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Introdução do jundiá (*Rhamdia quelen*) e da tilápia-do-Nilo (*Oreochromis niloticus*) no tradicional sistema de policultivo de carpas do Rio Grande do Sul. Introdução isolada ou conjunta.

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Dissertação apresentada como um dos requisitos à obtenção do Grau de Mestre em Zootecnia
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Introdução do jundiá (*Rhamdia quelen*) e da tilápia-do-Nilo (*Oreochromis niloticus*) no tradicional sistema de policultivo de carpas do Rio Grande do Sul. Introdução isolada ou conjunta [1]

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RESUMO

O policultivo de peixes é praticado em mais de 95% das propriedades do Rio Grande do Sul. Objetivando melhorar os índices de produtividade e desempenho das espécies utilizadas no atual sistema, o trabalho buscou identificar a melhor relação de introdução de *Rhamdia quelen* e de *Oreochromis niloticus* no policultivo tradicional de carpas praticado no Estado. Durante a fase de crescimento inicial, o presente estudo foi conduzido num período experimental de 86 dias em nove tanques escavados de 250m^2 de área superficial (1,2 m de profundidade). Um dos tanques foi estocado com a proporção usual empregada na região como o controle, ou seja, 35% de carpa comum (CC), 35% de carpa-capim (GC), 15% de carpa prateada (CP) e 15% de carpa cabeça-grande (CCG) em uma densidade de estocagem de 2875 peixes/ha. Dois tanques foram estocados com a mesma relação de espécies, mas com densidade de 5750 peixes/ha (tratamento 1, T1). Dois tanques com 20%CC: 30%GC: 10%CP: 20%CCG e 20% de jundiá (JN), densidade de 5750 peixes/ha (tratamento 2, T2). Como tratamento 3 (T3), dois tanques com 35%GC: 5%CP: 10%CCG: 20% JN e 30% de tilápia-do-Nilo (TN), densidade de 5750 peixes/ha e o quarto tratamento (T4) com 15%CC: 30%GC: 5%CP: 10% CCG: 20% JN e 20%TN, com a mesma densidade. Todos os parâmetros da qualidade de água avaliados estavam dentro da faixa ideal para o cultivo de peixes. Nenhuma correlação significativa foi encontrada entre as relações de espécies e os parâmetros da qualidade de água. O peso final por espécie nos diferentes tratamentos mostrou algumas diferenças estatísticas mostrando efeito no crescimento das espécies. A sobrevivência foi considerada satisfatória em todos os tratamentos testados. Quando os dados são analisados pela perspectiva zootécnica, a relação de espécies mais promissora para o policultivo parece ser a usada no T4. A exclusão completa da CC no T3 não se refletiu em bom resultado zootécnico, já a redução do percentual de CC de 35% para 15% e introdução de 20% de JN mostrou efeito positivo. A introdução de JN nos policultivos testados não causou efeito sobre as outras espécies. A TN cresceu melhor no T3 onde não havia CC, entretanto a CC mostrou melhor desempenho na presença da TN. A associação da CC e da TN aumenta o crescimento da CC. Baseado nos dados apresentados a relação de espécies para policultivo (fase inicial) que se mostrou mais promissora foi usada no T4. A redução da taxa de CC e a introdução da TN e do JN provocou efeitos positivos em todos os parâmetros zootécnicos avaliados.

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[1] Dissertação de Mestrado em Zootecnia – Produção Animal, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, (50p.). Março de 2007.

Introduction of jundia (*Rhamdia quelen*) and Nile tilapia (*Oreochromis niloticus*) in the traditional carp polyculture practiced in Rio Grande do Sul. Isolate or conjugate introduction [1]

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ABSTRACT

Fish polyculture is practiced in more than 95% fish farm of Rio Grande do Sul. Aiming to increase productivity and performance of the species traditionally used, the present work was conducted in an attempt to identify the better species ratio of introduction of jundia (*Rhamdia quelen*) and Nile tilapia (*Oreochromis niloticus*) in the traditional carp polyculture practiced in the state. The experiment was conducted over 86 days, in nine 250 m2 earthen ponds (1.2 m deep), and comprised the initial growing period of fish. As control, one pond was stocked with a species ratio usually employed in the region: 35% common carp, *Cyprinus carpio* (CC), 35% grass carp, *Ctenopharyngodon idella* (GC), 15% silver carp, *Hypophtalmichthys molitrix* (SC) and 15% bighead carp, *Aristichthys nobilis* (BC) with a density of 2875 fish/ha. Treatment I consisted of two ponds stocked with the same species ratio, but with a density of 5750 fish/ha; this fish density was also used in the remaining treatments. Treatment II consisted of two ponds with 20% CC, 30% GC, 10% SC, 20% BC and 20% jundia, *Rhamdia quelen* (JN). Treatment III consisted of two ponds with 35% GC, 5% SC, 10% BC, 20% JN and 30% Nile tilapia, *Oreochromis niloticus* (NT). Treatment IV consisted of two ponds with 15% CC, 30% GC, 5% SC, 10% BC, 20% JN and 20% NT. All water quality parameters evaluated were within acceptable limits for fish culture in pond water. No significant correlation was found between species rate and the water quality parameters. The final weight of different species, in different treatments, showed statistical differences. Survival rate was satisfactory in all treatments employed. Considering growth parameters, the best result was obtained in treatment IV. A complete exclusion of the CC in treatment III had no advantage over the other treatments; however, the reduction of CC percentage from 35% to 15% allowed the introduction of JN, with positive effects. In addition, the introduction of JN in the polycultures tested had no effect over the other species. Nile tilapia grew better in treatment III with no CC, but CC had a better performance in the presence of NT. The association of CC and TN improve the grow of CC. Based on the data presented herein, the most promising polyculture ratio for initial growing season seems to be that used in treatment IV. The reduction of the CC ratio and the introduction of NT and JN had positive effects in all growth parameters evaluated.

