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EFEITO DA INFESTAÇÃO DE MACRÓFITAS AQUÁTICAS NA COMUNIDADE PLANCTÔNICA EM UM VIVEIRO DE PISCICULTURA

Cecília Anatriello Boareto

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TÍTULO: EFEITO DA INFESTAÇÃO DE MACRÓFITAS AQUÁTICAS NA COMUNIDADE PLANCTÔNICA EM UM VIVEIRO DE PISCICULTURA

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DADOS CURRICULARES DO AUTOR

CECÍLIA ANATRIELLO BOARETO – nascida em 18 de julho de 1988, em Bebedouro, São Paulo, é filha de Ernesto Antonio Boareto e Celina Rita Anatriello. Formou-se em Licenciatura e Bacharelado em Ciências Biológicas na Faculdade de Ciências Agrárias e Veterinárias (FCAV) – UNESP, câmpus de Jaboticabal, SP, em dezembro de 2010 e de 2012, respectivamente. Foi bolsista de iniciação científica pela Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) no período de setembro de 2009 a janeiro de 2012. Em março de 2012 ingressou no curso de Mestrado, no Programa de Pós-Graduação em Microbiologia Agropecuária, da Faculdade de Ciências Agrárias e Veterinárias (FCAV) – UNESP, Câmpus de Jaboticabal, São Paulo, onde foi bolsista da Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP).

“Pedras no caminho? Guardo todas, um dia vou construir um castelo...”

Fernando Pessoa

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RESUMO – As invasões de macrófitas são recorrentes e causam diversas implicações nos ecossistemas de água doce. O objetivo do estudo foi avaliar se dois tipos de invasões de macrófitas, uma monoespecífica e outra heteroespecífica, que ocorreram naturalmente em um viveiro de piscicultura, modificaram as varáveis químicas, físicas e biológicas da água, em comparação com o período de ausência dessas macrófitas. Na primeira invasão de macrófitas foram realizadas coletas nos períodos com e sem macrófitas, semanalmente, nos meses de Fevereiro, Março, Maio e Junho de 2009, sendo coletadas amostras da água e da comunidade zooplanctônica. Na segunda invasão de macrófitas foram realizadas coletas nos períodos com e sem macrófitas, mensalmente, nos meses de Maio de 2010 a Fevereiro de 2011, sendo coletadas amostras de água e das comunidades zooplanctônica e fitoplanctônica. Os resultados da primeira invasão pela *S. auriculata* mostrou que a macrófita flutuante causou mudanças negativas nas concentrações das variáveis físicas e químicas da água selecionando espécies tolerantes a amplas variações no ambiente aquático (*Filinia terminalis*, *Lecane proiecta, Trichocerca longiseta* e *Thermocyclops decipiens).* No período de ausência da *S. auriculata a* concentração de oxigênio dissolvido aumentou e diminuiram as concentrações de matéria orgânica, coliforme termotolerante e amônia, que proporcionaram a ocorrência principalmente de Cladocera, que é um bom alimento vivo disponível para outros organismos. Já na segunda invasão, a presença das macrófitas emergentes e flutuantes reduziu principalmente a matéria orgânica, proporcionando a ocorrência de Cladocera (*Alona monacantha*), Copepoda (náuplio de Cyclopoida e Calanoida) e maior abundância de Chlorophyceae. Esses fatores proporcionam uma maior qualidade de alimento vivo disponível na água. Já na ausência dessas plantas, as concentrações de algumas variáveis aumentararam e foram essenciais para selecionar novamente espécies que possuem alta plasticidade (*Brachionus havanaensis, Brachionus calyciflorus, Keratella cochlearis, Filina longiseta, Aulacoseira granulata)* e que podem ser prejudicial ao ecossistema aquático (*Planktolyngbya contorta* e *Aphanocapsa delicatissima*). Portanto, o período de ausência de macrófitas flutuantes, *S. auriculata*, e o período em que havia a presença das macrófitas flutuantes e emergentes, foram melhores em relação à qualidade da água e do alimento vivo disponível na água.

Palavras-chave: *Salvinia auriculata*, macrófitas flutuantes, macrófitas emergentes, plâncton, Cladocera, Copepoda, Rotifera

EFFECT OF INFESTATION OF MACROPHYTES AQUATIC IN THE PLANKTONIC COMMUNITY IN A FISHPOND

ABSTRACT - The invasions of macrophytes are recurrent and cause various implications in freshwater ecosystems. The aim of the study was to evaluate if two types of invasions of macrophytes, one monospecific and other heteroespecífica, occurred naturally in a pond, changed the chemical, physical and biological variables of the water, compared to the period of absence of macrophyte. In the first invasion of macrophytes, the samples were collected during periods with and without macrophytes weekly during the months of February, March, May and June 2009, and it were collected samples of water and zooplankton. In the second invasion of macrophyte, the samples were collected during periods with and without macrophytes, monthly, during the months of May 2010 to February 2011, and it were collected samples of water and zooplankton and phytoplankton communities. Results from the first invasion by *S. auriculata* showed that the floating macrophyte caused negative changes in the concentrations of the physical and chemical parameters and selected the tolerant species to wide variations in the aquatic environment (*Filinia terminalis*, *Lecane proiecta*, *Trichocerca longiseta* and *Thermocyclops decipiens*). In the period of absence from *S. auriculata* the concentration of dissolved oxygen increased, decreased concentrations of organic matter, thermotolerant coliform and ammonia, which provided the occurrence mainly Cladocera (*Daphnia gessneri* and *Diaphanossoma birgei*), which is a good live food available in the water. In the second invasion, the presence of emergent and floating macrophytes decreased mainly concentration of organic matter, favoring the occurrence of Cladocera (*Alona monacantha*), Copepoda (Cyclopoida and Calanoida nauplii) and greater abundance of Chlorophyceae. These factors provide a higher quality of live food available in the water. Already in the absence of these plants, the concentrations of some variables aumentararam and were essential to select again of species that have high plasticity (*Brachionus havanaensis, Brachionus calyciflorus, Keratella cochlearis, Filina longiseta, Aulacoseira granulata*) and that can be harmful to the aquatic ecosystem (*Planktolyngbya contorta* and *Aphanocapsa delicatissima).* Therefore, the period of absence of floating macrophytes, *S. auriculata*, and the period in which there was the presence of floating and emergent macrophytes were better in relation to water quality and living food available in the water.

Keywords: *S. auriculata*, floating macrophyte, emergent macrophyte, plankton, Cladocera, Copepoda, Rotifera

CAPÍTULO 1 – CONSIDERAÇÕES GERAIS

INTRODUÇÃO

As macrófitas aquáticas em condições favoráveis tendem a proliferar e ocupar toda a superfície e até mesmo a coluna d’água, sendo que essas invasões biológicas são uma das perturbações ambientais mais importantes para os ecossistemas aquáticos. Em ecossistemas de água doce, que são especialmente vulneráveis aos impactos antrópicos, as invasões são recorrentes e produzem vários efeitos.

No Centro de Aquicultura da Universidade Estadual Paulista de Jaboticabal, ocorreu primeiramente uma colonização monoespecífica (uma espécie) de macrófita, *Salvinia auriculata* Aublet, em um dos viveiros de estudo. Posteriormente por falta de gestão adequada, houve uma segunda invasão com a mesma espécie de macrófita, que ao longo do tempo, ocorreram sucessões ecológicas até a colonização se tornar heteroespecífica (várias espécies de macrófitas emergentes e flutuantes). As mudanças nas comunidades das macrófitas acarretam em mudanças nas condições abióticas e consequentemente na comunidade dos organismos associados, como, por exemplo, na comunidade planctônica presente, que podem, por meio de interações tróficas, estender o efeito para todo o ecossistema.

Com isso, o presente trabalho teve por objetivo avaliar se ocorreram ou não, mudanças nas variáveis abióticas e se essas mudanças interferiram na comunidade planctônica nos períodos de presença e ausência nas duas formas de invasão de macrófitas: monoespecífica (*S. auriculata*) e heteroespecífica (emergentes e flutuantes)

O primeiro capítulo desta dissertação aborda os principais problemas enfrentados com a eutrofização na aquicultura, favorecendo o crescimento das macrófitas aquáticas, que modificam todo o ecossistema e pode afetar as variáveis físicas, químicas e biológicas, com enfoque na comunidade planctônica (zooplâncton e fitoplâncton). Neste capítulo, também são caracterizados o objetivo e a área de estudo.

Os capítulos 2 e 3 são compostos de artigos científicos. O capítulo 2 visa avaliar o efeito da primeira invasão ocorrida naturalmente em um viveiro de piscicultura por uma única macrófita, *S. auriculata* Aublet, na qualidade da água e na comunidade zooplanctônica. O capítulo 3 aborda o resultado do manejo inadequado dessa primeira infestação que ocasionou um novo crescimento natural de macrófitas com diferentes espécies, flutuantes e emergentes, sendo analisada a relação da presença e ausência dessas plantas sobre as comunidades zooplanctônica e fitoplanctônica.

REVISÃO DE LITERATURA

Aquicultura

A produção na aquicultura é provavelmente o setor de alimentos que mais cresce em todo o mundo, sendo responsável por quase 40% da produção mundial de peixes. Nas últimas três décadas (1980-2010) a produção na aquicultura obteve um aumento extremamente elevado de 12 vezes (RAMÍREZ-GODÍNEZ et al., 2013). Com a maximização na produção ou na eficiência alimentar, promoveu o aumento na entrada de resíduos, causando eutrofização desses sistemas artificiais rasos (GILLES et al., 2012).

A adição de grandes quantidades de nutrientes inorgânicos, nitrogênio e fósforo, aumentam o grau de eutrofização das águas superficiais e a degradação dos ecossistemas aquáticos, sendo importantes problemas ambientais em escala global e local (CHEN; DALTON; TAYLOR, 2010). Grandes quantidades desses nutrientes não são utilizadas pelos peixes e frequentemente são acumulados nos viveiros ou tanques de piscicultura (FERDOUSHI et al., 2008).

Como resultado, a maioria dos tanques de peixes tornam-se eutróficos e os piscicultores enfrentam problemas inesperados, como a degradação ambiental, através da proliferação de algas tóxicas, a toxicidade da amônia, diferentes doenças dos peixes, mudança na diversidade e abundância de espécies planctônicas e o crescimento indesejado de macrófitas (FERDOUSHI et al., 2008; BORGES et al., 2010; LONE; BHARDWAJ; SHAH, 2014).

Macrófitas

O crescimento das macrófitas aquáticas é controlado por uma variedade de fatores, como a qualidade, profundidade e circulação da água, além das características do substrato e interações bióticas (ZELNIK; POTISEK; GABERSCIK, 2012). Os nutrientes e a luz solar são os principais fatores abióticos limitantes que afetam o crescimento, desenvolvimento, densidade e diversidade das macrófitas aquáticas (HILT et al., 2010).

A distribuição de macrófitas aquáticas tem sido relacionada a diversos fatores ambientais sendo que os principais são: a espécie, o tipo ecológico, processos ecológicos (especialmente competição e predação) e as características abióticas, como, temperatura, radiação fotossinteticamente ativa, transparência da água, velocidade de corrente, tipo de substrato e concentrações de nutrientes (POKORNÝ; KEVET, 2004).

As diversas propriedades intrínsecas das macrófitas fazem delas um componente indispensável do ecossistema aquático (LONE; BHARDWAJ; SHAH, 2014), incluindo tanques ou viveiros e frequentemente elas caracterizam as zonas litorais de lagos rasos, tendo um importante papel na ciclagem de nutrientes, estruturando e modificando os parâmetros físicos e químicos através da fotossíntese, decomposição e mineralização (JONIAK; KUCZYŃSKA-KIPPEN; NAGENGAST, 2007; THOMAZ; CUNHA, 2010). A presença dessas plantas pode melhorar a qualidade da água, devido à capacidade de absorver cargas excessivas de nutrientes (FERDOUSHI et al., 2008).

Apesar das macrófitas representar um componente essencial para o ecossistema aquático, elas podem ser invasoras e alterar negativamente as propriedades do ecossistema, gerando custos para à sociedade humana (MADSEN et al. 2001, PIMENTEL; ZUNIGA; MORRISON, 2005). As invasões são muitas vezes vista como um processo, que pode ser descrito e avaliado por uma série de etapas, incluindo o transporte, introdução, criação, propagação, e, finalmente, o impacto (LOCKWOOD et al. 2007). Em cada fase há oportunidade para uma determinada espécie ter sucesso (filtro para a próxima fase) ou falhar (morrer ou deixar de reproduzir). A última fase, de estabelecimento, pode ser de maior interesse para os ecologistas pois é a fase onde se determina se a espécie foi bem sucedida e se há interações com as demais comunidades (SHEA; CHESSON 2002).

As macrófitas são afetadas por sucessões ecológicas, onde uma comunidade vegetal altera as condições ambientais de uma maneira que faz com que o habitat seja menos favorável para a sua própria sobrevivência, mas mais favorável para o desenvolvimento de uma comunidade diferente. Espécies invasoras não nativas foram identificadas como uma das principais causas de perda de biodiversidade (LOCKWOOD et al. 2007).

