, 1774) (Bivalvia, Corbiculidae) no baixo rio Negro, Amazônia central. *Acta Amazonica*, *38*(3), 589–591. https://doi.org/10.1590/S0044-59672008000300026

Pinheiro, M., & Taddei, F. (2005). Crescimento do caranguejo de água doce, *Dilocarcinus pagei* Stimpson (Crustacea, Brachyura, Trichodactylidae). *Revista Brasileira de Zoologia*, *22*, 522–528. https://doi.org/https://doi.org/10.1590/S0101-81752005000300002

Pok, P. S., Stefanini, M. I., & Calvo, N. S. (2023). Sustainable production of astaxanthin from *Dilocarcinus pagei* crab and optimisation of its extraction with edible oils. *Heliyon*, *9*(6). https://doi.org/10.1016/j.heliyon.2023.e17381

Qin, W., Sun, Y., Müller-Schärer, H., & Huang, W. (2024). Responses of non-native and native plant species to fluctuations of water availability in a greenhouse experiment. *Ecology and Evolution*, *14*(7), e11692. https://doi.org/10.1002/ECE3.11692

Quinn, B. K. (2020). Potential kleptoparasitism-scavenging interactions between crabs and shell-boring gastropods feeding on bivalve prey: a global survey. *Plankton and Benthos Research*, *15*(2), 132–145. https://doi.org/10.3800/PBR.15.132

Ricciardi, A. (1998). Global range expansion of the Asian mussel Limnoperna fortunei (Mytilidae): Another fouling threat to freshwater systems. *Biofouling*, *13*(2), 97–106. https://doi.org/10.1080/08927019809378374

Riera, P., Stal, L. J., Nieuwenhuize, J., Richard, P., Blanchard, G., & Gentil, F. (1999). Determination of food sources for benthic invertebrates in a salt marsh (Aiguillon Bay, France) by carbon and nitrogen stable isotopes: importance of locally produced sources. *Marine Ecology Progress Series*, *187*, 301–307. https://doi.org/10.3354/MEPS187301

Robinson, J. V., & Wellborn, G. A. (1988). Ecological resistance to the invasion of a freshwater clam, Corbicula fluminea: fish predation effects. *Oecologia*, *77*(4), 445–452. https://doi.org/10.1007/BF00377258

Rodrigues, S. C., & Silva, T. I. (2012). Dam construction and loss of geodiversity in the araguari river basin, brazil. *Land Degradation and Development*, *23*(4), 419–426. https://doi.org/10.1002/ldr.2157

Rudnick, D., & Resh, V. (2005a). Stable isotopes, mesocosms and gut content analysis demonstrate trophic differences in two invasive decapod crustacea. *Freshwater Biology*, *50*(8), 1323–1336. https://doi.org/10.1111/j.1365-2427.2005.01398.x

Rudnick, D., & Resh, V. (2005b). Stable isotopes, mesocosms and gut content analysis demonstrate trophic differences in two invasive decapod crustacea. *Freshwater Biology*, *50*(8), 1323–1336. https://doi.org/10.1111/j.1365-2427.2005.01398.x

Sala, O. E., Chapin, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H. A., Oesterheld, M., Poff, N. L. R., Sykes, M. T., Walker, B. H., Walker, M., & Wall, D. H. (2000). Global Biodiversity Scenarios for the Year 2100. *Science*, *287*(5459), 1770–1774. https://doi.org/10.1126/SCIENCE.287.5459.1770

Sant'Anna, B. S., Andrade, D. R., Watanabe, T. T., & Hattori, G. Y. (2014). Behavioral repertoire and substrate choice of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda, Trichodactylidae). In *Crabs: Global Diversity, Behavior and Environmental Threats* (pp. 57–73). https://www.researchgate.net/profile/Kostas-Kapiris/publication/271384449_CRABS_eBook/links/54c674650cf2911c7a58de4f/CRABS-eBook.pdf#page=71