[1] Master of Science dissertation in Animal Science, Faculdade de Agronomia , Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, (50p.). March, 2007.

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RELAÇÃO DE ABREVIATURAS E SÍMBOLOS

A	alkalinity = alcalinidade
ANOVA	Analysis of Variance = Análise da Variância
BC	bighead carp
$CaCO_3$	carbonato de cálcio
$(CaMg(CO_3)_2)$	carbonato de cálcio e magnésio
CC	common carp = carpa comum
CCG	carpa cabeça-grande
CEPAGRO	Centro de Extensão e Pesquisa Agropecuária
cm	centímetro
CP	carpa prateada
CV	coefficient of variation = coeficiente de variação
ºC	graus Celsius
DE	digestible energy = energia digestível
DO	dissolved oxygen = oxigênio dissolvido
DWG	daily weight gain = ganho de peso diário
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
EPAGRI	Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina S.A.
FAO	Food and Agricultural Organization

FAPERGS	Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul
FCR	food conversion rate = taxa de conversão alimentar
FIGIS	Fish Global Information System
fW	final weight = peso final
g	gramas
GC	grass carp = carpa capim
h	hora
ha	hectare
iW	initial weight = peso inicial
JN	jundiá
Kg	quilograma
Kcal	quilocaloria
K_2O_5	pentóxido de potássio
L	litro
Ln	logarítimo natural
m	metro
m^2	metro quadrado
med T	medium temperature = temperatura média
mg	miligrama
min	minuto
mm	milímetro
mT	minimum temperature = temperatura mínima
MT	maximum temperature = temperatura máxima
N_2	nitrogênio

NT	Nile tilápia = tilápia-do-Nilo
pH	potencial de hidrogênio
P_2O_5	pentóxido de fósforo
RS	Rio Grande do Sul
SC	silver carp = carpa prateada
SCI	Secretaria de Cooperação Internacional
SD	standard deviation = desvio padrão
SEM	standard error of mean = erro padrão da média
SGR	specifc growth rate = taxa de crescimento específico
t	tempo de cultivo
T	tonelada
T1	tratamento 1
T2	tratamento 2
T3	tratamento 3
T4	tratamento 4
TH	total hardness = dureza total
TN	tilápia-do-Nilo
UFRGS	Universidade Federal do Rio Grande do Sul
UPF	Universidade de Passo Fundo
USA	United States of America
WCV	weight coefficient of variation = coeficiente de variação de peso
Wg	weight gain = ganho de peso
%	porcento

CAPÍTULO I

INTRODUÇÃO

A população mundial vem crescendo em acelerada progressão. Com o contínuo decréscimo dos estoques pesqueiros naturais, o cultivo de peixes é encarado como uma alternativa para suprir a demanda por carne de pescado.

A região sul do Brasil é privilegiada com uma extensa lâmina d'água. Barragens para irrigação de lavouras, barragens para movimentação de usinas hidrelétricas e um grande número de açudes bebedouros para o gado, perfazem uma área de água ainda hoje sub-utilizada, que perfeitamente podem ser utilizadas para piscicultura.

A necessidade de produção de alimentos de qualidade superior e em quantidades capazes de suprir a crescente demanda, justifica o investimento em pesquisa de cultivos de peixes em modelos alternativos. A aquacultura se encaixa neste contexto como atividade produtora de proteína animal de alta qualidade e em grande quantidade por área utilizada. Ao mesmo tempo, a cultura alimentar mundial procura alimentos mais saudáveis e que de alguma forma possam contribuir para o estabelecimento e a preservação da saúde do ser humano. Neste aspecto a carne de pescado vem sendo considerada como uma excelente fonte de proteína e alimento extremamente saudável. Pesquisas demonstram que os altos teores dos ácidos graxos ômega-3 presentes nas carnes de pescado atuam como eficazes preventivos de cardiopatias. Médicos do mundo inteiro já apontam o consumo semanal de peixes como fator de vida saudável.

Uma das formas de piscicultura praticadas em mais de 95% das propriedades no Rio Grande do Sul é o policultivo. O modelo atual de policultivo de carpas difundido pela Associação Riograndense de Empreendimentos de Assistência Técnica e Extensão Rural (Emater-RS), apesar de possibilitar razoáveis índices de produção, apresenta rejeição de algumas espécies trabalhadas. Neste modelo, a espécie principal é a carpa húngara (*Cyprinus carpio*), e as complementares são as carpas chinesas: capim (*Ctenopharyngodon idella*), cabeça-grande (*Aristichthys nobilis*) e prateada (*Hipophtalmichthys molitrix*), em percentuais variados de acordo com o mercado e disponibilidade de alimentos. O resultado deste modelo é a produção média de 0,9 a 2 T/ha/ano (Mardini *et al.*,1997).