As macrófitas aquáticas são classificadas em submersas, emergentes, com folhas flutuantes e flutuantes livres (BRUM; ESTEVES, 2001). As macrófitas aquáticas flutuantes adquirem os nutrientes inorgânicos, principalmente pelas raízes, embora a absorção pelas folhas também possa ser significativa (FERDOUSHI et al., 2008).

Nos neotrópicos, comunidades de macrófitas flutuantes são geralmente formadas por um mosaico de diferentes espécies em competição. Entretanto, *Eichhornia crassipes* e *Salvinia* sp. podem prover um substrato para colonização secundária por outras espécies, ocorrendo dessa maneira sucessões ecológicas que favoreceram a presença de um grande número de espécies emergentes, ancoradas, capazes de predominar em corpos d'água rasos (MITCHELL; PIETERSE; MURPHY, 1990). Essas plantas aquáticas podem alcançar um novo ambiente, infestando-se, através de mecanismos de dispersão como, por exemplo, aves aquáticas e os peixes (THOMAZ, 2002).

Como as macrófitas possuem reprodução vegetativa, o seu é crescimento rápido, que os tornam potenciais invasores (SANTAMARÍA, 2002). Entre as macrófitas invasoras a *Salvinia auriculata* Aublet é uma

Pteridophyta aquática nativa da família Salviniaceae situada dentro da ordem Hydropteridales e consiste de um simples gênero *Salvinia* com dez espécies, apresenta folha livre flutuante com rizoma horizontal que ajuda a manter-se na superfície da água (BEYRUTH, 1992).

A folha da *S. auriculata* também suporta órgãos produtores de esporos, os esporocarpos, que são estruturas de resistência aos períodos desfavoráveis. Estes quando germinam promovem o crescimento de novos ramos. Em condições favoráveis são rapidamente disseminadas por propagação vegetativa e, qualquer parte da planta com um broto, pode formar outra planta, colonizando amplas superfícies de água em um curto espaço de tempo (COELHO; LOPES; SPERBER, 2005).

A espécie *Eichhornia crassipes*, macrófita flutuante nativa da América do Sul, pertence à família Pontederidaceae e se reproduz sexualmente por sementes, viáveis por pelo menos 15 anos no sedimento dos corpos d´água (HOLM; YEO, 1980), e de forma assexuada por estolões. Apresenta ampla distribuição geográfica e se prolifera rapidamente de forma indesejada em diversos ecossistemas aquáticos, podendo acarretar problemas aos usos múltiplos de rios, lagos e represas, dificultando a navegação e a captação de água, prejudicando a geração de energia elétrica e comprometendo as atividades de lazer (MARTINS et al., 2003).

A espécie *Lemna minor*, da família Lemnaceae, é uma espécie representativa de corpos de água lênticos e são as menores plantas vasculares do mundo, espécies vegetais que se adaptaram ao ambiente aquático ao longo de seu processo evolutivo (VIDOTTI; ROLLEMBERG, 2004). Possui rápido crescimento e vem sendo utilizada no monitoramento de metais em recursos hídricos, e também de outros tipos de poluentes. Possuem características favoráveis para seu uso em testes de toxicidade, como: pequeno tamanho, estrutura simples e rápido crescimento e propagação vegetativa. Além disso, é um dos agentes de fitorremediação eficazes utilizados para corpos d'água contaminados (MKANDAWIRE; DUDEL, 2007).

As macrófitas aquáticas emergentes são definidas como plantas que estão enraizadas em águas rasas com partes vegetativas emergentes acima da superfície da água. A abundância de macrófitas emergentes é o principal determinante da estrutura biológica e ecológica do funcionamento de lagos rasos (SCHEFFER; BROCK; WESTLEY, 2000). Constituem a base nutricional para os organismos herbívoros, incluindo invertebrados, peixes e aves, na zona litorânea de lagos (SCHMIEDER; WERNER; BAUER, 2006).

A macrófita emergente *Panicum repens* é uma espécie perene, pertencente à família Poaceae, de ampla importância e distribuição no Brasil. Essa macrófita produz grande quantidade de rizomas, que suportam longos períodos secos e adaptam-se facilmente à condição de alagamento. Em razão de seu rápido desenvolvimento vegetativo, as plantas podem ocupar as margens de reservatórios rapidamente, sendo considerada uma das mais graves macrófitas invasoras. Ela suprime outras plantas por seus produtos alelopáticos (inibidores) (PERERA et al., 1989).

A macrófita emergente *Cyperus rotundus* é de difícil manejo e causadora de prejuízos em diversas culturas comerciais. Por se tratar de uma espécie perene, pela ampla adaptabilidade a muitos ambientes agrícolas e pela capacidade de se reproduzir sexuada e assexuadamente, a *Cyperus rotundus* encontra-se entre as 20 espécies de macrófitas que mais causam prejuízos no mundo (PANOZZO et al., 2009).

A espécie *Typha domingensis* é uma macrófita emergente e a sua importância nos ecossistemas de áreas úmidas é devido à grande quantidade de matéria orgânica produzida por sua decomposição (THOMAZ; CUNHA, 2010). Essa macrófita está presente em povoamentos densos, ocorrendo em regiões pantanosas, margens da lagoa, lagos, rios e canais artificiais e pode ser encontrada em todo o território brasileiro (KISSMANN, 1997). Em alguns casos, é considerada indesejável quando as condições são favoráveis para o seu crescimento, que de forma rápida se torna uma macrófita invasiva.

O levantamento de macrófitas aquáticas é importante do ponto de vista da diversidade de espécies, assim como os fatores que explicam a diversidade de outros grupos (como, por exemplo, macroinvertebrados e perifíton) e como indicadores de qualidade da água (ZELNIK; POTISEK; GABERSCIK, 2012).

Outro fator importante é verificar os danos que as macrófitas podem gerar como, por exemplo, a *Typha* sp., onde a sua presença é interpretada como sinal de assoreamento, estágio final de degradação ambiental e seus povoamentos criam excelentes condições para a reprodução de mosquitos (BIANCO; PITELLI; PITELLI, 2003). Esse tipo de informação é muito importante, pois permite o monitoramento de espécies invasoras à medida que os ambientes aquáticos são alterados pela atividade antrópica (SANTOS, 2004).

A presença de macrófitas em viveiros de criação de peixe pode ocorrer desde que seja somente 10% do espelho de água, porém quando esta ocupação passa a ser maior que 50% ou mesmo total, como é o caso deste estudo, o efeito torna-se adverso não só pela falta de penetração de luz na água como também, pela drástica diminuição de oxigênio dissolvido e aumento excessivo de matéria orgânica no sedimento, afetando, consequentemente, a comunidade planctônica (SIPAUBA-TAVARES; BARROS; BRAGA, 2003).

As macrófitas aquáticas possuem muitos papéis importantes na manutenção da biodiversidade e funcionamento dos ecossistemas de água doce. Bancos de macrófitas promovem uma grande diversidade de organismos que dependem deles para alimentação (PELICICE; AGOSTINHO, 2006), ou abrigo e refúgio (AGOSTINHO et al, 2007).

Relação entre macrófitas e o plâncton

A presença de macrófitas aumenta a riqueza de espécies aquáticas, sendo importante para o entendimento dos mecanismos que sustentam a diversidade em um viveiro, podendo ser utilizado na conservação da biodiversidade (AKASAKA et al., 2010).

Ao preencher a coluna de água com estrutura física densa e complexa, as macrófitas fornecem alimentos e habitat para uma série de organismos, tais como peixes, macroinvertebrados e para espécies de zooplâncton

(SAYER; DAVIDSON; JONES, 2010). A disponibilidade da macrófitas como recursos alimentares e refúgio depende de vários fatores, incluindo a arquitetura, tamanho e densidade dessas plantas, e, também, sobre os predadores que estas plantas hospedam (MEERHOFF et al., 2007).

O efeito do refúgio também parece depender do tamanho dos “bolsões”, a densidade e o volume das macrófitas, e também do estado trófico do lago (LAURIDSEN; PEDERSEN; JEPPESEN; SONDERGAARD, 1996).

De acordo com Villabona-González, Aguirre e Estrada (2011) e Spoljar et al. (2012) as macrófitas podem influenciar nas características estruturais do zooplâncton, mudando a sua composição, distribuição, densidade e diversidade. As macrófitas além de influenciar o zooplâncton, podem excretar substâncias alelopáticas que inibem o crescimento de outros fotoautótrofos, assim como perifíton e fitoplâncton (SCHEFFER, 1998).

Como componente biótico dos ecossistemas aquáticos, o zooplâncton desempenha um papel fundamental no ciclo de materiais orgânicos, ajudando, através do pastejo, na regulação da população microbiana e de algas (Dejen et al., 2004), sendo elo entre produtores e consumidores de nível superior na cadeia trófica (ARIMORO; OGANAH, 2010; SIPAÚBA-TAVARES; MILLAN; SANTEIRO, 2010).

As comunidades de zooplâncton em água doce constituem um conjunto extremamente diversificado de organismos representados principalmente por Rotifera, Cladocera e Copepoda. Algumas espécies são comumente encontradas em áreas abertas, enquanto que outras se encontram dentro ou nas proximidades das plantas aquáticas (ALI; MAGEED; HEIKAL, 2007).

Rotifera são organismos dióicos de reprodução partenogênica. Apresentam diferentes hábitos alimentares, como carnívoros, onívoros e herbívoros (MATSUMURA-TUNDISI; TUNDISI, 2005). Geralmente ocorrem em densidades de até 1.000 indivíduos por litro, e são importantes filtradores de algas e bactérias (SEGERS, 2008).

As espécies de Cladocera vivem na região litorânea e pelágica de águas lênticas, alimentam-se de fitoplâncton e perifíton associados às macrófitas aquáticas e outros substratos. A locomoção desse grupo ocorre de forma intermitente (ESTEVES, 2011) e geralmente se reproduzem por partenogênese cíclica (mas também são conhecidas linhagens assexuadas), e as populações são majoritariamente dominadas por fêmeas (FORRÓ et al., 2008). O dimorfismo sexual é normalmente bastante distinto. Ovos de resistência produzidos sobrevivem à dessecação e outras condições desfavoráveis, e podem até sobreviver à passagem através do trato digestório das aves (FIGUEROLA; GREEN, 2002).

As espécies de Copepoda são extremamente abundantes em água doce, de vida livre, mas também podem se comportar como parasita em peixes e moluscos (BOXSHALL; DEFAYE, 2008). Habitam diferentes ambientes aquáticos, são filtradores, herbívoros, detritívoros ou carnívoros. A locomoção é realizada por apêndices com reprodução sexuada (LOUREIRO et al., 2011).

De acordo com Imoobe e Adeyinka (2010) a comunidade zooplanctônica é bioindicadora do estado trófico de água, pois apresentam mudanças drásticas em resposta às alterações que ocorrem nas propriedades físico-químicas e bióticas do ambiente aquático.

Flutuações na comunidade planctônica indicam que a dependência destes organismos às condições físico-químicas da água e ao manejo empregado nos sistemas de criação, são causados pela intensa dinâmica que ocorre nos tanques e viveiros de criação de peixe (SIPAÚBA-TAVARES; MILLAN; SANTEIRO, 2010).

Dependendo do grau de trofia dos viveiros de piscicultura, estão presentes diferentes espécies planctônicas com ciclo reprodutivo curto e bem adaptadas às alterações constantes destes sistemas, podendo aparecer em elevada densidade (MACEDO; SIPAÚBA-TAVARES, 2005).

Os fitoplânctons são reconhecidos mundialmente como organismos bioindicadores no ambiente aquático (YAKUBU et al., 2000) e são a base da cadeia alimentar aquática, fator mais importante para a produção de matéria orgânica no ecossistema aquático (MUSTAPHA, 2010). A estrutura da comunidade fitoplanctônica é determinada por indicadores como a composição específica, densidade celular, a riqueza e a uniformidade de espécies, e isso pode ser usado para avaliar a qualidade do ecossistema aquático e as medidas de diversidades específicas, constituindo um índice apropriado para comparar as condições do ambiente (ROSA et al., 1988).

A dinâmica da comunidade fitoplanctônica em ecossistemas de águas doces naturais são regulados pela complexa interação entre as microalgas e muitas outras variáveis como a hidrodinâmica (descarte de água, fluxo e tempo de residência), ciclo de nutrientes e presença de predadores (WANG et al., 2010). Em água doce, o fitoplâncton inclui organismos de diversos grupos, como Chlorophycea, Cyanobacteria e Bacillariophyceae, entre outros (MOURA et al., 2007).

As Cyanobacteria ocorrem em muitos sistemas de água de superfície, inclusive em viveiros ou tanques de aquicultura, e componente comum do fitoplâncton e com importante papel, não somente por sua capacidade de rápida proliferação, mas também pelos efeitos no ambiente aquático e nos organismos (SEN; SONMEZ, 2006; POIRIER; CATTANEO; HUDON, 2010).

As espécies de Cyanobacteria excedem a taxa de crescimento de outras microalgas, algumas vezes tornando-se dominantes (MELO-MAGALHÃES et al., 2009) principalmente, em condições eutróficas, sendo responsáveis em muitos casos por produção de algumas toxinas (CHELLAPPA; CÂMARA; ROCHA, 2009).