Sant'Anna, B. S., Takahashi, E. L. H., & Hattori, G. Y. (2015). Cultivo experimental do caranguejo de água doce *Dilocarcinus pagei*: Efeito da densidade no crescimento. *Boletim Do Instituto de Pesca*, *41*(3), 645–653. https://www.pesca.sp.gov.br/boletim/index.php/bip/article/view/41_3_645-653

Santiago do Vale, V., Raymundo, D., Afonso do Prado Júnior, J., Cristina da Silva Santos, L., Paulo Costa, J., Eugênio Alves Macedo Oliveira, P., Gabriele Vaz Souza, A., & Júnior, P. (2021). Impacts on seasonal dry forests located for several years near dams in the Araguari River Basin. *Scientia Forestalis*, *49*, 130. https://doi.org/10.18671/scifor.v49n130.25

Sethi, S., Ram, N., & Venkatesan, V. (2013). Food and feeding habits of *Macrobrachium lar* (Decapoda, Palaemonidae) from Andaman and Nicobar islands, India. *Indian Journal of Fisheries*, *60*(4), 131–135. http://eprints.cmfri.org.in/9819/

Sichieri, G., Lopes, B., Moura, P., Faciole, F., Costa, F., & Nunes, I. (2021). Predation on leptodactylid and hylid frogs by the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Decapoda, Trichodactylidae) in the Brazilian Pantanal. *Herpetology Notes*, *14*, 1133–1136. https://www.biotaxa.org/hn/article/view/68371/68184

Silva-Junior, E. F., Silva-Araújo, M., & Moulton, T. P. (2017). Distribution and abundance of freshwater decapods in an Atlantic rainforest catchment with a dammed future. *Brazilian Journal of Biology*, *77*(4), 820–829. https://doi.org/10.1590/1519-6984.01916

Simon, T. N., Binderup, A. J., Flecker, A. S., Gilliam, J. F., Marshall, M. C., Thomas, S. A., Travis, J., Reznick, D. N., & Pringle, C. M. (2019). Landscape patterns in top-down control of decomposition: omnivory disrupts a tropical detrital-based trophic cascade. *Ecology*, *100*(7), e02723. https://doi.org/10.1002/ecy.2723

Siqueira, T., Bini, L. M., Cianciaruso, M. V., Roque, F. O., & Trivinho-Strixino, S. (2009). The role of niche measures in explaining the abundance-distribution relationship in tropical lotic chironomids. *Hydrobiologia*, *636*(1), 163–172. https://doi.org/10.1007/s10750-009-9945-z

Soares, M. P., Jesus, F., Almeida, A. R., Zlabek, V., Grabic, R., Domingues, I., & Hayd, L. (2017). Endemic shrimp *Macrobrachium pantanalense* as a test species to assess potential contamination by pesticides in Pantanal (Brazil). *Chemosphere*, *168*, 1082–1092. https://doi.org/10.1016/j.chemosphere.2016.10.100

Stanford, J. A., & Ward, J. V. (2001). Revisiting the serial discontinuity concept. *Regulated Rivers: Research & Management*, *17*(4–5), 303–310. https://doi.org/10.1002/RRR.659

Strayer, D. L., & Dudgeon, D. (2010). Freshwater biodiversity conservation: recent progress and future challenges. *Journal of the North American Benthological Society*, *29*(1), 344–358. https://doi.org/10.1899/08-171.1

Štrus, J., Žnidaršič, N., Mrak, P., Bogataj, U., & Vogt, G. (2019). Structure, function and development of the digestive system in malacostracan crustaceans and adaptation to different lifestyles. *Cell and Tissue Research*, *377*(3), 415–443. https://doi.org/10.1007/S00441-019-03056-0

Sylvester, F., Boltovskoy, D., & Cataldo, D. H. (2007). Fast response of freshwater consumers to a new trophic resource: Predation on the recently introduced Asian bivalve Limnoperna fortunei in the lower Paraná river, South America. *Austral Ecology*, *32*(4), 403–415. https://doi.org/10.1111/J.1442-9993.2007.01707.X