No norte e noroeste do estado do Rio Grande do Sul, o modelo alternativo de policultivo já empregado com algum sucesso em algumas regiões de Santa Catarina, pode oferecer uma alternativa de cultivos com maior produtividade e fornecer espécies de maior aceitação e valor de mercado. No modelo proposto pelo presente estudo, o percentual de carpas húngaras diminuiria sensivelmente sendo substituídas pelo jundiá no cultivo, e os percentuais das carpas filtradoras (cabeça-grande e prateada) diminuiriam com a entrada das tilápias-do-Nilo.

As justificativas principais deste modelo alternativo são: (1) possibilidade de aumento de produtividade para até 5 a 6 T/ha/ano e (2) maior aceitabilidade e valor de mercado das espécies introduzidas, jundiá e tilápia-do-Nilo.

O presente estudo visa desenvolver uma alternativa de policultivo, substituindo algumas espécies e alterando proporções entre as mesmas, objetivando maior produtividade e maior rentabilidade por trabalhar com espécies de maior aceitação comercial como o jundiá (*Rhamdia quelen*) e a tilápia-do-Nilo (*Oreochromis niloticus*).

REVISÃO BIBLIOGRÁFICA

Uma das características mais atrativas da atividade de piscicultura é a plasticidade dos sistemas de produção, abrangendo desde os grandes empreendimentos industriais até a agricultura familiar, tanto de subsistência quanto como forma de renda alternativa.

Segundo Horváth e Tamás (1984) o policultivo de peixes evoluiu muito depois dos anos 50, com a introdução das carpas herbívoras e plantófagas originárias da China. Assim o policultivo de diferentes espécies de carpas promoveu um grande acréscimo de produtividade por ocupar nichos tróficos vagos. Souza e Barcellos (1998) afirmaram que o policultivo pode elevar a produção do reservatório, por utilizar totalmente a cadeia alimentar, diminuindo o custo em ração. No policultivo, se utilizam peixes que vivem nas diferentes camadas, superior, média e inferior. Para que a cadeia alimentar seja plenamente utilizada, os peixes escolhidos devem ter hábitos alimentares diferentes, evitando a competição por alimentos. O policultivo usual de carpas é empregado em mais de 95% das propriedades gaúchas (Mardini *et al.*, 1997).

Horváth e Tamás (1984) também postularam que além do melhor aproveitamento dos diferentes níveis tróficos, criam-se novas fontes alimentares a serem aproveitadas. Lutz (2003) afirmou que há um sinergismo entre as espécies, ou seja, que muitas espécies têm um desempenho melhorado na presença de outras. Um exemplo é a carpa capim, que tem grande apetite, mas por falta de enzimas e outros mecanismos que desdobrem as fibras em seu intestino, ela digere somente as células rompidas, trituradas por seus dentes faríngeos. Desta forma, seus excrementos contêm abundância de detritos que auxiliam na fertilização do tanque e conseqüentemente estimulam a produção de fitoplâncton, zooplâncton e bentos. Se a carpa-capim não for criada juntamente com peixes de hábito alimentar diferente, a produção será baixa e a água irá tornar-se excessivamente eutrofizada.

Lutz (2003) afirmou que os policultivos vêm recebendo atenção devido à possibilidade de aumento de eficiência nos sistemas de produção aqüícola e por reduzir os impactos ambientais do excesso de nutrientes presentes nos efluentes da piscicultura. O autor comenta que o uso de peixes que se alimentam no fundo e de peixes que filtram plâncton, ajuda a melhorar a qualidade do efluente nos tanques de criação, quando comparados a tanques de monocultivo.

Milstein *et al.* (2006) corroboram afirmando que os efeitos na produção e/ou reprodução de uma ou mais espécies criadas em policultivo, é resultado das interações ecológicas entre as espécies, as quais influenciam na disponibilidade de alimento natural e no ambiente dentro dos tanques.

O estudo dos níveis tróficos de cada uma das espécies que compõem estes policultivos, permite que se alterem proporções de acordo com as características do ambiente. Corroborando, Horváth e Tamás (1984) afirmaram que geralmente se trabalha com 70% de carpas húngaras e 30% de plantófagas/herbívoras, mas que estes percentuais podem se alterar de acordo com a abundância de algas que o tanque oferece.

Sob esta ótica, o estudo dos níveis tróficos de alimentação também nos permite idealizar e testar substituições de espécies. A escolha de espécies de um policultivo deve se basear na ocupação dos níveis tróficos, além de aspectos econômicos e de mercado. Sendo assim, podem-se introduzir novas espécies em detrimento de outras, desde que ocupem o mesmo nível trófico.

A carpa húngara, tende a ser a espécie usada em maior proporção nos policultivos, pois se alimenta de bentos e espécies de zooplâncton maior, bem como larvas de insetos, outros invertebrados, sementes e plantas aquáticas. No policultivo as necessidades protéicas são supridas por fontes naturais (bentos e plâncton) e as necessidades energéticas, por uma suplementação de grãos com alto teor de amido (Horváth e Támas, 1984). Além disso, a carpa comum exerce importante papel dentro do ecossistema de um tanque. Segundo Ritvo *et al.* (2004), a presença desta espécie nos policultivos favorece o incremento de oxigênio no solo (devido ao seu hábito alimentar de revolver o solo), redução da concentração de compostos reduzidos tóxicos, facilitando a oxidação de material orgânico e disponibilizando nutrientes para reaproveitamento. Contribuindo com esta idéia, Rahman *et al.* (2006) demonstram que, dependendo da densidade de estocagem utilizada, a carpa comum contribui positivamente na disponibilidade de alimento natural nos tanques de cultivo. Isso é refletido nas quantidades de fito e zooplâncton disponíveis na coluna d'água.