Essas toxinas podem afetar a saúde dos peixes e consequentemente, dos humanos, uma vez que a carne dos peixes torna-se impalatável ao consumidor, reduzindo assim, a demanda. Foi encontrado também que alguns gêneros de Bacillariophyta (*Melosira granulata*, *Synedra* sp., *Navicula* sp., *Nitzschia* sp.) e Chlorophyceae (*Scenedesmus* sp.) podem causar “off-flavor” em peixes criados em tanques (XU et al., 2010).

Em um sistema eutrófico, o excesso de entrada de nutrientes, como o nitrogênio e fósforo, resulta em um aumento gradual da biomassa fitoplanctônica e frequentes florações de algas, levando à inibição ou destruição do ecossistema de um lago (HILT; GROSS, 2008).

A densidade, a composição e o tamanho da distribuição das espécies de fitoplâncton são regulados não só pelas condições de nutrientes, mas também pela presença do zooplâncton, que pode estimular o crescimento ou interferir na sua biomassa e abundância através da predação (GASIUNAITE; OLENINA, 1998).

O grande interesse no estudo da comunidade planctônica é entender os fatores ambientais que influenciam a sua diversidade e a sua abundância, o conhecimento dessas respostas é de grande importância no gerenciamento de operações na aqüicultura e poderão constituir como metodologia para avaliar e melhorar a qualidade de água na piscicultura (ARIMORO; OGANAH, 2010).

Desta forma, este estudo busca analisar se ocorreram mudanças nas variáveis abióticas e na comunidade planctônica da água em dois tipos de invasões de macrófitas, uma com apenas uma espécie de macrófita flutuante e a segunda com macrófitas emergentes e flutuantes.

ÁREA DE ESTUDO

O estudo foi realizado no Centro de Aquicultura (21°11’S e 48°18’O) da Universidade Estadual Paulista (CAUNESP) em Jaboticabal (SP), durante 3 anos consecutivos (2009 – 2011). Esse centro possui três setores de estudo: piscicultura, carcinicultura e ranicultura.

O viveiro estudado é o quarto de seis viveiros sequenciais e possui uma área de aproximadamente 4.268,04 m^2, com 1–1,2m de profundidade, adotando-se prática de criação semi-intensiva de organismos aquáticos para fins de pesquisa, com densidade de estocagem de 400 carpas capim (*Ctenopharyngodon idella*). A entrada de água ao norte do viveiro recebe água de 33 tanques e/ou viveiros e a outra entrada na região nordeste do viveiro recebe água de 13 tanques e/ou viveiros (200 m^2). A saída de água está localizada a extremo sul do viveiro (Figura 1).

A circulação da água no viveiro é do tipo sequencial, ou seja, recebe água de outros viveiros e deságua diretamente no próximo, sem tratamento prévio. O viveiro estudado apresenta as piores condições limnológicas de todo o conjunto de viveiros sequenciais do CAUNESP. Estas condições estão

Figura 1. Vista dos diferentes pontos amostrados, onde: P_1 e P_3 = entrada de água; P_2 = localizado entre o P_1 e P_3, ponto mais raso; P_4 = ponto mais central do viveiro e P_5 = saída de água.

relacionadas ao aporte de material que flui diretamente da ranicultura, cujos viveiros são lavados diariamente carreando grandes quantidades de matéria orgânica, ração não digerida e fezes de rãs, além de receber diretamente água de 24 viveiros localizados acima deste sistema (SIPAÚBA-TAVARES et al. 2010b).

A primeira invasão ocorreu em 2009, de forma natural, por uma única espécie de macrófita, *S. auriculata,* que ocupou toda a superfície da água, por alguns meses. Essas macrófitas foram retiradas por uma equipe não especializada (trabalhadores do próprio CAUNESP) e de forma inapropriada, pois entraram no viveiro, re-suspendendo o sedimento e descartaram as macrófitas na borda deste, que acarretou em uma nova invasão com a mesma espécie de macrófita. Ao longo do tempo, ocorreram sucessões ecológicas e a *S. auriculata* serviu como substrato para o crescimento natural de outras macrófitas emergentes, como a espécie invasora *Panicum repens*, *Typha domingensis*, *Cyperus rotundus* e *Polygonum capitatum* e as espécies flutuantes *Eichhornia crassipes* e *Lemna minor* (Figura 2). Esse período de crescimento de macrófitas emergentes e flutuantes consistiu a segunda invasão ocorrida nesse viveiro, em 2010 e 2011. Dessa vez, a retirada das macrófitas foi feita por uma empresa especializada, de maneira apropriada

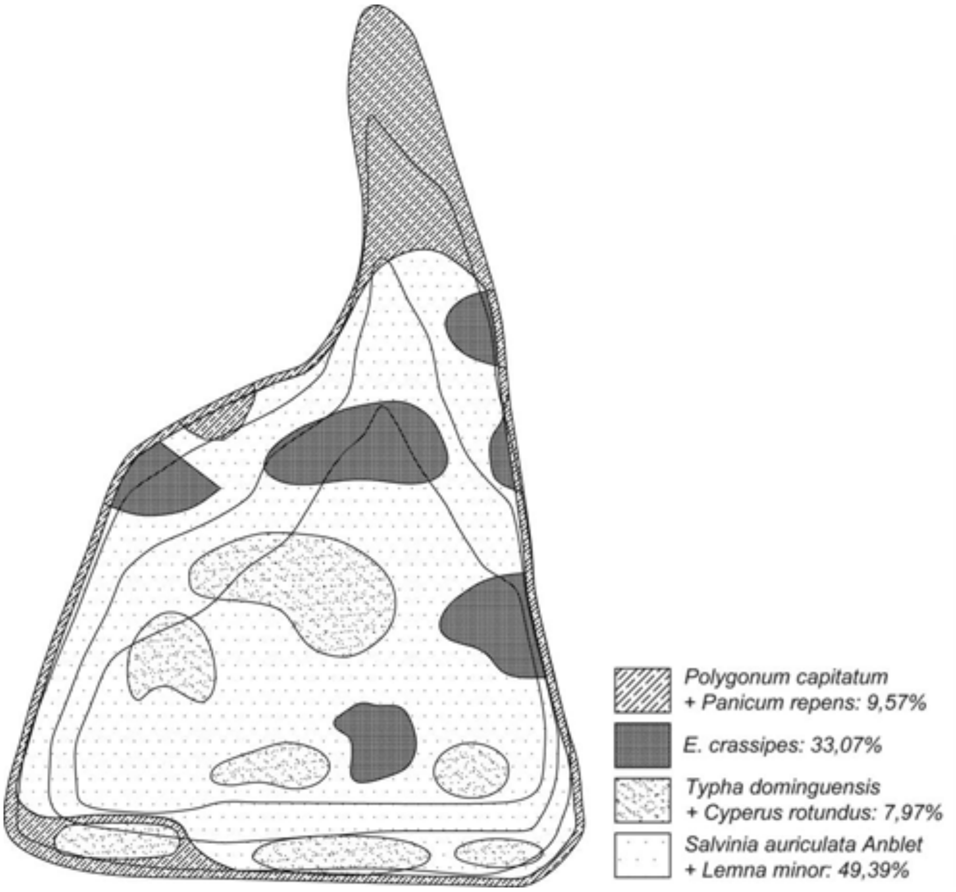

Figura 2. Representação gráfica do viveiro infestado pelas macrófitas

(não entraram no viveiro). Posteriormente, não houve mais adição de ração, sendo que os peixes sobreviviam da própria biota local e o viveiro não apresentou mais nenhuma invasão por macrófitas. As amostragens das duas invasões foram realizadas nos períodos com e sem as macrófitas.

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CAPÍTULO 2 – Effect of *Salvinia auriculata* Aublet infestation on the water quality and zooplankton community in a flow through neotropical fishpond

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ABSTRACT

Effect of S*alvinia auriculata* Aublet infestation on the water quality and zooplankton community in a flow through neotropical fishpond

The aim of the study was to evaluate if the macrophyte monospecific invasion (*Salvinia auriculata* Aublet), that occurred naturally in a pond, changed the chemical, physical and biological (zooplankton community) variables of the water, compared to the period without macrophyte. The samples were collected during periods with and without macrophytes weekly during the months of February, March, May and June 2009, and it were collected samples of water and zooplankton. Results from the invasion by *S. auriculata* showed changes in the concentrations of the physical and chemical parameters and selected the tolerant species to wide variations in the aquatic environment (*Filinia terminalis, Lecane proiecta, Trichocerca longiseta* and *Thermocyclops decipiens*). In the period without *S. auriculata*, the concentration of dissolved oxygen increased and, decreased concentrations of organic matter and thermotolerant coliform, which provided the occurrence mainly Cladocera species (*Daphnia gessneri* and *Diaphanossoma birgei*), which they are a good live food available in the water. Therefore, the period without floating macrophytes, *S. auriculata*, was better in relation to water quality and living food available in the water.

Keywords: Macrophyte, zooplankton, *Salvinia auriculata*, environmental parameters.

RESUMEN

Efecto de infestación del Salvinia auriculata Aublet en la calidad del agua y comunidad de zooplancton en un estanque neotropical.

El objetivo del estudio fue evaluar si el monoespecífico invasión de macrófitos (Salvinia auriculata Aublet), que se produjo de forma natural en un estanque, cambió la química, física y biológica (la comunidad de zooplancton) variables del agua, en comparación con el período de ausencia de macrófitos. Las muestras fueron colectadas durante los periodos con y sin macrófitos semanal durante los meses de febrero, marzo, mayo y junio de 2009, y se recogieron muestras de agua y zooplancton. Los resultados de la invasión de S. auriculata mostraron cambios en las concentraciones de los parámetros físico-químicos y ha seleccionado las especies tolerantes a grandes variaciones en el medio acuático (Filinia terminalis, Lecane proiecta, Trichocerca longiseta y Thermocyclops decipiens). En el período de ausencia del S. auriculata la concentración de oxígeno disuelto aumentado, disminución de las concentraciones de materia orgánica y coliformes termotolerantes, que proporcionaron la ocurrencia principalmente Cladocera (Daphnia gessneri y Diaphanossoma birgei), que es un buen alimento vivo disponible en el agua. Por lo tanto, el período de ausencia de los macrófitos flotantes, S. auriculata, fue mejor en relación con la calidad del agua y alimento vivo disponible en el agua.

Palabras clave: *Macrófitos, zooplancton, Salvinia auriculata, parámetros ambientales*

INTRODUCTION

In southeastern Brazil continuous water flow are used, where the water is drained directly from one fishpond to the next without previous treatment, eventually the composition of the first fishpond may affect the characteristic of second, and increasing of nutrients load. In this kind of system the aquatic plants tend to propagate quickly and to cover the entire surface of the pond, mainly due to lack of adequate management (Sipaúba-Tavares *et al*., 2003). In freshwater ecosystems, which are especially vulnerable to the anthropogenic impacts, macrophytes invasions are recurrent and their effects are several (Strayer, 2010).

Biological invasions are one of the most important environmental disruptions to aquatic ecosystems and invasive species are those which become extremely successful in their own (native) or new (exotic) habitats and put new pressures on the environment and resident species (Strayer, 2010).

The aquatic plants are highly capable of removing nutrients of the water column affecting plankton density and some species have developed morphological and physiological adaptive strategies for surviving in different environment based on nutrients (Christie *et al.*, 2009).

Macrophytes beds are an important habitat for many planktonic organisms, owing to the refuge they provide against fish predation and should also favored the development of zooplankton by increasing the water residence time, allowing more time for populations of planktonic organisms to develop (Basu *et al*., 2000).

The refuge effect also seems to depend on plant architecture (Nurminen & Horppila, 2002), bed size (Lauridsen *et al.*, 1996), density (Burks *et al.*, 2001) and volume (Schriver *et al*., 1995), and on the trophic state of the pond (Lauridsen *et al*., 1999). Maia-Barbosa *et al.* (2008) observed that the large numbers of zooplankton species were related mainly of presence of extensive aquatic macrophytes bed.

In our study, there was a monospecific macrophyte invasion, the *Salvinia auriculata*, covered temporally the fishpond and after some months was removed manually due to the possible loss the fish production. *Salvinia auriculata* Aublet (1775) (Pteridophyta: Salvinaceae) commonly known as “water fern”, is a free-floating fern and have a wide geographical distribution in southeastern Brazil. *Salvinia auriculata* is prevalent in fishponds and, under favorable conditions, it reproduces rapidly colonizing extensive areas in a short time mainly in shallow ponds (Henry-Silva & Camargo, 2006).

Despite of the widespread occurrence of *S. auriculata* in shallow freshwater reservoir of neotropical regions and their environmental importance, the extant information is scanty on the macrophyte infestation in fishpond and its effect in the water quality and in the zooplankton community in fish farm systems. Considering the great potential this aquatic macrophyte invasive to affect aquatic ecosystems, the present investigation aims at evaluating if there were changes in water quality parameters and in zooplankton community, in the periods with and without macrophyte.

METHODS

Study area

Current investigation was carried out during four months in a fishpond of the Aquaculture Center (21°15’S and 48°17’W). The fishpond is 4,268 m^2 in area, 1 - 1.3 m deep, and has a continuous water flow with a daily exchange rate of 5 % of its volume. This fishpond is the fourth of six similar size fishponds in a sequential line, that receiving water from the previous one and has high concentrations in physical and chemical variables (such as nitrate, nitrite and electrical conductivity) due to the contribution of material flowing directly from frog farm for this pond, as seen by Sipaúba-Tavares *et al*. (2010).