Taddei, F. G., Davanso, T. M., Castiglioni, L., Herrera, D. R., Fransozo, A., & Da Costa, R. C. (2015). Population structure, recruitment, and mortality of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Brachyura, trichodactylidae) in Southeastern Brazil. *Invertebrate Reproduction & Development*, *59*(4), 189–199. https://doi.org/10.1080/07924259.2015.1081638

Taddei, F., & Herrera, D. (2010). Crescimento do caranguejo *Dilocarcinus pagei* Stimpson, 1861 (Crustacea, Brachyura, Trichodactylidae) na represa Barra Mansa, Mendonça, SP. *Boletim Do Instituto de Pesca*, *36*(2), 99–110. https://www.pesca.agricultura.sp.gov.br/boletim/index.php/bip/article/view/906

Thomaz, S. M., Kovalenko, K. E., Havel, J. E., & Kats, L. B. (2014). Aquatic invasive species: general trends in the literature and introduction to the special issue. *Hydrobiologia*, *746*(1), 1–12. https://doi.org/10.1007/s10750-014-2150-8

Toh, E. X. P., Gan, L. X., & Yeo, D. C. J. (2022). A global overview of climate change impacts on freshwater decapods: Substantial research gaps across taxa and biogeographic regions. *Journal of Crustacean Biology*, *42*(1). https://doi.org/10.1093/JCBIOL/RUAB088

Torres, M. V., Giri, F., & Williner, V. (2012a). Size selective predation on an invasive bivalve, *Limnoperna fortunei* (Mytilidae), by a freshwater crab, *Zilchiopsis collastinensis* (Trichodactylidae). *Journal of Crustacean Biology*, *32*(5), 698–710. https://doi.org/10.1163/193724012X649444

Torres, M. V., Giri, F., & Williner, V. (2012b). Size Selective Predation on an Invasive Bivalve, *Limnoperna Fortunei* (Mytilidae), by a Freshwater Crab, *Zilchiopsis Collastinensis* (Trichodactylidae). *Journal of Crustacean Biology*, *32*(5), 698–710. https://doi.org/10.1163/193724012X649444

Vander Zanden, M. J., Cabana, G., & Rasmussen, J. B. (1997). Comparing trophic position of freshwater fish calculated using stable nitrogen isotope ratios ($\delta^{15}N$) and literature dietary data. *Canadian Journal of Fisheries and Aquatic Sciences*, *54*(5), 1142–1158. https://doi.org/10.1139/CJFAS-54-5-1142

Vander Zanden, M. J., Clayton, M. K., Moody, E. K., Solomon, C. T., & Weidel, B. C. (2015). Stable isotope turnover and half-life in animal tissues: A literature synthesis. *PLoS ONE*, *10*(1). https://doi.org/10.1371/journal.pone.0116182

Viana, C. R. S., Junior, E. S. O., Santos, M. F. dos, Lázaro, W. L., Lizieri, C., & Muniz, C. C. (2023). Among macrophytes and microplastics: diet of Crustacea Decapoda *Dilocarcinus pagei* (Stimpson, 1861) and *Trichodactylus petropolitanus* (Göldi, 1886) in the Pantanal region of Cáceres - MT. *Research, Society and Development*, *12*(2), e29012240148–e29012240148. https://doi.org/10.33448/RSD-V12I2.40148

Viana, M. L. P. (2019). *Preferência Alimentar e o Efeito de Abrigos Naturais no Cultivo do Caranguejo Vermelho <:/>Dilocarcinus pagei</> Stimpson, 1861 (Tese de doutorado). Universidade Estadual Paulista (Unesp), Botucatu-SP.*

Viozzi, M. F., Cabrera, J. M., Giri, F., Carvalho, D. de A., & Williner, V. (2021). Ontogenetic shifts in natural diet, chelae, and mandibles of the omnivorous freshwater crab aegla uruguayana: Linking morphology and function. *Canadian Journal of Zoology*, *99*(8), 625–641. https://doi.org/10.1139/CJZ-2020-0290/ASSET/IMAGES/LARGE/CJZ-2020-0290CON1.JPEG