O jundiá não apresenta exatamente esse hábito alimentar na cadeia trófica. É um peixe onívoro de leve tendência carnívora (Gomes *et al*. 2000), mas também se alimenta de plâncton maior e bentos, tendo uma alta preferência por proteína de origem animal, fazendo, no policultivo, papel de predador para controle na reprodução natural da carpa húngara.

A espécie tem despertado interesse de muitos pesquisadores no sul do Brasil, e sua introdução no policultivo se justifica pelo bom potencial de produção em cativeiro. Este peixe apresenta excelentes características zootécnicas como a docilidade, a rusticidade e a boa qualidade de carne, atraindo cada vez mais os piscicultores, principalmente para o cultivo nas áreas nas quais é endêmico. Pois, segundo Barcellos *et al.* (2003) o jundiá (*Rhamdia quelen*) é uma espécie apropriada para a produção em regiões onde o clima subtropical é o predominante. Em culturas intensivas, no sistema de monocultivo em gaiolas, apresenta alta sobrevivência (90-100%) e peso final de 63,74 $\pm$ 3,69 g após três meses de cultivo aproximadamente (Barcellos *et al.*,2004). Aspectos relacionados à fisiologia reprodutiva da espécie, já estão bem caracterizados (Barcellos *et al.*, 2001 e Barcellos *et al.*, 2002). O uso da espécie dentro do policultivo integrado no oeste de Santa Catarina também já vem sendo cogitado (Jorge Casaca - EPAGRI, informação pessoal).

As carpas filtradoras utilizadas no sistema de policultivo são as carpas prateadas e cabeça-grande. A primeira, filtra o fitoplâncton (cianobactérias e algas verdes), os quais podem ter suas quantidades aumentadas pela fertilização (adubação) dos tanques. É imperativo que se use a espécie em policultivos a fim de aproveitar toda a produção de algas do mesmo. A segunda se alimenta de zooplâncton, aproveita também as algas verdes e cianobactérias e uma enorme variedade de substâncias orgânicas em suspensão e detritos.

A substituição das carpas prateadas e cabeça-grande se baseia no fato de que as tilápias também são filtradoras e apresentam rápido ganho em peso na época mais quente e excelente aceitação de mercado. A tilápia pode apresentar, em cultura de gaiolas, taxas de crescimento específico de até 0,931% por dia (Huchette e Beveridge, 2003).

O uso das tilápias-do-Nilo em policultivos com carpas é relativamente comum em sistemas semi-intensivos de produção com base em fertilização (Abdelghany e Ahmad, 2002). Os autores afirmam que a combinação de tilápia-do-Nilo, carpa comum e carpa prateada, maximiza a utilização do alimento natural disponível. Os mesmos autores verificaram que a suplementação com dieta inerte seca em taxas variáveis, aumenta a produtividade. Nas condições daquele estudo a taxa de 3% da biomassa em suplementação de ração, ofereceu o melhor resultado zootécnico e econômico. Outros autores também já utilizaram tilápias-do-Nilo em policultivos com carpas em sistemas semi-intensivos. Milstein *et al.* (1995) verificaram os efeitos combinados da fertilização química, adubação orgânica e suplementação artificial na performance dos peixes, obtendo melhores rendimentos nas situações em que todas estas variáveis foram aplicadas. Na mesma linha, Bhakta *et al.* (2004) demonstraram melhor performance em policultivo de carpas indianas e carpa comum, à medida que doses de fertilizantes químicos e orgânicos eram aumentadas.

A carpa capim alimenta-se de forragem verde e macrófitas que se desenvolvem na água do viveiro. Espécie excelente no controle da eutrofização causada por poluição industrial e fertilizantes químicos usados na agricultura que provocam o crescimento de plantas aquáticas difíceis de serem controladas de forma mecânica ou química (Horváth e Tamás, 1984). Segundo Souza e Barcellos (1998), seus excrementos contêm abundância de detritos que auxiliam na fertilização do tanque e conseqüentemente estimulam a produção de fitoplâncton, zooplâncton e bentos. Altas taxas de sobrevivência (90-100%) foram verificadas por Jena *et al*. (2002) e Zoccarato *et al*. (1995) para a carpa capim quando cultivadas em consórcio com outras espécies de carpas, reforçando a idéia de excelente adaptação da mesma em policultivos.

A introdução de novas espécies ao policultivo das quatro carpas tradicionais (húngara, capim, prateada e cabeça-grande) difundido e consolidado no mundo, vem sendo estudado por grupos de pesquisa. Luong *et al.* (2005), avaliaram a introdução do "marble goby" (*Oxyeleotris marmorata*) no policultivo de carpas. Esta espécie é um peixe de fundo que ocorre no continente asiático, com hábito alimentar onívoro e preferência por proteína animal, ou seja, hábito muito semelhante ao jundiá. Além disso, possui um alto valor de mercado nos locais de sua ocorrência. O trabalho foi conduzido em uma enseada controlada junto a um reservatório natural, e a alimentação foi apenas a natural. Foram avaliados parâmetros de rendimento, com produção de 575,6 Kg/ha/7 meses, isto é, valores mais altos quando comparados ao mesmo sistema sem a utilização do “marble goby”. Os autores afirmam que o “marble goby” pode explorar recursos de alimentação do ambiente inutilizados pelas carpas, como bentos, pequenos peixes e camarões de água doce. Portanto, os resultados indicaram que a introdução dessa espécie ao policultivo de carpas é uma promissora alternativa ecológica, tecnológica e econômica.