The studied fishpond has two water inlets. The inlet pipe the northeast side receives water from thirteen 200 m^2 fishponds. The inlet pipe in the northern and receives water from thirty-three 50-8,067 m^2 fishponds. All fishponds source water for the studied pond receives water from the first pond in the line, and had average fish density of 1 fish/m^2.

The water outlet is located in the southern end of the pond. Intense feed management (high feed addition) continuous water flow and high temperature during the summer (rainy season, from November to March) increase nutrients and provided a natural growth of *S. auriculata*, occupying almost the entire the water surface of fishpond and typically a free-floating aquatic macrophyte, annual or perennial, with small-size leaves. After two months of study, the plants were removed and samples of water and zooplankton were collected again. Thus two periods with and without macrophytes were analyzed.

Field work

Samples were collected weekly at 9:00 am in the two periods: with macrophyte, from February to March 2009 and without of macrophyte, from May to June 2009. Physical and chemical parameters of water and zooplankton community were measured at five sampling sites, three close to the inlet water; one in the deep water and the last one in the water outlet. The samples were collected in surface with a Van Dorn bottle.

Environmental parameters and analysis

Temperature, dissolved oxygen and pH were measured on the spot by a multi-electrode Horiba U-10. Concentrations of nitrite (NO_2; sulfanilamide and naftil colorimetric reagents) and nitrate (NO_3; cadmium for its reduction to nitrite) were determined according to Golterman *et al.* (1978). Ammonia (NH_3) levels were determined by spectrophotometer with phenolic acid method, following Koroleff

(1976), and total alkalinity ($CaCO_3$) with the phenolphthalein method (Mackereth *et al.*, 1978).

To determine chlorophyll-*a* (Chl-a), water was filtered through Whatman glass fiber filters (0.45 µm pore), extracted with 90% alcohol and quantified at 663 and 750 nm (Nusch, 1980). Total suspended solids (TSS) and 5-days biochemical oxygen demand (BOD_5) were determined according to Boyd & Tucker (1992). Analyses were performed after sampling or samples were duly stored under refrigeration. Water samples for microbiological analysis using the Most Probable Number (MPN) method, were collected in sterilized 500 ml-flasks and taken to the laboratory in an isothermal container. The material used in the microbiological analyses was sterilized prior to use (Greenberg *et al.*, 1992).

Zooplankton

For zooplankton community samples 10 l of water were filtered through a net of 58 µm are stocked in a plastic bottle (200 ml), adding formalin to reach 4% final concentration. Cladocera and Copepoda species were quantified in a reticulated acrylic chamber under stereomicroscope. Rotifera species were identified and counted in Sedgewick-Rafter chamber were examined under a Leitz microscope after 30 minutes sedimentation. Numerical densities data were expressed as percentage abundance (%). Cladocera, Copepoda and Rotifera were identified at species level. The Rotifera species were grouped at family level to Canonical Correspondence Analysis. Copepoda species were subdivided into Calanoida, Cyclopoida and nauplii. Taxonomic identification followed specialized literature (Koste, 1978; Reid, 1985; Segers, 1995; Elmoor-Loureiro, 1997; Silva & Matsumura-Tundisi, 2005).

Data analysis

A Mann-Whitney U-test was carried out to test for statistically significant differences of the environmental parameters between the periods, with and without macrophyte. Statistical analyses were performed using the program Statistica 8.0. In addition, ordination analysis CCA (Canonical Correspondence Analysis) was performed (PC-ORD 4) between the periods with and without aquatic macrophyte, data sets comprising the environmental parameters and zooplankton densities.

Lobo and Leighton (1986) criteria described species dominance (D) and abundance (a). Species were considered abundant when specimens were higher than the mean density of all species; they were dominant when the density was higher than 50% of the total number of specimens.

RESULTS

The results of the Mann-Whitney U-test between the periods to water parameters showed that the mean values for temperature, pH, dissolved oxygen, biochemical oxygen demand, ammonia, chlorophyll-a and thermotolerant coliforms were statistically different ($p<0.03$). During the period with macrophyte, there was an increase of the concentration of thermotolerant coliforms, ammonia, BOD_5 and chlorophyll-a. In the without macrophyte period there was an increase of dissolved oxygen and pH concentrations (Table 1).

Zooplankton community consisted of 43 taxa during the period under analysis. Rotifera was the most representative (37 species) followed by Cladocera (4) and Copepoda (2) (Table 2, Fig. 1).

Copepoda species were present in the all sampling period and Cyclopoida nauplii, was numerically the most abundant, with 1,900 and 1,147 organisms per liter of water, in the period with and without macrophyte, respectively. The *Daphnia gessnei*, the only among Cladocera species, was present only in the period without macrophytes. The most abundance of Cladocera species was *Diaphanossoma birgei* in the period without macrophyte, with 427 organisms/l (Table 2).

Thermocyclops decipiens occurred at higher density in both periods when compared to *Argyrodiaptomus furcatus*, reaching the 902 organisms/l in the period with macrophyte (abundant), whereas the *Argyrodiaptomus furcatus* get 123 organisms/l (Table 2). The Copepoda group decreases the density in the period without *S. auriculata*, the opposite was observed to Rotifera and Cladocera species (Fig. 1).

The Rotifera species had the highest abundance in both periods (with and without macrophytes) (Fig. 1). The Rotifera species abundant during the period with macrophyte were *Filinia longiseta*, *Lecane Proiecta* and *Trichocerca longiseta*, and in the period without macrophyte was *Keratella serrulata*. The *Asplanchna* sp, *Asplanchnopus girordi* and *Euchlanis arenosa* were present only in the period without macrophyte. No dominant species extant throughout the study (Table 2).

The top the CCA plot featured Cladocera species and some Rotifera families, such as Asplanchnidae, Euchlanidae and Brachionidae had higher correlation with dissolved oxygen and pH during the period without *S. auriculata*. In the period with macrophyte there was a higher correlation with the variables temperature, thermotolerant coliform, chlorophyll-a, ammonia, 5-days biochemical oxygen demand and with Cyclopoida Copepoda, Lecanidae, Filinidae and Trichotriidae (Fig. 2).

DISCUSSION

According to the results it can be seen that the floating macrophytes modified some environmental variables and consequently influenced the composition, density and abundance of the zooplankton community. The decrease in the concentration of ammonia in the period without macrophytes is due to the increase in the nitrification process, because in this period there was greater availability of dissolved oxygen to the occurrence of this process.

Concentrations of dissolved oxygen had a mean of 5.0 mg/l in the period without macrophytes and according Sipaúba-Tavares *et al.* (2003) the concentration of dissolved oxygen should be kept above 4 to 5 mg/l for excellent fish growth.

The macrophytes influence the concentrations of oxygen and biochemical oxygen demand, given the dynamics of this plant which decomposes in the environment and its almost complete coverage of the water surface hindered the incidence of sunlight, decreasing the photosynthetic process. These changes promoted occurrence of species with high plasticity and that survive in eutrophic environments, such as *Filinia terminalis* (Filiniidae), *Lecane proiecta* (Lecanidae) and *Trichocerca longiseta* (Trichotriidae). According to Bartumeus & Catalan (2008) the Rotifera species have ability to adapt to changes in the water's physical-chemical variables and several taxa are resistant to conditions of hypoxia and anoxia. According to Kulikova & Syarki (2004), high rates of organic matter favor the occurrence of the Rotifera species such as *Filinia* sp.

Dissolved oxygen concentration, below 5 mg/l, probably affected Cladocera abundance directly, which may explain its great amount during the period without infestations, since these organisms are sensitive and do not survive to high variations in oxygen concentrations (Güntzel *et al*., 2010).

In the period with macrophyte, there was an inverse relationship occurred in Cladocera with regard to high rates of chlorophyll-a, because this organisms are filter and herbivores, controlling phytoplankton growth, determined by the concentration of chlorophyll-a in the water (Moustaka-Gouni et al., 2006). In this study, Cladocera also had an inverse relationship with organic matter, since this material decrease primary productivity and ingestion efficiency of algae (Güntzel et al., 2010).

The presence of *Daphnia gessneri* and abundance of *Diaphanossoma birgei* (Cladocera) only period without macrophyte was important, since these organisms are filter feeders that play an important role in the food webs of many lakes: they graze mostly on phytoplankton and are a main food source for planktivorous fish (Rellstab et al., 2007).

High pH concentration during the periods under analysis benefitted the occurrence of most species zooplankton, such as *K. cochlearis,* this species tolerance for high pH concentration (Landa & Mourgúes-Schuter, 2000).

In fact, decomposition triggers the development of bacteria that affect some Rotifera families. The reduction of bacteria in the period without macrophytes may have been influenced by the abundance of species of the genus *Brachionus,* which can insert into your diet food bacteria (Bonecker & Aoyagui, 2005). The great number (7 species) of the genus *Brachionus,* present was found during the periods under analysis. These organisms live in eutrophized environments, owing to their high plasticity, or rather, their ability to adapt themselves to different environments. They are tolerant to polluted waters and indicators species of water quality (Silva *et al.*, 2009).

The species *P. dolichoptera* was abundant throughout the period under analysis. According to Bartumeus & Catalan (2008), the species of the family Synchaetidae depends on water temperature for its high density. Water temperature is directly related to zooplankton abundance and affects its distribution since it controls population growth when associated with oxygen, food availability and pH (Bozkurt & Guven, 2009).

In the period with macrophyte the Asplanchnidae and Euchlanidae families were not present because surely species are considered sensitive when exposed to polluted environments, as seen by Arimoro & Oganah (2010).

Thermocyclops decipiens, Cyclopoida, featured higher abundance throughout the period with macrophyte and according to Sampaio *et al.* (2002) the total number of Cyclopoida is usually associated with highly eutrophic environments.

In addition the fishpond studied is shallow and constantly receives large nutrients loads (feed, fertilizers, fish waste) which contribute towards the growth of *S. auriculata,* influenced some water parameters such as temperature, ammonia, thermotolerant coliforms, BOD5 that increased during the study with and without macrophyte and influenced the decreased the concentration of dissolved oxygen.

The floating macrophytes at the water surface of the fishpond, affected directly water quality and the zooplankton community, modifying the concentration of environmental parameters and consequently, zooplankton density and composition. The macrophyte period favored the abundance of species which were more characteristics of eutrophic environments, such as Rotifera and Copepoda Cyclopoida, with a decrease in Cladocera, which are the food-source organisms available.

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Table 1. Mean and standard deviation (SD) of environmental parameters of water that showed significant difference to Mann-Whitney U-test ($p < 0.03$) among the periods with (WI) and without (WT) macrophyte. Media y desviación estándar (DE) de los parámetros ambientales del agua a què no mostró diferencias significativas Mann-Whitney U-test ($P < 0{,}05$) durante los períodos con (WI) y sin (WT) macrófitos.

Table 2. Specific composition (+,-) and frequency occurence (a) of zooplankton taxa in the fishpond in two periods with (WI) and without (WT) macrophyte; + = present; - = absent; a = abundant. Composición específica (+, -) y ocurrencia de frecuencia (a) de los taxones del zooplancton en el estanque de peces durante los períodos con (WI) y sin (WT) macrófitos; + = Presente; - = Ausente; A = abundante.

Figure 1. Relative abundance of three major taxonomic groups of zooplankton during the period with (WI) and without (WT) macrophyte. La abundancia relativa de los tres principales grupos taxonómicos de zooplancton durante el período con (WI) y sin (WT) de macrófitos.

Figure 2. Canonical correspondence analysis biplot illustrating the relationships between water parameters and zooplankton abundances during the periods with (WI) and without (WT) macrophyte. Environmental variables: pH, Dissolved Oxygen (DO), ammonia (NH_3), 5-days biochemical oxygen demand (BOD_5), alkalinity (Alk), thermotolerant coliforms (TC), chlorophyll-a (Chl-a) and temperature (°C). Biological variables: Cladocera (Clad), Asplanchnidae (Asplanch), Brachionidae (Brachion), Colurellidae (Colurell), Euchlanidae (Euchlani), Filiniidae (Filiniid), Gastropodidae (Gastropo), Lecanidae (Lecanida), Proalidae (Proalida), Synchaetidae (Synchaet) and Trichotriidae (Trichotr). Canónica biplot Análisis de Correspondencias que ilustra la relación entre los parámetros del agua y la abundancia de zooplancton durante los períodos con (WI) y sin (WT) macrófitos. Las variables ambientales: pH, oxígeno disuelto (OD), amoníaco (NH_3), 5-dias demanda bioquímica de oxígeno (DBO_5), alcalinidad (Alc), coliformes termotolerantes (TC), clorofila-a (Chl-a) y la temperatura (°C). Las variables biológicas: Cladocera (Clad), Asplanchnidae (Asplanch), Brachionidae (Brachion), Colurellidae (Colurell), Euchlanidae (Euchlani), Filiniidae (Filiniid), Gastropodidae (Gastropo), Lecanidae (Lecanida), Proalidae (Proalida), Synchaetidae (Synchaet) y Trichotriidae (Trichotr).

.

Table 1.