Viozzi, M. F., Martínez Del Rio, C., & Williner, V. (2021). Tissue-specific isotopic incorporation turnover rates and trophic discrimination factors in the freshwater shrimp macrobrachium borellii (Crustacea: Decapoda: Palaemonidae). *Zoological Studies*, *60*. https://doi.org/10.6620/ZS.2021.60-32

Voelz, N. J., McArthur, J. V., & Rader, R. B. (1998). Upstream mobility of the asiatic clam corbicula fluminea: Identifying potential dispersal agentsa. *Journal of Freshwater Ecology*, *13*(1), 39–45. https://doi.org/10.1080/02705060.1998.9663589

Vogt, G. (2013). Abbreviation of larval development and extension of brood care as key features of the evolution of freshwater Decapoda. *Biological Reviews*, *88*(1), 81–116. https://doi.org/10.1111/J.1469-185X.2012.00241.X

Wada, E., Mizutani, H., & Minagawa, M. (1991). The Use of Stable Isotopes for Food Web Analysis. *Critical Reviews in Food Science and Nutrition*, *30*(4), 361–371. https://doi.org/10.1080/10408399109527547

Wang, J., Chen, L., Tang, W., Heino, J., & Jiang, X. (2021). Effects of dam construction and fish invasion on the species, functional and phylogenetic diversity of fish assemblages in the Yellow River Basin. *Journal of Environmental Management*, *293*, 112863. https://doi.org/10.1016/j.jenvman.2021.112863

Wantzen, K. M., Marchese, M. R., Marques, M. I., & Battirola, L. D. (2016). Invertebrates in neotropical floodplains. In *Invertebrates in Freshwater Wetlands: An International Perspective on Their Ecology* (pp. 493–524). Springer International Publishing. https://doi.org/10.1007/978-3-319-24978-0_14

Williner, V., & Collins, P. A. (2002). Daily Rhythm of Feeding Activity of the Freshwater Crab *Dilocarcinus Pagei* in the Rio Pilcomayo National Park, Formosa, Argentina. In *Modern Approaches to the Study of Crustacea* (pp. 171–178). Springer US. https://doi.org/10.1007/978-1-4615-0761-1_27

Williner, V., Collins, P. A., Pozo, E., & Fe, S. (2013). Trophic ecology of Trichodactylus borellianus feeding ecology of the freshwater crab *Trichodactylus borellianus* (Decapoda: Trichodactylidae) in the floodplain of the Paraná River, southern South America. *Lat. Am. J. Aquat. Res*, *41*(4), 781–792. https://doi.org/doi: 10.3856/vol41-issue4-fulltext-15

Winemiller, K. O., Zeug, S. C., Robertson, C. R., Winemiller, B. K., & Honeycutt, R. L. (2011). Food-web structure of coastal streams in Costa Rica revealed by dietary and stable isotope analyses. *Journal of Tropical Ecology*, *27*(5), 463–476. https://doi.org/10.1017/S0266467411000277

Yeo, D. C. J., Ng, P. K. L., Cumberlidge, N., Magalhães, C., Daniels, S. R., & Campos, M. R. (2008). Global diversity of crabs (Crustacea: Decapoda: Brachyura) in freshwater. *Freshwater Animal Diversity Assessment*, 275–286. https://doi.org/10.1007/978-1-4020-8259-7_30

Supplementary material

Table S1. Results of isotopic analyses performed by the Stable Isotope Center (CEI). N = sample number; NT (%) = Percentage of Total Nitrogen in relation to the mass of the sample (with an uncertainty of ± 0.20%); $\delta^{15}N$ (‰) = Relative difference in the isotopic ratio or δ-value (with an uncertainty of ± 0.15‰); TOC (%) = Percentage of Total Organic Carbon in relation to the mass of the sample (with an uncertainty of ± 0.20%); δ13C (‰) = Relative difference in the isotopic ratio or δ-value (with an uncertainty of ± 0.15‰).