Kestemont (1995) afirma que o crescimento e o rendimento de cada espécie pode ser mais alto nos policultivos do que nos monocultivos, devido às interações positivas entre as espécies. Confirmando esta interação de espécies, Milstein (1992) afirma que as partículas fecais da carpa prateada, ricas em fitoplâncton, servem de alimento para a carpa comum, que normalmente não se alimentaria desta fonte de alimento natural. Papoutsoglou *et al*. (1991) também verificaram que a carpa comum e a tilápia-do-Nilo quando cultivadas juntas apresentaram melhores rendimentos do que quando em sistemas de monocultivo.

Rahman *et al.* (2006) analisaram o desempenho (crescimento, produção e preferência alimentar) da carpa “rohu” (*Labeo rohita*) em monocultivo e em associação com a carpa comum, utilizando ou não alimentação artificial. O melhor rendimento foi demonstrado no tratamento onde foram cultivadas as duas espécies em conjunto com utilização de alimento inerte. Os melhores índices obtidos para a carpa rohu, em 137 dias de cultivo, foram: média de peso de aproximadamente 190 gramas, 100% de sobrevivência e 2860 Kg/ha de peixes despescados. Os dados obtidos neste trabalho mostraram eficiência duas vezes maior do policultivo quando comparado à cultura de apenas a carpa “rohu” e sem alimentação.

Segundo Jena *et al*. (2002), um policultivo com carpas pode atingir produtividade em torno de 7 T/ha/ano em sistemas de múltiplas colheitas. A densidade de estocagem utilizada nessa observação foi de 10.000 alevinos por hectare com índices de conversão alimentar que variaram de 1,47 até 3,16 Kg de alimento consumido por Kg de peixe produzido. Já Abdelghany e Ahmad (2002)*,* obtiveram índices menores, variando de 0,46 a 1,37 kg de alimento por Kg de peixe produzido, demonstrando que bons índices podem ser alcançados em policultivos baseados em fertilização e suplementados com alimento inerte.

Azim *et al*. (2002) obtiveram produtividade de aproximadamente 5 T/ha/ano em policultivo com três espécies de carpas. Estes resultados foram obtidos com sistemas de fertilização dos tanques, suplementação alimentar inerte e utilização de substratos (bambu) para fixação do perifiton, o qual serviu de alimento natural para os peixes. Entretanto, Azim *et al.* (2004a) apresentaram resultados de produtividade abaixo dos valores citados acima, 2 T/ha/ano, utilizando também três espécies nativas das carpas indianas, sendo que uma espécie (*L.calbasu*) foi substituída por outra (*Cirrhinus mrigala*). As outras duas espécies utilizadas foram as mesmas do trabalho anterior (*Labeo rohita* e *Catla catla*). Estes mesmos autores realizaram análise econômica dos cultivos demonstrando que, a análise do custo benefício indicou que uma aquacultura baseada na utilização de perifiton bem manejada, pode ser um negócio lucrativo.

Utilizando novamente esse sistema de aquacultura baseada em substrato/perifíton, Azim *et al.* (2004b) investigaram a melhor relação entre superfície de área e substrato para perifíton. O trabalho utilizou um policultivo com três espécies de carpas indianas filtradoras e/ou raspadoras (*Labeo rohita*, *Catla catla* e *Labeo calbasu*), demonstrando que o rendimento combinado das três espécies tem correlação linear com a densidade de substrato.

De acordo com Fréchette (2005), tão importante quanto o rendimento final e o peso final de cada espécie dentro de um policultivo, é o coeficiente de variação do peso dos peixes. Daí a importância de coeficientes baixos (menores de 10%), que demonstram uniformidade do lote.

Com relação à análise econômica, Roy *et al.* (2003) analisaram um sistema de policultivo de carpas indianas associadas a pequenas espécies nativas, em propriedades rurais. Após sete meses de cultivo, ficou demonstrado maior receita líquida por hectare nos cultivos apenas com as carpas indianas, sem as espécies nativas. Neste mesmo caso, obtiveram produtividade de aproximadamente 4,5 T/ha/ano.

OBJETIVOS E HIPÓTESES

O experimento realizado para atingir os objetivos descritos a seguir, foi conduzido em tanques escavados de terra, entre os meses de fevereiro e abril, utilizando a estrutura da Estação de Piscicultura da Universidade de Passo Fundo, RS. Os alevinos de carpas e jundiás utilizados no experimento foram provenientes da Estação da UPF e os alevinos de tilápias adquiridos de produtores particulares. Foram testadas introduções parciais em diferentes taxas, de duas novas espécies. A substituição total de uma espécie de carpa com introdução de uma das novas espécies também foi testada. Além disso, foi estudada, concomitantemente às substituições de espécies, uma densidade de estocagem maior em relação ao modelo tradicionalmente empregado.

Objetivo geral

Estabelecer uma alternativa de policultivo com maior produtividade e rentabilidade através da introdução de espécies de maior valor comercial, melhor desempenho e maior aceitabilidade de mercado.