Variables	WI	WT
Temperature (ºC)	27.0±0.4	21.4±1.7
pH	9.1±0.1	9.3±0.1
Dissolved Oxygen (mg/l)	3.1±0.1	5.1±0.2
Amnonia (µg/l)	438.5±34.5	314.6±55.4
Biochemical Oxygen Demand (mg/l)	6.1±0.6	4.3±0.6
Chlorophylla-a (µg/l)	47.0±5.0	18.0±2.6
Thermotolerant Coliforms (MNP/100 ml)	1,117.5±36.1	231.7±41.8

Table 2.

TAXA	**WI**	**WT**
Cladocera		
Daphnia gessneri (Herbst, 1967)	-	+
Alona monacantha (Sars, 1901)	+	+
Bosmina hagmani (Stingelin, 1904)	+	+
Diaphanosoma birgei (Korinek, 1981)	+	a
Copepoda		
Argyrodiaptomus furcatus (Sars, 1901)	+	+
nauplii	a	a
Thermocyclops decipiens (Lowndes, 1934)	a	a
nauplii	a	+
Rotifera		
Ascomorpha agilis (Zacharias, 1983)	+	+
Ascomorpha eucadis (Perty, 1850)	+	+
Asplanchnopus girordi (Guerne, 1888)	-	+
Asplanchna sp	-	+
Beauchampiella eudactylota (Gosse, 1886)	+	-
Brachionus bidentata (Anderson, 1889)	+	-
Brachionus calyciflorus (Pallas, 1766)	+	+
Brachionus caudatus (Barrois &Daday,1894)	+	+
Brachionus falcatus (Zacharias, 1898)	+	+
Brachionus havanaensis (Rousselet, 1911)	a	a
Brachionus quadridentatus (Hermann,1783)	+	+
Brachionus patulus (Pallas, 1766)	+	-
Cephalodella remanei (Wulfert, 1937)	+	-
Colurella uncinata (Müller, 1773)	-	+
Euchlanis arenosa (Myers, 1936)	-	+
Filinia terminalis (Plate, 1886)	a	+
Keratella cochlearis (Gosse, 1851)	a	a
Keratella serrulata (Ehrenberg 1838)	+	a
Keratella tropica (Apstein, 1907)	+	+
Lecane aquila (Harring & Myers, 1926)	+	-
Lecane bula (Gosse, 1886)	+	-
Lecane elsa (Hauer, 1931)	a	a
Lecane lunaris (Ehrb., 1832)	+	+
Lecane monotyla (Daday, 1897)	+	-
Lecane ovalis (Jakubski, 1914)	+	-
Lecane proiecta (Hauer, 1956)	a	+
Lepadella costata (Wulfert, 1940*)*	-	+
Lepadella ovalis (Müller, 1786)	+	+
Lepadella patella (Müller, 1786)	+	+
Polyarthra dolichoptera (Idelson, 1925)	a	a
Proales doliaris (Rousselet, 1895)	a	a
Proales globulifera (Hauer, 1921	+	+
Proalinopsis caudatus (Collins, 1872)	+	+
Proalinopsis sp.	-	+
Trichocerca cavia (Gosse, 1886)	+	+
Trichocerca elongata (Murray, 1913)	+	-
Trichocerca longiseta (Schrank, 1802)	a	+

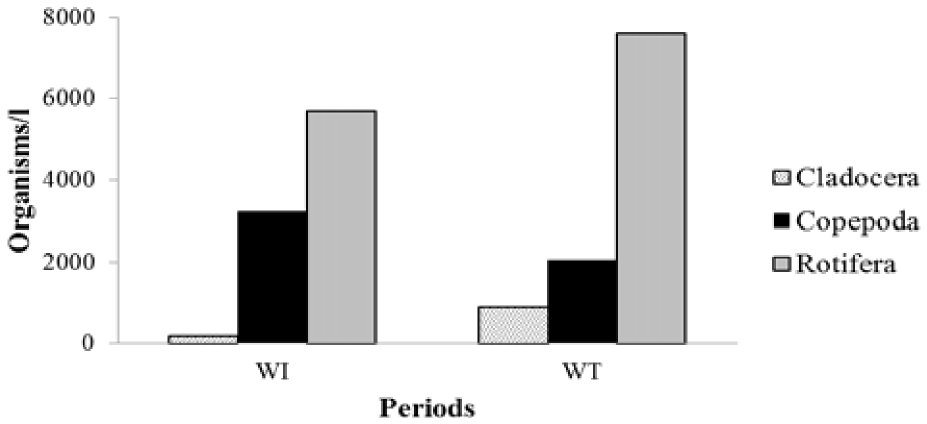
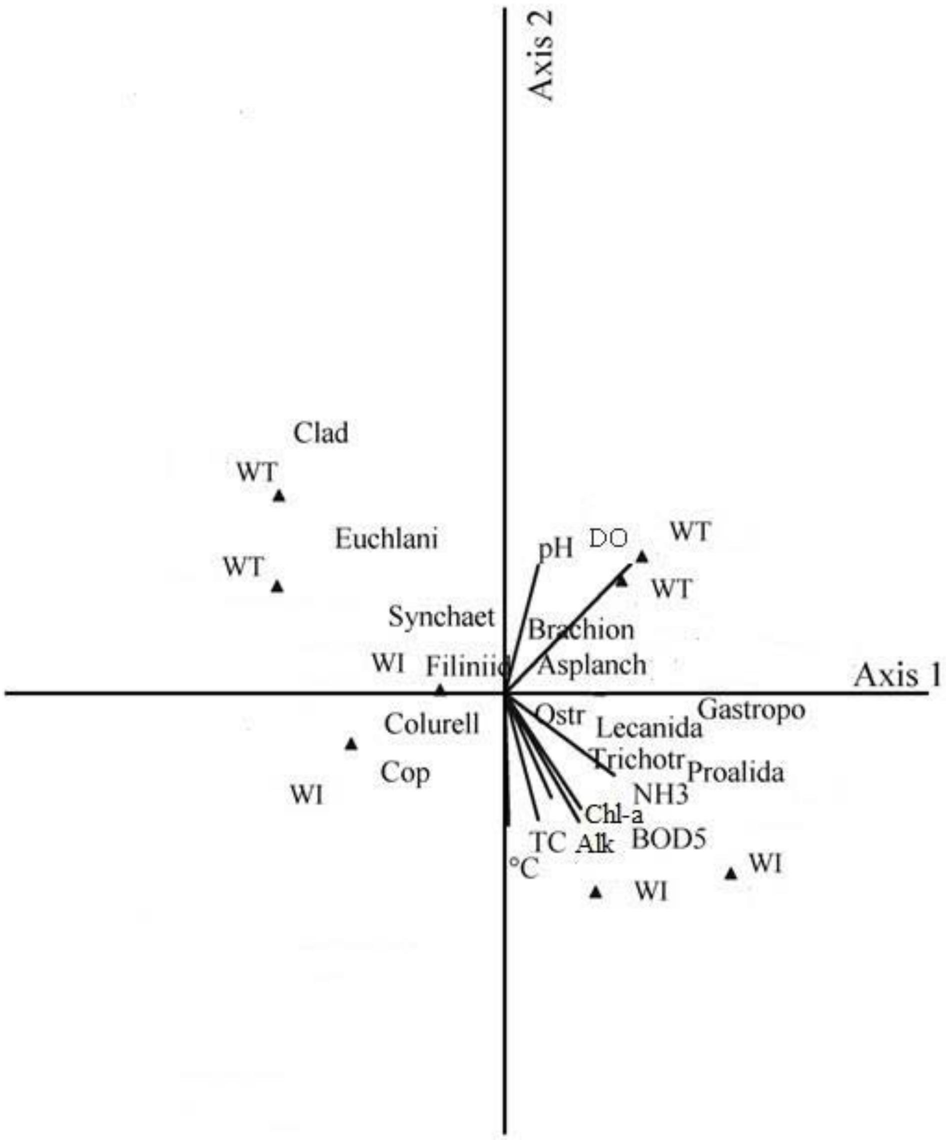

8000
6000
4000
2000
0
Organisms/l
WI
WT
Periods
Cladocera
Copepoda
Rotifera

Figure 1.


Axis 2
Axis 1
Clad
WT
Euchlani
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DO
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Synchaet
Brachion
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Filiniid
Asplanch
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Lecanida
Gastropo
Colurell
Trichotr
Proalida
Cop
NH3
WI
Chl-a
TC
Alk
BOD5
°C
WI
WI

Figure 2.

CAPÍTULO 3 – Changes of plankton community in the presence and absence of macrophytes in fishpond.

Short title: Plankton community and macrophyte in fishpond

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Abstract The effects of the presence (naturally infested) and absence of macrophytes on plankton community and the water quality were analyzed in a fishpond. The samples were taken monthly during 10 months. The presence of aquatic plants caused variations in environmental parameters, providing occurrence of major groups of organisms such as Cladocera (*Alona monacantha*) and Copepoda (Cyclopoida nauplii and Calanoida nauplii), and also abundance of Chlorophyceae. The absence of macrophyte caused an increase of the trophic level of the system that indirectly reflected in the density of plankton, Cyanobacteria, thermotolerant coliform and organic matter in the water body. Tolerant species to eutrophic environment were selected such as *Brachionus havanaensis*, *Brachionus calyciflorus*, *Keratella cochlearis*, *Filina longiseta*,

Aulacoseira granulate, and there was an increase of Cyanobacteria (*Planktolyngbya contorta* and *Aphanocapsa delicatissima*), causing deleterious effects to water.

Keywords Copepoda·Cladocera· Rotifera· Phytoplankton· Environmental Parameters

Abbreviations

IW33	Inlet Water from 33 fishponds
IW13	Inlet Water from 13 fishponds
FP1	between the sites Inlet Water
FP2	center and deep water site
WO	Water Outlet
°C	Temperature
DO	Dissolved Oxygen
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
BOD_5	5- Biochemical Oxygen Demand
TC	Thermotolerant Coliforms
Cond	Electric Conductivity
Chl-a	Chlorophyll-a

Introduction

It is well known that excessive plant growth in aquatic systems is caused by sunlight and the supply of nutrients, especially nitrogen and phosphorus. Macrophytes colonize many different types of aquatic ecosystems, generally shallow ecosystems where they become important components, influencing the functioning and structure of ecological processes and attributes of other aquatic attached assemblages. Plants that have the capacity to proliferate and to disperse maintaining a viable population over time was considered invasive species can be both as exotic or allochthonous (Espínola and Júlio Junior 2007).

The presence of macrophytes in aquatic habitats can completely alter the ecosystem and increase biodiversity e.g. zooplankton through of refuge and protection, influencing your feeding habits and such structural characteristics as composition, distribution, density and diversity (Villabona-González et al. 2011).

The habitat choice by zooplankton depend as well of biotic variables like food quality and quantity, interspecific competition and predation risk from littoral and pelagic invertebrates, as well as differences in physico-chemistry (González-Sagrario et al. 2009).

Good indicators of environmental change, the zooplankton is characterized by a fraction of the aquatic community composed of primary consumers, predators of various trophic levels (Matsumura-Tundisi and Tundisi 2005), playing a key role in energy flow and nutrient cycling in aquatic ecosystems. They are the link between producers and consumers of higher level in the trophic chain because feed on phytoplankton and bacteria (Arimoro and Oganah 2010).

The linkage between phytoplankton and zooplankton is a dynamic process controlled by environmental and biological factors which affect the growth of each community and the interaction between them (Abdel-Aziz et al. 2006). Phytoplankton live in environments where many factors such as grazing pressure, sinking, light availability, nutrient uptake and turnover influence the distribution of phytoplankton in time and space (Alam et al. 2001).

Both quality and quantity abundance of plankton communities in fishponds are of great importance in managing successful aquaculture operations, and they vary from location and pond to pond within the same location even under similar ecological conditions (Bhuiyan et al. 2008).

The objective of this study was evaluate the invasion period of macrophytes emergent and floating (heterospecific) and the period of absence of these plants in relation of fishpond in the physical, chemical and biological variables of water and in the distribution of plankton community in the differents sites into the fishpond. The resulting information will contribute as an important tool to evaluate the fishpond conditions, which can provide subsidies indicative of the qualitative and quantitative plankton community in the fishpond when covered by macrophytes.

Methods

Study area

Current investigation was conducted monthly for 10 months in a fishpond of the Aquaculture Center (21°11'S and 48°18'W) of the University of São Paulo State (UNESP) at Jaboticabal (SP Brazil) (Figure 1), close to an agricultural area.

The fishpond has 4,268 m^2 in area, 1 - 1.3 m deep and has a continuous water flow with a daily exchange rate of 5% of its volume. This fishpond is the fourth of six similar size fishponds in a sequential line, each of directly or indirectly receiving water from the previous one and has high concentrations in physical and chemical variables (such as nitrate, nitrite and electrical conductivity) due to the contribution of material flowing directly from frog farm for this pond, as seen by Sipaúba-Tavares *et al*. (2010) (Figure 1).

The fishpond studied has two water inlets. The inlet water in the northern receives water from thirty three (400 m^2) fishponds and the inlet water in the northeast side receives water from thirteen (200 m^2) fishponds. The water outlet is located in the southern end of the pond (Figure 1). The fishpond studied has an average 400 *Ctenopharyngodon idella* individual (grass carp).