Decapoda	N	NT	$\delta^{15}N$	COT	$\delta^{13}C$
Dilocarcinus pagei	1	16.13	9.89	48.52	-19.48
Dilocarcinus pagei	2	16.67	10.08	49.83	-24.23
Dilocarcinus pagei	3	16.44	9.50	51.39	-20.51
Dilocarcinus pagei	4	16.38	10.81	50.96	-21.96
Dilocarcinus pagei	5	16.57	9.87	48.63	-21.16
Dilocarcinus pagei	6	16.18	12.35	47.85	-19.06
Dilocarcinus pagei	7	11.85	14.66	33.17	-23.01
Macrobrachium pantanalense	8	16.04	13.18	51.18	-26.45
Macrobrachium pantanalense	9	16.32	12.35	49.59	-23.10
Macrobrachium pantanalense	10	16.03	13.08	49.70	-24.09
Macrobrachium pantanalense	11	14.39	12.48	44.45	-24.83
Macrobrachium pantanalense	12	15.80	14.91	49.20	-24.06
Macrobrachium pantanalense	13	15.47	13.64	45.53	-24.10
Macrobrachium pantanalense	14	15.26	13.68	48.50	-25.42

Food resources

Benthic insect larvae (Mixing: Aeshnidae+Libellulidae+Hemiptera)	15	13.35	13.39	50.29	-26.73
Benthic insect larvae (Mixing: Aeshnidae+Libellulidae+Hemiptera)	16	10.50	13.36	39.48	-24.80
Benthic insect larvae (Mixing: Aeshnidae+Libellulidae+Hemiptera)	17	11.33	13.30	42.24	-25.18
Benthic insect larvae (Mixing: Aeshnidae+Libellulidae+Hemiptera)	18	14.57	13.89	51.71	-25.03
Benthic insect larvae (Mixing: Aeshnidae+Libellulidae+Hemiptera)	19	13.43	13.43	47.09	-25.26
Aquatic plants (Mixing: *Eichhornia crassipes+Salvinia sp.*)	20	4.59	16.60	53.56	-30.53
Aquatic plants (Mixing: *Eichhornia crassipes+Salvinia sp.*)	21	4.39	10.31	47.85	-28.85
Aquatic plants (Mixing: *Eichhornia crassipes+Salvinia sp.*)	22	4.11	10.84	44.84	-29.06
Aquatic plants (Mixing: *Eichhornia crassipes+Salvinia sp.*)	23	4.21	10.79	47.75	-29.88
Aquatic plants (Mixing: *Eichhornia crassipes+Salvinia sp.*)	24	4.42	10.44	53.90	-29.41
Terrestrial plant (Mixing: *Alberta edulis* + *Annona crassfolia+Hirtela gracilpes*)	25	1.10	0.21	44.42	-32.26

Terrestrial plant (Mixing: *Alberta edulis* + *Annona crassfolia*+*Hirtela gracilpes*)	26	3.83	-1.30	49.01	-32.73
Terrestrial plant (Mixing: *Alberta edulis* + *Annona crassfolia*+*Hirtela gracilpes*)	27	4.03	-1.23	67.31	-33.46
Terrestrial plant (Mixing: *Alberta edulis* + *Annona crassfolia*+*Hirtela gracilpes*)	28	4.08	-0.35	63.63	-33.73
Terrestrial plant (Mixing: *Alberta edulis* + *Annona crassfolia*+*Hirtela gracilpes*)	29	3.90	-1.14	68.47	-33.97
Melanoides tuberculata	30	15.26	11.64	49.30	-16.60
Melanoides tuberculata	31	8.40	10.58	32.55	-16.82
Melanoides tuberculata	32	10.55	10.31	39.27	-17.50
Melanoides tuberculata	33	10.56	10.50	41.06	-16.56
Melanoides tuberculata	34	10.99	11.26	44.12	-17.73
Limnoperna fortunei	35	11.02	10.82	59.10	-34.77
Limnoperna fortunei	36	13.74	10.98	51.05	-31.03
Limnoperna fortunei	37	13.54	10.61	49.56	-31.22
Limnoperna fortunei	38	14.18	10.92	50.64	-31.71
Limnoperna fortunei	39	13.99	11.17	51.29	-31.54
Corbicula flumínea	40	11.27	11.35	42.59	-31.88
Corbicula flumínea	41	12.08	7.27	51.27	-27.19
Corbicula flumínea	42	13.58	7.41	50.69	-27.18
Corbicula flumínea	43	14.08	8.48	50.88	-27.70