Objetivos específicos

1) Testar um policultivo com as mesmas proporções de espécies do policultivo tradicional, porém com densidade de estocagem duplicada (5000 alevinos por hectare).

2) Testar a substituição parcial da carpa húngara pelo jundiá.

3) Testar a substituição total da carpa húngara pelo jundiá.

4) Testar a substituição parcial da carpa húngara pelo jundiá e das carpas filtradoras (prateada e cabeça-grande) pela tilápia-do-Nilo simultaneamente, ou seja, um policultivo com as seis espécies.

Hipótese

O uso de espécies alternativas no policultivo de carpas aumenta a produtividade do cultivo, e contribui positivamente com a aceitação e valor de mercado das espécies.

CAPÍTULO II

ARTIGO PUBLICADO

Título: Alternative species for traditional carp polyculture in southern South America: Initial growing period.

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Alternative species for traditional carp polyculture in southern South America: Initial growing period

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Abstract

Fish polyculture is practiced aiming to increase productivity. Complementary species can increase the maximum standing crop of a pond by allowing a wider range of available foods and ecological niches. The present work was conducted in an attempt to identify the better species ratio and the introduction of jundia (*Rhamdia quelen*) and Nile tilapia (*Oreochromis niloticus*) in the traditional fish polyculture practiced in South Brazil. The experiment was conducted over 86 days, in nine 250 m^2 earthen ponds (1.2 m deep), and comprised the initial growing period of fish. As control, one pond was stocked with a species ratio usually employed in the region: 35% common carp, *Cyprinus carpio* (CC), 35% grass carp, *Ctenopharyngodon idella* (GC), 15% silver carp, *Hypophtalmichthys molitrix* (SC) and 15% bighead carp, *Aristichthys nobilis* (BC) with a density of 2875 fish/ha. Treatment I consisted of two ponds stocked with the same species ratio, but with a density of 5750 fish/ha; this fish density was also used in the remaining treatments. Treatment II consisted of two ponds with 20% CC, 30% GC, 10% SC, 20% BC and 20% jundia (JN). Treatment III consisted of two ponds with 35% GC, 5% SC, 10% BC, 20% JN and 30% Nile tilapia (NT). Treatment IV consisted of two ponds with 15% CC, 30% GC, 5% SC, 10% BC, 20% JN and 20% NT. All water quality parameters evaluated were within acceptable limits for fish culture in pond water. No significant correlation was found between species rate and the water quality parameters. The final weight of different species, in different treatments, showed statistical differences. Considering growth parameters, the best result was obtained in treatment IV. A complete exclusion of the CC in treatment III had no advantage over the other treatments; however, the reduction of CC percentage from 35% to 15% allowed the introduction of JN, with positive effects. In addition, the introduction of JN in the polycultures tested had no effect over the other species. Nile tilapia grew better in treatment III with no CC, but CC had a better performance in the presence of NT. Based on the data presented herein, the most

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promising polyculture ratio for initial growing season seems to be that used in treatment IV. The reduction of the CC ratio and the introduction of NT and JN had positive effects in all growth parameters evaluated.

Keywords: Polyculture; Carp; Jundia; Nile tilapia; Growth

1. Introduction

Quantitatively, Cyprinids form the most important group of teleost fish cultivated worldwide (reviewed by Kaushik, 1995). According to the Fish Global Information System (FIGIS, FAO), the world production of the common carp (*Cyprinus carpio*) and the three Chinese carps used in Brazilian polycultures (*Ctenopharyngodon idella, Hypophtalmichthys molitrix*, *Aristichthys nobilis*) was more than 12.6 million metric tons in 2003, representing about 55% of the total production of freshwater fish in that year.

Culturing different carp species in the same pond optimizes the utilization of the food available in the ecological niches of the pond ecosystem (Kestmont, 1995). In addition, the polyculture aims to increase productivity by a more efficient utilization of the ecological resources in the aquatic environment (Lutz, 2003). Thus, stocking two or more complementary species can increase the maximum standing crop of a pond by allowing a wider range of available foods and ecological niches.

One of the major problem facing the polyculture in southern Brazil involves the low acceptance, by consumers, of the species of fish utilized, e.g. common carp (CC), grass carp (GC), silver carp (SC) and bighead carp (BC). Only GC has good market value and acceptance. Thus, the introduction in the polyculture scenario of other species with a higher market price and better acceptance by consumers seems to be the best alternative to improve fish productivity. In this study, the species chosen to co-cultivate with the different carp species were the jundia (JN, *Rhamdia quelen*), a native omnivore bagrid fish but with preference for protein of animal source (Gomes et al., 2000), and the well known omnivorous and filtrating fish, the Nile tilapia (NT, *Oreochromis niloticus*). Thus, the aim of the present study was to evaluate the introduction of two more valuable species in the traditional polyculture practiced in Southern Brazil.

2. Methods

This study was conducted from February to April, 2005, at the facilities of the University of Passo Fundo, Rio Grande do Sul (687 m asl).

2.1. Fish and culture techniques

Fish used in the present study were jundia (*R. quelen*) and carps (*C. carpio*, *C. idella*, *H. molitrix* and *A. nobilis*), bred and maintained in the Aquaculture Laboratory of the University of Passo Fundo, and Nile tilapia (*O. niloticus*) acquired from local suppliers. At the beginning of the experiments, all fingerlings weighted between 2.0 ± 1.0 g and the mean length was 4.5 ± 0.5 cm.