Macrophyte growth was a result of an initial infestation in 2009, which occupied the total area of the fishpond, with one species of macrophyte, *Salvinia auriculata* Aublet, considered an invasive plant. After removal of aquatic plant the fishpond, it was drained, refilled and put 400 grass carp in the fishpond. The incorrectly way of plant remotion, by a non-specialist team, entry into the fishpond and suspended sediment, and excess of nutrients promoted favorable conditions so that the growth was again of *S. auriculata*, because the reproduction of macrophyte can be sexually (sporocarps) and asexually (fragmentation). This plant served as a substrate for the natural growth of other macrophytes emergents such as the invasive species *Panicum repens*, *Typha domingensis*, *Cyperus rotundus* and *Polygonum capitatum*, and floating plants such as *Eichhornia crassipes* and *Lemna minor*.

Sampling sites

Water and plankton samples were measured monthy at five sampling sites, during two periods, or rather, one infested with macrophytes and the other absence macrophytes. Water samples were registered at 9:00 am at the surface by a 1L Van Dorn bottle, between May and July 2010 (dry season), the period of presence of macrophytes, and between August 2010 and February 2011 (rainy season), period of absence of macrophytes. The five samples sites were: IW33 = inlet water from 33 fishponds; IW13 = inlet water from 13 fishponds; FP1= between IW33 and IW13; FP2 = center and deep water site; WO = water outlet (Figure 1).

Environmental parameters and analysis

Temperature, DO, Cond and pH were measured on the spot by a multi-electrode Horiba U-10. Concentrations of total phosphorus and orthophosphate (ascorbic acid method), nitrite (NO_2-N; sulfanilamide and naftil colorimetric reagents) and nitrate (NO_3-N; cadmium for its reduction to nitrite) were determined according to Golterman et al. (1978).

Ammonia levels were determined by spectrophotometer with phenolic acid method, following Koroleff (1976), and alkalinity ($CaCO_3$) with the phenolphthalein method (Mackereth et al. 1978). To determine Chl-a, water was filtered through Whatman glass fiber filters (0.45 µm pore), extracted with 90% alcohol and quantified at 663 and 750 nm (Nusch 1980). Total suspended solids, TDS and BOD_5 were determined according to Boyd and Tucker (1992). Analyses were performed immediately after samplings which were duly stored under refrigeration.

Water samples submitted to Most Probable Number ($MPN.100ml^{-1}$), TC, were collected in sterilized 500 mL-flasks and taken to the laboratory in an isothermal box. The material used in microbiological analyses was previously sterilized (Greenberg et al. 1992).

Plankton analyses

For zooplankton, 10 L of water were filtered through a net of 58 µm pore, concentrated to 50 ml, adding formaldehyde to reach 4%. Final concentration the mesozooplankton (Copepoda and Cladocera) was counted in acrylic chamber under stereomicroscope. The microzooplankton (Rotifera) was counted in a Sedgewick-Rafter chamber under an optical microscope.

For phytoplankton, 5 L of water were filtered through a net of 25 µm pore and preserved in Lugol iodine solution. The net samples were observed in an optical microscope (200 x magnification) for preliminary taxonomical identifications. Samples for the quantitative analyses of the phytoplankton were counted under an inverted microscope (400x magnification) using 2 mL Utermöhl sedimentation chambers.

Transects of each sample were counted to an error of less than 20 %, via random field (Uehlinger 1964) until the most abundant species reaches at least 100 individuals. Simultaneously, counting the number of fields follow the methodology proposed by Bicudo (1990), where the minimum number of fields counted is determined by stabilizing the graph curve obtained with the addition of new species with increased numbers of fields. Data were expressed in abundance percentage and as the number of organisms per water volume following APHA (1992).

The dominant species were those whose occurrence exceeded 50% of the total number of individuals of the sample and the abundant species were those whose occurrence was higher than the mean of the total number of individuals of the sample (Lobo and Leighton 1986). The richness was determined by the number of taxa present in the samples. Taxonomic identification followed the specialized literature (Koste 1978; Reid 1985; Elmoor-Loureiro 1997; Bicudo and Menezes 2006).

Data analysis

Mean difference of variables between the periods was examined by Kruskal-Wallis non-parametric test, which is a one-way analysis of variance by ranks and does not make any assumptions about data distribution. Pearson correlations were run between physico-chemical and plankton parameters to distinguish key abiotic variables that may affect plankton distribution. In addition, ordination analysis CCA (Canonical Correspondence Analysis) (Ter Braak 1987) was performed with PC-ORD 5 (Mccune and Mefford 2006) between data sets comprising variables and plankton densities to assess possible relationships between environmental parameters and plankton species.

The significance of the relationship between plankton community patterns and environmental variables was assessed by using Monte Carlo permutation tests. The results are presented as a biplot where species and environmental variables course are plotted together. Proportional abundances and densities for each taxon and major taxonomic groups were calculated by a counting cell.

Results

The zooplankton community was composed of 37 taxa, including 30 Rotifera, 3 Copepoda and 4 Cladocera. There was a predominance of Rotifera in the period without macrophytes, reaching approximately 95% of total richness in FP_1. In the presence of macrophytes occurred greater abundance of Copepoda and Cladocera, with approximately 80.7% of the richness found in FP_2 and 12% in WO, respectively (Table 1).

The most abundant species were Cyclopoida nauplii, *Polyarthra dolichoptera* and *Trichocerca longiseta. Trichocerca longiseta* was not observed in FP_2 during the period of presence of macrophyte. In the absence of macrophytes was observed dominance of *Polyarthra dolichoptera* in FP2. There was abundance of Calanoida nauplii and dominance of Cyclopoida nauplii during the presence of macrophytes in the FP2 and WO sites, respectivelly (Table 1).

In presence of macrophytes was observed increase of Cladocera and Copepoda. *Alona monacantha* (Chydoridae), among the species of Cladocera presented abundance in WO site. *Thermocyclops decipiens* adult and nauplii were more abundant than *Argyrodiaptomus furcatus* adult and nauplii (Table 1).

Thermocyplops decipiens was present in the all sampling period, with abundance in IW13 (presence and absence of macrophyte) and in the WO (presence of macrophytes). *Asplanchna* sp. was observed only in the presence of with macrophytes and *Brachionus calyciflorus* was abundant in FP2 and WO sites, in the absence of macrophytes (Table 1).

The phytoplankton consisted of total 58 taxa belonging to Chlorophyceae (33), Zygnemaphyceae (7), Bacillariophyceae (8), Cyanobacteria (4), Coscinodoscophyceae (3), Fragilariophyceae (1) and Chrysophyceae (2). Chlorophyceae was the most dominant class and taxon richness in both periods. The IW13 in the presence of macrophytes was observed almost 100% (9.8×10^{10} organisms.m^{-3}) of total phytoplankton density. The Coscinodoscophyceae species had the greater abundance in absence of macrophytes (Table 2).

The species that were abundant in almost all sampling sites were *Crucigenia quadrata*, *Oocystis lacustris*, *Kirchneriella lunaris* and *Coelastrum reticulatum*. *Monoraphidium nanum* was abundant in all sites and the only phytoplanktonic species dominant throught the period studied. The dominance of *M. nanum* in IW13 site in the presence of macrophyte with density of 8 x 10^{10} organisms.m^{-3}. *Aphanocapsa delicatissima* had abundance only in the absence of macrophytes in WO site (Table 2).

The results of Kruskal–Wallis test were significant ($p<0.05$) between the periods presence and absence of macrophytes to the water variables: °C (19.3 to 23.4 °C), pH (5.7 to 7.3), COND (63.9 to 109.4 μS.cm^{-1}), alkalinity (52.8 to 130.5 mg.L^{-1}), BOD_5 (4.5 to 9.8 mg.L^{-1}), TSS (4.8 to 36.2 mg.L^{-1}), nitrite (15.5 to 28.4 mg.L^{-1}), TC (9.5 to 1224.1 MNP.100mL^{-1}) and Chl-a (69.8 to 179.5 mg.L^{-1}) (Table 3). The DO, nitrate, TDS, ammonia, Cond and orthophosphate were not significant ($p>0.05$).

The first two axes in CCA explained 75 % of the variance of plankton and environmental data. °C, pH, TSS, Cond, nitrite correlated negatively with the first axis, whereas TC and BOD_5 correlated negatively with the second axis. The positively value of correlation with the second axis was observed for the alkalinity (Figure 2).

The major environmental variables influencing the occurrence of Rotifera and Zygnemaphyceae site, in the absence of macrophyte in the sites FP1, FP2 and WO, were pH, TSS and TC. The presence of macrophyte, the organisms suffered the greatest influence were the Copepoda, Cladocera, Chlorophyceae, Bacillariophyceae and Fragilariophyceae. *Brachionus havanaensis* were present only in the period without macrophytes and correlated with pH and °C, respectively (Figure 2).

According to Pearson correlation Rotifera had significant positive association with TC, Zygnemaphyceae species and negative significant correlation with Cladocera species. The class Zygnemaphyceae species also had significant positive correspondence with TC. The Cyanobacteria take significant positive correlation with electrical conductivity. Cladocera showed significant negative correlation with Rotifera, °C and BOD_5. Chlorophyceae was negatively correlated with COND and TSS (Table 4). The °C was higher in absence of macrophytes coinciding with the summer period.

Electric conductivity, TC, nitrite and pH increased in the absence of macrophytes. The concentrations of alkalinity ($p < 0.05$) were elevated and was correlated with the presence of macrophytes, ranging from 70.4 to 130.5 $mg.L^{-1}$, while the concentration of Chl-a showed high values in absence of macrophytes (Table 3, Table 4).

Discussion

The increase in the number of taxa of Rotifera observed in this study is generally found in Brazilian freshwater environments (Sampaio et al., 2002). According to Bekleyen and Ipek (2010) Rotifera are the most abundant organisms contributing to the biomass of the zooplankton community. The success can be explained due to its small size, ability to phenotypic plasticity and highly adaptable masticatory apparatus (Segers 2008).

The increase of autochthonous and allochthonous materials in the absence of macrophytes, observed in this study, influenced the decomposition process (BOD_5) and high electrical conductivity. According to Caron and Hutchins (2012) high levels of organic matter accelerate and via a cascade effect, can promote a change in the zooplankton taxonomic composition and diversity.

Rotifera are able to endure a large range of temperatures (Sulehria and Malik 2013) and had a positive correlation with temperature in this study. The dominance of the species *Polyarthra dolichoptera*, in the absence of macrophytes, is directly correlated with the high temperatures, also observed by Bartumeus and Catalan (2008).

The Coscinodiscophyceae species, in the absence of macrophytes, had a significant positive correlation with abiotic variables such as °C and BOD_5, in which *Aulacoseira granulata* was the major representative species and adapted to environments with high concentrations changes in these variables. The tolerant specie has been reported to be resistant to organic pollution and associated with waters of relatively high conductivity (Almeida and Fernandes 2013), as seen in this study.

The BOD_5 and °C favored the growth Coscinodiscophyceae species but affected the Cladocera species, because according with Güntzel et al. (2010) high concentrations of suspended solids and organic matter decrease primary productivity and ingestion efficiency of algae by Cladocera.

The decreased abundance of Cyanobacteria species which can be explained by presence of macrophytes *Typha domingensis*, *Panicum repens* and *Cyperus rotundus*, that are used to inhibit potential Cyanobacteria blooms (Zhang et al., 2010). The increase of abundance of Cyanobacteria in the period of absence of macrophyte also due to increased concentrations of nutrients and electrical conductivity, the same was observed by Blanco et al. (2008).

An increasing number of studies have aimed at identifying allelopathically active macrophyte species, that may be suitable as control measure for Cyanobacteria or detecting natural allelochemicals with the potential to develop effective biological ‘‘algicides’’ against Cyanobacteria blooms (Zhang et al. 2010). Allelochemicals are released either directly/indirectly by live or dead plants by root exudation, volatilization, leaching from leaves and other aerial parts, and the decomposition of plant material (Arimura et al. 2010). It has been shown in laboratory experiments that the inhibition of phytoplankton growth by allelopathic substances from some species of macrophytes can be between 50 and 80% (Mulderij et al., 2005).

High temperature and organic load in the absence of macrophytes, may also have influenced the abundance of Cyanobacteria. According to Liu et al. (2011)

Cyanobacteria tend to dominate phytoplankton assemblages in eutrophic, freshwater environments during the warmest periods of the year.

The Zygnemaphyceae species *Staurastrum inversenii*, *S. mamillatum*, *S. paradoxum* and *S. trifidum* were recorded in the period of absence of macrophyte and according with Reynolds (1987) some species of genus *Staurastrum* are tolerant, growing in eutrophic waters.

Brachionus sp. and *Filina longiseta* species found in this study are indicators of eutrophic conditions. *Brachionus havanaensis* occurred only during the absence of macrophytes, because this species tolerate wide range of temperature and nutrient concentration in the water. The absence of this species during the presence of macrophytes may also have been influenced by predation Asplanchna sp., present only in this period. The same behavior was observed by Pavón-Mesa et al. (2005) in artificial conditions.

An increase in the concentration of TC in the absence of macrophyte in this study was similar that found by Souza et al. (2004), where the macrophytes influenced in the reduction of coliforms, which occurs through a combination of physical (filtration and biofilm), chemicals (for some biocidal effect excreted macrophytes) and biological (antibiosis). With mechanical removal of macrophyte in the fishpond studied gives off the thermotolerant coliform which was retained in biofilm, increasing its density in the absence macrophyte.