Corbicula fluminea	44	13.02	7.29	53.60	-26.73

Conclusão geral

Os estudos apresentados nesta tese fornecem insights sobre a biologia populacional e os hábitos alimentares do caranguejo de água doce *Dilocarcinus pagei*, além de investigar a dieta e as interações tróficas de *D. pagei* e *Macrobrachium pantanalense* sob a perspectiva da análise de isótopos estáveis, em um trecho de amostragem do rio Araguari.

A estrutura populacional de *D. pagei* varia ao longo do ano e é influenciada por fatores ambientais como precipitação e níveis de água do reservatório. A variação na composição populacional, particularmente a ocorrência sazonal de fêmeas ovígeras, indica que a reprodução nesta espécie é um evento sazonal associado ao aumento das chuvas. Esses achados ampliam a compreensão das caraterísticas reprodutivas dos caranguejos de água doce e do papel ecológico desta espécie nos ambientes que habita.

Em termos de ecologia trófica, a pesquisa sobre a dieta alimentar de *D. pagei* revelou os hábitos alimentares, evidenciando a influência de diferentes grupos demográficos e variações sazonais em sua dieta. O estudo destacou o consumo de tecidos vegetais, a predação de moluscos e a ingestão de microplásticos.

Por fim, a análise das interações tróficas de *D. pagei* e *M. pantanalense* revelou a complexidade dessas interações em sistemas aquáticos tropicais. As diferenças na amplitude dos nichos e dos níveis tróficos são indicativas de que essas espécies coexistem minimizando a competição direta e utilizando diferentes recursos alimentares, ampliando nossa compreensão sobre a ecologia trófica dessas duas espécies, destacando a importância da diferenciação de nicho para sua coexistência.

Em termos gerais, pesquisas sobre biologia populacional e ecologia trófica das espécies podem ser utilizadas como base para estratégias de manejo e conservação dos ecossistemas aquáticos dulcícolas, particularmente no contexto de introduções de espécies invasoras e modificação de habitats.

Sugestões para pesquisas futuras

1. **Impactos de poluentes e espécies invasoras**: Considerando os potenciais impactos dos microplásticos e das espécies invasoras, futuros estudos devem se concentrar nos efeitos a longo prazo desses fatores na dieta e ecologia dos crustáceos decápodes. Uma compreensão mais profunda desses impactos poderia informar ações de manejo visando mitigar os efeitos negativos desses poluentes e espécies não nativas nos ecossistemas aquáticos.
2. **Integração de técnicas complementares**: A aplicação de técnicas, como a espectrometria de massa de isótopos, em outras populações e espécies, poderia ajudar a expandir a compreensão das interações tróficas e padrões de coexistência em diferentes ecossistemas. O uso de técnicas moleculares poderia, por exemplo, aumentar a precisão na identificação das fontes alimentares, complementando assim as análises de isótopos e a convencional do conteúdo estomacal.
3. **Modelagem ecológica**: O desenvolvimento de modelos ecológicos que integrem dados sobre reprodução, dieta e interações tróficas pode ser uma ferramenta poderosa para prever como essas espécies responderão às mudanças ambientais. Esses modelos poderiam ajudar a desenvolver políticas de conservação mais eficazes, adaptadas às necessidades específicas das espécies e ecossistemas envolvidos.
4. **Estudos experimentais:** Experimentos focados no consumo de diferentes tipos de presas por *Dilocarcinus pagei*, incluindo moluscos, macroinvertebrados e diversas fontes de material vegetal, como macrófitas. Esses experimentos devem

avaliar a seleção de presas com base em diferentes tamanhos e tipos, observando as preferências alimentares do caranguejo.