Fingerlings were cultivated in earthen ponds stocked with different proportions of carps (grass, silver, bighead and common carp), Nile tilapia and jundia. The productivity, climate and water quality parameters were evaluated over 86 days in the summer season.

The experiment was carried out in 9 earthen ponds with 250 m^2 and 1.2 m deep each. Ponds were prepared by draining and sun drying for 30 days and then liming with 6 metric ton/ha of agricultural lime ($CaMg(CO_3)_2$). The fertilization program consisted of chicken litter (1.2% N_2, 1.8% P_2O_5, 0.6% K_2O_5, 27.6% organic matter, 30.7% of dry matter), spread on the bottom of the ponds at a rate of 6 metric ton/ha. The ponds were then filled with water (up to 40 cm in depth) and after four days the level of water in all ponds was raised to 1 m; fish were then stocked and the water inlet and outlet pipes were protected with nylon enclosures to prevent entry of unwanted species and escape of cultured fish. Water influx rate was approximately 6 l/min.

To maintain an ideal population of phyto and zooplankton, several additional applications of chicken litter and inorganic fertilizers (super-phosphate and urea) were applied, using as parameter the water transparency obtained with a Secchi-disk.

At the beginning of the experiment (February 14th) the ponds were stocked with different proportions of carps, jundia and Nile tilapia, as stated in Table 1. The jundia and Nile tilapia were chosen to co-cultivate with the traditional carp polyculture because those species are preferred by consumers. A polyculture using the four carp species in a density of 2875 fingerlings/ha was used as control; this specific polyculture system is the most commonly used for carp production in the study region.

Table 1
Experimental treatments

Species (designation)	Species rate (%) per treatment [a]				
	Control	I	II	III	IV
Cyprinus carpio (CC)	35	35	20	–	15
Ctenopharingodon idella (GC)	35	35	30	35	30
Hipophtalmicthys molitrix (SC)	15	15	10	5	5
Aristichthys nobilis (BC)	15	15	20	10	10
Rhamdia quelen (JN)	–	–	20	20	20
Oreochromis niloticus (NT)	–	–	–	30	20

Stocking rate of each species in each polyculture system.
[a] Stocking density was 2875 fingerlings/ha for the control group and 5750 fingerlings/ha for treatments I to IV.

2.2. Growth and yield

For weight determination, measurements and feed adjustment, samples of at least 10% of the fish from each species were collected periodically (every 2–4 weeks) with a pen net. The fish was weighed, measured and immediately returned to the water. The total fish weight of each pond was then estimated using the mean weight of the sampled fish multiplied by the total number of fish initially stocked. At the end of the experiment, all fish were harvested and the total number, weight and size of each fish species were determined. Survival rate and yield data were then calculated.

The growth and yield indexes measured and or calculated were: total biomass (g), mean body weight by species (g), weight gain ($Wg = fW - iW$), daily weight gain ($DWG = fW - iW/t$), standard length (cm), weight coefficient of variation ($WCV = SD/Mean$, %), specific growth rate ($SGR = 100 \cdot [Ln(fW) - Ln(iW)/t]$) where fW is final weight, iW is initial weight and t is days of culture, as mentioned previously (Barcellos et al., 2004). The survival rate and food conversion were also analyzed.

2.3. Feed and feeding regime

Because fish species with different feeding habit were used, several types of foods were used. A single commercial type of extruded feed (floating pellets with 1–2 mm, up to 60 days, and 3–4 mm from 60 days to the end of experiment, with 42% crude protein and 3400 kcal/kg DE) was used to feed jundia and Nile tilapia. For the grass carp, fresh double triturated camerun grass (*Pennisetum purpureum*) was offered 1 h before other foods; common carps were fed with triturated corn previously hydrated for 1 h. The fertilization regimen described above allowed the growth of phyto and zooplankton which were used by the filtrating species. In the first month, all foods were fed ad libitum; after that, fish were fed three times a day (10:00, 13:30 and 17:00 h) with 2–4% of biomass.

2.4. Climate conditions

The climate data (atmospheric temperature and rainfall) were obtained with the meteorological station at Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Trigo, Passo Fundo, RS.

2.5. Water quality measurements

Water temperature and dissolved oxygen concentrations were measured two times a day (8:00 and 16:00 h) at a depth of 30 cm with an oxygen meter (YSI model 550A, Yellow Spring Instruments, USA). Simultaneously the pH (Bernauer pH meter), total ammonia-N (colorimetric test) and water transparency (Secchi-disk) were also measured. Every two weeks, total alkalinity and hardness were measured with colorimetric tests.

2.6. Statistical analysis

The data obtained are presented as treatment means ± standard error of mean (SEM). To compare two groups, the means of each group were compared using Student's T test; to compare three or more groups, the analysis of variance (ANOVA) for completely randomized design, followed by Tukey's multiple range test at 5% level of significance was used. Data of yield and species rate and yield species rate and water quality parameters were submitted to regression analysis.

3. Results and discussion

3.1. Climate conditions

The climate conditions in Passo Fundo City (28°15′ S/52°24″W, 687 m above sea level) during the period of the experiment are shown in Fig. 1. Rainfall were unusually low in February and March and much higher than normal during April (Table 2).