The distribution of phytoplankton classes in the water column were strongly influenced by the physical-chemical conditions of the water and according to Basavaraja et al. (2013) the light availability, temperature, turbulence and nutrients influence the distribution of phytoplankton.

The Chlorophyceae was the most specious phytoplankton group and this structural characteristic seems to be a consistent pattern for the phytoplankton assemblages. This group is most common and one of the classes most represented in number of taxa, generally stands out due to its extensive distribution, diversity, and species richness, in addition to being essential in ecological studies (Nogueira et al. 2008).

The BOD_5 concentration was lower in the period with macrophyte due to the presence of *E. crassipes* beds. According to Poudel & Simon (2008) this aquatic plant has the ability to reduce the BOD_5 concentration, since their roots are covered with the organic material and mucilaginous (biofilm). The *Lemna minor*, according to El-Kheir et al. (2007) also show excellent results as in the reduction of pollutants contained in wastewater such as BOD_5 (biochemical oxygen demand), TSS (total suspended solids) and thermotolerant coliform (TC). The same was observed in this study.

The results showed that the concentration of alkalinity was higher in the presence of macrophytes in practically all points and the response of species of zooplankton was positive, having an increase in the density. Rabman and Hussain (2008) also observed significant positive correlations between alkalinity and densities of zooplankton.

Bacillariophyceae had higher occurrence in the presence of macrophytes and was correlated with lower concentrations of temperature. According Gharib and Abdel-Halim (2006) diatoms preferred low temperature and nutrients. The richness of Cladocera and Copepoda in the presence of macrophyte can be attributed to the abundance of aquatic plants, particularly *Typha*, which makes it difficult the rate of predation by fish, which prefer open water to feed on zooplankton (Abubakar and Abubakar 2013).

The presence of macrophytes created appropriate substrates for specie occurrence *Alona monacantha* (Chydoridae). Among all families of Cladocera, the Chydoridae has the highest species richness and abundance for most systems, highlighting its importance in relation to the diversity of freshwater invertebrates (Santos-Wisniewski et al. 2002).

The Copepoda may have also negatively influenced the growth of the class Coscinodiscophyceae species through predation, such as observed in this study. Sommer et al. (2001) found that Copepoda generally prefer large phytoplankton, as Coscinodiscophyceae species.

Conclusion

The results of this study showed that the removal of macrophytes caused increase concentrations of environmental parameters of water that indirectly reflected in the community planktonic and organic matter in the water body. This provided specific species that tolerate large changes in environmental parameter, such as *Brachionus havanaensis*, *Brachionus calyciflorus*, *Keratella cochlearis* and *Filina longiseta*, with also promoted an increase of Coscinodiscophyceae and Cyanobacteria species, causing deleterious effects on water bodies. There was a positive effect of combination of floating and emergent macrophtes on the community zooplankton and phytoplankton. The presence of aquatic plants caused variations in environmental parameters providing occurrence of major groups of organisms such as Cladocera and Copepoda, and also abundance of Chlorophyceae species.

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Fig. 1 Location of fishpond studied, where: IW33, IW13 = inlet water; FP_1 and FP_2 = inside the fishpond; WO= water outlet. Inset A: shade area indicates southeastern Brazil (São Paulo State). Inset B: aquaculture farm of São Paulo State University. Inset C: fishpond studied with sampling sites (IW33, FP1, IW13, FP2 and WO).

Fig. 2 Canonical Correspondence Analysis biplot illustrating the relationships between zooplankton abundances, phytoplankton abundances, physico-chemical parameters in the two periods presence (P) and absence of macrophyte (A). Environmental variables: pH, electrical conductivity (Cond), total suspended solids (TSS), Biochemical Oxygen Demand (BOD5), thermotolerant coliforms (TC), and temperature (°C). Biological variables: Cladocera (Cladocer), Bacillariophyceaa (Bacillar), Cyanobacteria (Cyanobac), Chlorophyceae (Chloroph), Chrysophyceae (Chrysoph), Coscinodiscophyceae (Coscinod), Zygnemaphyceae (Zygnemap).

Table 1 Composition, abundance and frequency of species of zooplankton in the five sites IW33, FP1, IW13, FP2, WO) and study periods presence (P) and absence (A) of macrophyte. + = presence; - = ausence; a = abundance; D = dominant.

Táxon	IW33		FP1		IW13		FP2		WO	
	P	A	P	A	P	A	P	A	P	A
Cladocera										
Alona monacantha (Sars, 1901)	+	+	+	+	+	-	a	+	a	+
Bosmina hagmani (Stingelin, 1904)	-	+	-	+	-	+	-	+	-	+
Diaphanosoma birgei (Korinek, 1981)	+	+	+	+	+	+	-	+	+	+
Echeneschia paulinesis	-	-	-	-	-	-	+	-	+	-
Copepoda										
Argyrodiaptomus furcatus (Sars, 1901)	+	+	+	+	+	+	+	+	+	+
nauplii	+	+	+	+	+	+	a	+	a	+
Thermocyclops decipiens (Lowndes, 1934)	+	+	+	+	a	a	+	+	a	+
nauplii	a	a	a	a	a	a	D	a	D	a
Haparticoida	-	-	-	-	-	-	+	+	+	+
Rotifera										
Ascomorpha agilis (Zacharias, 1893)	-	+	-	+	+	+	-	+	-	+
Ascomorpha eucadis (Perty, 1850)	+	-	+	-	-	a	-	-	-	-
Asplanchnopus girordi (Guerne, 1888)	-	+	-	+	+	+	-	+	-	+
Asplanchna sp	-	-	+	-	+	-	+	-	+	-
Beauchampiella eudactylota (Gosse, 1886)	+	-	-	-	-	-	-	-	+	-
Brachionus calyciflorus (Pallas, 1766)	+	+	+	+	+	+	+	a	-	a
Brachionus caudatus (Barrois & Daday, 1894)	-	+	-	-	-	-	-	+	-	+
Brachionus falcatus (Zacharias, 1898)	+	+	+	+	-	+	-	+	-	+
Brachionus havanaensis (Rousselet, 1911)	-	+	-	+	-	-	-	+	-	+
Brachionus quadridentatus (Hermann, 1783)	-	-	-	+	-	+	-	-	-	+
Brachionus patulus (Pallas, 1766)	-	-	-	+	-	-	+	-	a	-
Colurella uncinata (Müller, 1773)	-	-	+	+	+	a	-	+	-	-
Euchlanis arenosa (Myers, 1936)	+	+	+	+	-	+	-	+	+	-
Filinia longiseta (Plate, 1886)	-	+	+	+	-	a	-	+	-	a
Keratella cochlearis (Gosse, 1851)	+	+	-	+	+	-	-	+	-	+
Keratella serrulata (Ehrenberg 1838)	a	a	+	a	-	+	-	a	-	+
Keratella tropica (Apstein, 1907)	a	+	a	+	a	-	-	-	-	+
Lecane bula (Gosse, 1886)	-	-	+	-	-	+	-	-	+	-
Lecane proiecta (Ehrb, 1832)	-	+	-	+	-	-	-	-	-	-
Lecane submagna (Daday, 1897)	+	-	-	-	-	-	-	-	+	-
Lepadella heterostyla (Murray, 1913)	-	-	-	-	+	-	-	-	+	-
Lepadella ovalis (Muller 1786)	-	-	-	-	+	-	-	-	+	-
Polyarthra dolichoptera (Idelson, 1925)	a	a	a	D	+	a	-	D	a	a
Proales doliaris (Rousselet, 1895)	+	a	a	a	a	a	-	+	+	+
Proales sordida (Gosse, 1886)	-	-	-	-	+	-	-	-	-	-
Proales globulifera (Hauer, 1921)	+	+	+	+	+	+	-	-	+	+
Proalinopsis caudatus (Collins, 1872)	-	+	+	+	+	+	-	-	-	-
Synchaeta stylata (Wierzejski, 1893)	-	-	-	-	-	-	-	-	+	-
Testudinella mucronata (Gosse 1886)	-	+	-	-	-	-	-	-	+	-
Trichocerca longiseta (Schrank, 1802)	a	a	a	a	a	a	-	a	a	a

Table 2 Composition, abundance and frequency of species of phytoplankton in the five sites IW33, FP1, IW13, FP2 and WO) and study periods presence (P) and absence (A) of macrophyte. + = presence; - = ausence; a = abundance; D = dominant.

Táxon	IW33		FP1		IW13		FP2		WO	
	P	A	P	A	P	A	P	A	P	A
Bacillariophyceae										
Amphora copulata (Schoeman and Archibald 1986)	-	-	+	-	-	-	+	+	+	+
Gomphonema constrictum (Ehrenberg 1832)	+	+	+	+	-	+	+	-	+	+
Gomphonema parvulum (Kützing 1849)	-	+	+	+	-	+	-	-	+	-
Navicula cryptotenella (Krammer and Lange-Bertalot 1985)	-	-	-	-	-	-	-	-	+	+
Navicula radiosa (Kützing 1844)	-	-	-	-	-	+	-	-	+	-
Pinnularia divergens (Smith 1853)	-	-	-	+	+	+	-	+	+	+
Rhopalodia gibba (Müller 1895)	-	+	-	+	-	+	-	+	+	-
Stauroneis anceps (Ehrenberg 1843)	+	-	-	-	+	-	-	-	+	-
Chlorophyceae										
Asterococcus limneticus (Smith 1918)	+	+	a	+	+	+	+	-	+	+
Coelastrum astroideum (De Notaris 1867)	a	+	+	+	+	+	+	+	-	+
Coelastrum reticulatum (Senn 1899)	a	a	a	a	+	a	a	+	a	+
Crucigenia quadrata (Morren 1830)	a	+	a	a	+	a	a	a	a	+
Crucigenia tetrapedia (Kuntze 1898)	+	-	+	-	-	-	-	-	-	-
Desmodesmus communis (Hegewald 2000)	-	-	+	-	+	+	+	-	-	+
Desmodesmus denticulatus (An, Friedl and Hegewald 1999)	-	-	-	-	-	+	-	-	+	-
Desmodesmus intermedius (Hegewald 2000)	+	+	+	+	+	+	+	+	+	a
Desmodesmus opoliensis (Hegewald 2000)	+	+	+	+	-	+	-	+	-	+
Desmodesmus spinosus (Hegewald 2000)	+	+	+	+	+	-	+	+	+	+
Dictyosphaerium pulchellum (Wood 1873)	+	a	a	a	+	+	a	a	a	a
Dimorphococcus lunatus (Braun 1855)	+	+	+	+	+	+	+	+	+	+
Golenkinia radiata (Chodat 1894)	+	a	a	+	-	-	-	a	+	-
Kirchneriella lunaris (Möbius 1894)	-	+	a	a	-	+	-	+	-	-
Keratococcus suecicus (Hindák 1977)	a	a	-	-	+	a	a	a	+	a
Monoraphidium arcuatum (Hindák 1970)	+	+	+	+	+	-	+	+	+	+
Monoraphidium nanum (Hindák 1980)	a	a	a	a	D	a	a	a	a	a
Oocystis solitaria (Wittrock and Nordstedt 1879)	a	a	a	-	-	-	-	a	a	-
Oocystis lacustris (Chodat 1897)	a	a	a	a	+	a	a	a	a	a
Pectodictyon cubicum (Taft 1945)	+	-	-	-	-	-	+	-	-	+
Pediastrum duplex (Meyen 1829)	+	+	+	+	+	+	+	-	+	+
Pediastrum tetras (Ralfs 1845)	+	+	+	+	-	+	-	-	+	-
Planktosphaeria sp. (Smith 1918)	+	+	-	+	+	-	-	-	-	-
Raphidocelis danubiana (Marvan, Komárek and Comas, 1984)	a	a	a	+	+	+	a	+	+	+
Scenedesmus acuminatus (Chodat 1902)	+	+	+	-	-	+	+	+	-	+
Scenedesmus acutus (Meyen 1829)	+	-	+	-	-	+	-	-	+	-
Scenedesmus linearis (Stearn 1973)	-	+	+	+	-	-	-	+	+	-
Scenedesmus protuberans (Fritsch and Rich 1929)	+	+	+	+	-	-	+	+	-	+
Scenedesmus quadricauda (Brébisson and Godey 1835)	a	+	+	a	+	+	+	+	+	a
Selenastrum gracile (Reinsch 1866)	+	+	+	+	+	+	+	a	+	+
Sphaerocystis schroeteri (Chodat 1897)	a	-	a	+	-	+	+	+	-	+
Tetraedron planctonicum (Smith 1916)	+	-	+	-	-	-	+	-	-	+
Tetrastrum heteracanthum (Chodat 1895)	+	-	+	-	-	-	+	-	+	-
Chrysophyceae										
Dinobryon elegantissimum(Bourrelly 1957)	-	-	+	-	+	-	+	-	-	-
Synura petersenii (Korshikov 1929)	+	+	+	+	-	-	-	-	+	+
Cyanobacteria										
Anabaena spiroides (Klebahn 1895)	-	+	+	+	-	-	-	-		-
Aphanocapsa delicatissima (West and West 1912)	+	+	-	-	-	+	-	+	+	a
Planktolyngbya contorta (Anagnostidis and Komárek 1988)	+	+	a	+	+	+	+	a	a	a
Planktolyngbya tallingii (Komárek and Kling 1991)	+	-	-	-	-	+	-	+	+	-

continued

Táxon	IW33		FP1		IW13		FP2		WO	
	P	A	P	A	P	A	P	A	P	A
Zygnemaphyceae										
Closterium parvulum (Nägeli 1849)	-	+	-	+	-	-	+	-	-	+
Closterium setaceum (Ralfs 1848)	+	-	+	+	+	-	-	-	-	+
Cosmarium reniforme (Archer 1874)	-	+	-	+	+	-	+	-	+	-
Staurastrum inversenii (Scott and Gronblad)	+	+	+	+	-	-	-	-	+	-
Staurastrum mamillatum (West 1891)	-	+	-	+	-	-	-	-	-	-
Staurastrum paradoxum (Ralfs 1848)	-	a	-	a	-	+	-	a	+	+
Staurastrum trifidum (West and West 1986)	-	+	-	+	-	-	-	-	-	-
Coscinodiscophyceae										
Aulacoseira granulata (Simonsen 1979)	+	a	+	a	+	+	+	+	a	a
Melosira italica (Kützing 1844)	-	+	+	+	-	-	-	-	-	+
Melosira granulata (Pritchard 1861)	+	+	+	-	-	-	-	+	-	+
Fragilariophyceae										
Synedra acus (Kützing 1844)	a	a	-	-	-	+	-	-	a	+

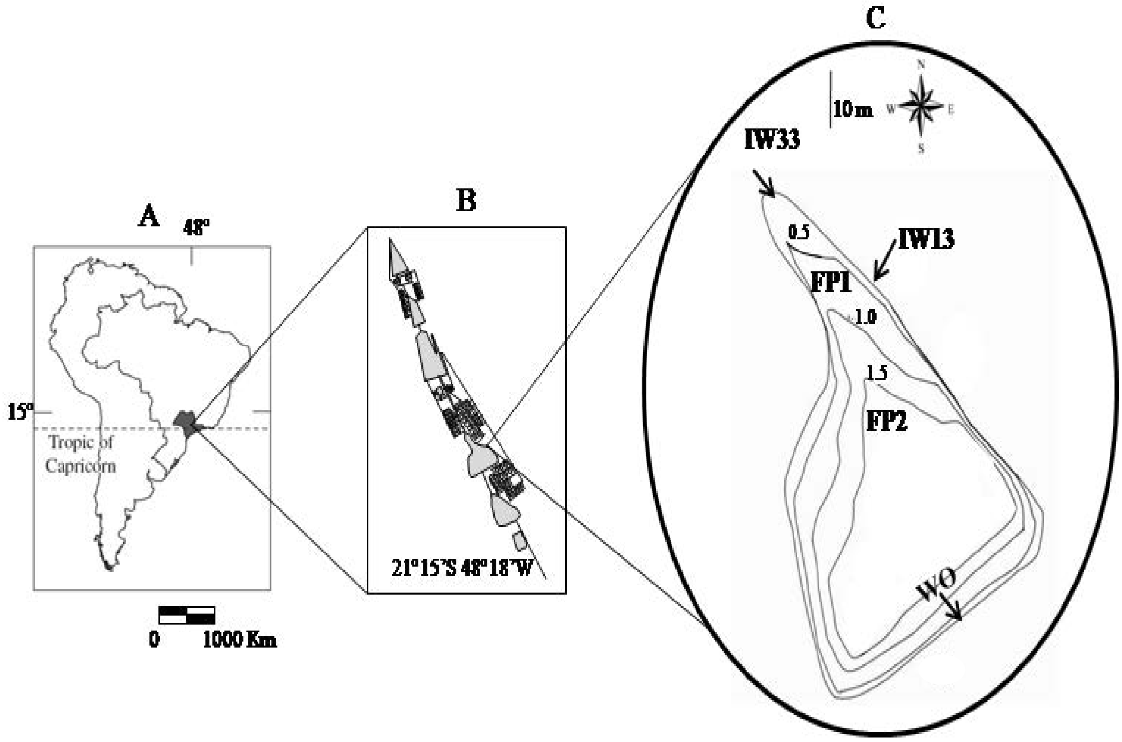
Table 3 Mean and SD of environmental parameters of water that showed significant difference to Kruskal-Wallis analysis ($p < 0.05$) among the presence (P) and absence (A) of macrophyte.

	IW33		FP1		IW13		FP2		OW	
	P	A	P	A	P	A	P	A	P	A
°C	20.6±0.9	23.4±1.9	20.7±0.9	23.4±1.6	19.3±0.8	22.7±2.6	20.0±0.8	23.0±2.1	19.5±0.9	23.1±2.4
pH	5.9±0.2	6.5±0.5	5.7±0.1	6.5±0.5	6.0±0.4	6.6±0.4	5.9±0.1	6.7±0.6	6.1±0.5	7.3±0.3
Electrical conductivity ($mg.L^{-1}$)	92.7±8.5	101.1±19.8	100.5±8.3	109.4±16.5	64.0±4.1	83.4±18.7	95.1±5.6	105.7±12.6	90.8±7.6	100.0±14.8
Alkalinity ($mg.L^{-1}$)	114.8±15.1	75.7±19.7	130.5±5.7	89.4±15.8	70.4±6.4	52.9±3.4	108.7±18.4	72.1±6.2	106.7±12.8	71.8±6.8
Biochemical oxygen demand ($mg.L^{-1}$)	6.7±1.4	8.6±2.1	7.7±1.1	7.6±1.9	6.0±1.3	8.7±1.0	4.5±0.6	9.9±0.8	5.0±0.9	9.6±0.6
Total suspended solids ($mg.L^{-1}$)	10.0±0.1	12.3±1.9	13.0±1.5	21.2±1.9	4.8±0.6	20.3±1.0	13.0±1.5	18.1±1.7	16.1±1.1	36.3±1.4
Nitrite ($\mu g.L^{-1}$)	21.4±1.1	21.3±1.2	21.5±1.8	23.6±1.9	16.6±1.1	25.3±0.9	21.7±0.7	28.2±0.8	15.6±1.0	28.4±1.6
Thermotolerant coliforms	31.3±6.4	1154.0±110.1	50.0±16.2	1224.2±81.0	9.5±0.3	94.9±5.2	42.2±8.2	165.2±15.4	27.5±1.5	91.4±6.6
Chlorophyll-a ($\mu g.L^{-1}$)	93.9±26.6	111.1±32.9	73.7±25.7	94.9±23.3	115.4±18.7	179.5±10.9	69.8±5.9	159.0±13.7	128.7±15.8	156.2±26.4

Table 4 Correlation matrix for environmental parameters of water, zooplankton and phytoplankton during the studied periods.

Parameters	Chlorophyceae	Zygnemaphyceae	Cyanobacteria	Coscinodiscophyceae	Cladocera	Rotifera
Zygnemaphyceae	0.09	1.00	-0.61	0.22	-0.45	0.67*
Cladocera	-0.07	-0.45	0.37	-0.70*	1.00	-0.63*
Rotifera	-0.27	0.67*	-0.33	0.40	-0.63*	1.00
Temperature	-0.36	0.47	-0.46	0.71*	-0.81*	0.60
Electrical condutivity	-0.71*	0.22	0.79*	0.10	-0.36	0.43
Biochemical oxygen demand	0.02	0.24	-0.31	0.75*	-0.91*	0.50
Total suspended solids	-0.76*	0.23	0.41	0.11	-0.30	0.61
Thermotolerant coliform	-0.38	0.82*	0.49	0.36	-0.46	0.73*

Significant interactions are indicated by the superscript * ($p<0.05$)


A
48°
15°
Tropic of
Capricorn
0
1000 Km
B
21°15'S 48°18'W
C
10 m
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IW33
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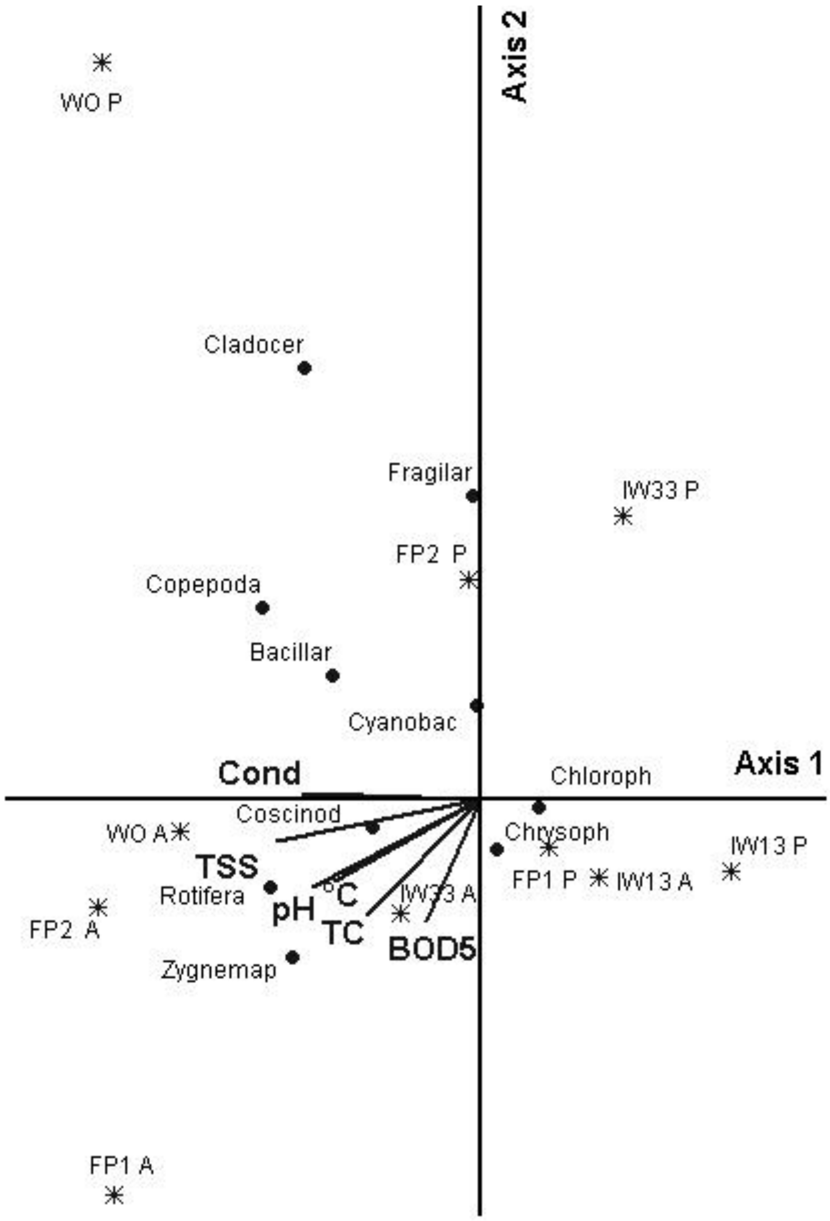
IW13
FP1
1.0
1.5
FP2
WO

Fig. 1


Axis 2
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Cladocer
Fragilar
IW33 P
FP2 P
Copepoda
Bacillar
Cyanobac
Cond
Chloroph
Coscinod
WO A
Chrysoph
IW13 P
TSS
FP1 P
IW13 A
Rotifera
°C
IW33 A
FP2 A
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TC
BOD5
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Fig. 2

CAPÍTULO 4 – Considerações finais

A invasão biológica por macrófitas é um fenômeno mundial e que precisa de estudos mais aprofundados sobre a influência dessas espécies nas comunidades aquáticas e na dinâmica dos ecossistemas. A forma contínua e sequencial com que tanques e viveiros são abastecidos é determinante para o acúmulo de nutrientes ao longo do sistema, favorecendo a invasão dessas macrófitas aquáticas no ambiente aquático. O monitoramento da qualidade ambiental é melhor forma de prevenir que ocorram as invasões de macrófita, uma vez que sua remediação física demanda um custo alto e as remediações biológicas e químicas podem impactar ainda mais o ecossistema aquático.

Uma forma de monitorar o ambiente aquático é analisar as comunidades fito e zooplanctônica e como elas são bioindicadoras de qualidade ambiental, pode-se ver através das espécies encontradas se o ambiente está eutrófico e favorável para o crescimento das macrófitas aquáticas.

Nesse estudo, foi visto que a invasão monoespecífica (macrófitas flutuantes) acabou selecionando espécies que indicam grau de trofia elevado e a posterior invasão heteroespecífica (macrófitas emergentes e flutuantes) proporciou condições estruturais e limnológicas para o desenvolvimento de espécies fitoplanctônica e zooplanctônica de maior qualidade para ser oferecida como alimento vivo para os demais organismos aquáticos. Apesar desses resultados favoráveis para a qualidade da água, essa invasão não é viável para um viveiro de produção de peixes. Como já visto em literatura a proporção ideal de macrófitas em um viveiro de piscicultura é de apenas 10%.

Com isso, seria importante a realização de estudos sobre os tipos de invasões de macrófitas que ocorrem no ambiente e essas informações juntamente com os dados ambientais poderiam ser usadas para criar modelos para prevenção desses impactos.