Climate conditions affect water parameters. In the beginning of 2005, average temperatures were higher and rainfall were much lower than usually expected for this time of the year, which might have had a positive affect on water transparency (Fig. 2). In contrast, the water transparency decreased significantly in April when rainfall was above the expected range and, consequently, there was a reduction of plankton availability to filtrating fish.

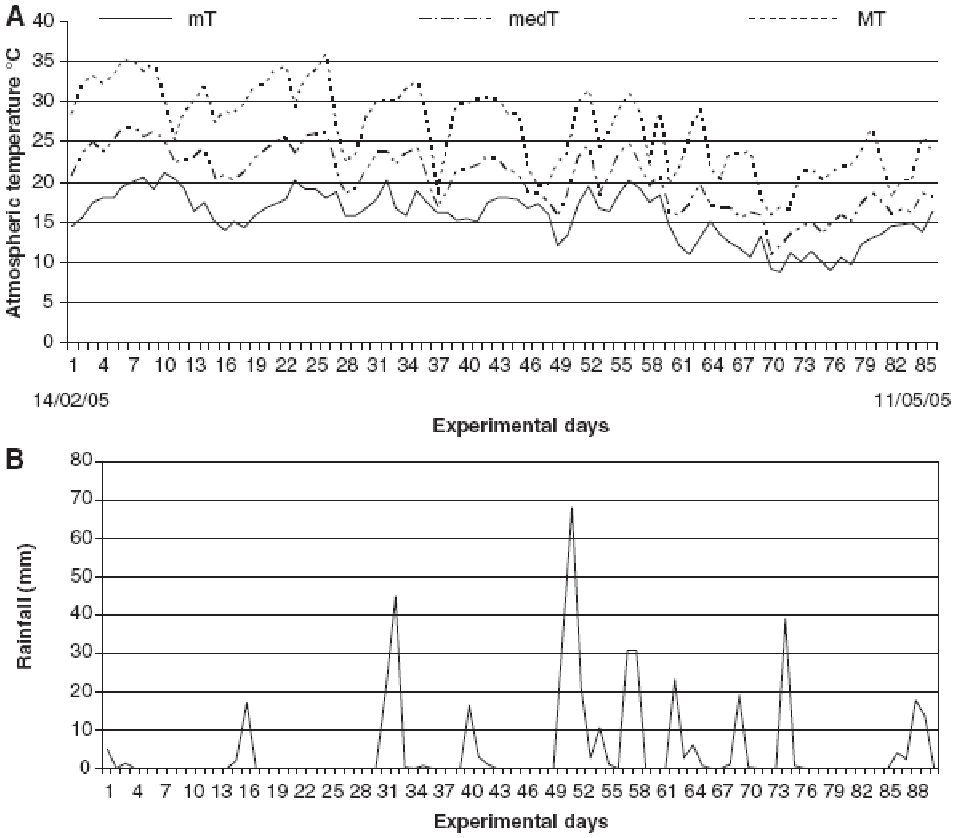

Fig. 1. Temperature and rainfall distribution during the experimental period. (A) Daily values of maximum temperature (MT), minimum temperature (mT) and medium temperature (medT). (B) Daily values of rainfall (mm/day). Day 1 corresponded to February 14th, 2005.

3.2. Water quality parameters

All parameters were found within acceptable values for water ponds used in fish culture as reported by Boyd (1982).

No difference in water temperature was observed among the 9 ponds of the experiment. In the morning, dissolved oxygen measurement ranged from 5.1 to 7.9 mg/L, showing statistical differences between the ponds.

Table 2
Temperature and rainfall data during the experimental period

Month	Temperature (°C)		Rainfall (mm)	
	2005 medium (range)	Expected medium (range)	2005	Expected
February	23.0 (17.5–30.2)	21.9 (17.5–28.0)	26.1	148.3
March	22.2 (17.0–29.4)	20.6 (16.3–26.7)	88.3	121.3
April	17.8 (14.3–23.2)	17.6 (13.5–23.7)	291.9	118.2
May	16.8 (13.0–22.3)	14.3 (10.9–20.7)	62.7	131.3

Medium and range (minimum and maximum) temperatures (°C) and rainfall (mm) from February to May, 2005, and expected values for this period of the year (normal conditions) according to the Meteorological station of EMBRAPA—Trigo, Passo Fundo, RS, Brazil.

The morning pH values ranged from 6.2 to 6.6 and in the afternoon from 6.4 to 7.2 with statistical differences between the ponds. The Secchi-disk water transparency ranged from 39.6 to 55.3 in the morning and from 39.1 to 60.7 in the afternoon also with statistical differences between ponds. The pond 7 (Treatment III, replicate 2) presented the higher value water transparency followed by the pond 8 (Treatment I, replicate 2).

The water transparency measurements by Secchi-disk were divided in three classes (<30 cm, from 30.1 to 60 cm and >60 cm) and the distribution in each tank is shown in Fig. 2. Ponds 7 and 8 had the higher percentile of days with Secchi-disk transparency over 60 cm.

The alkalinity and total hardness values are shown in Table 3. In all ponds the alkalinity value was lower than total hardness. The alkalinity values were lower than the recommended values (50–200 mg $CaCO_3$/L). No significant correlation was found between species rate and the water quality parameters.

In water quality parameters a clear pond effect was noted. Since all ponds were adjacent and receive water from the same source, no difference in water temperature could be detected. Regarding DO levels, all morning and afternoon values were within the ideal

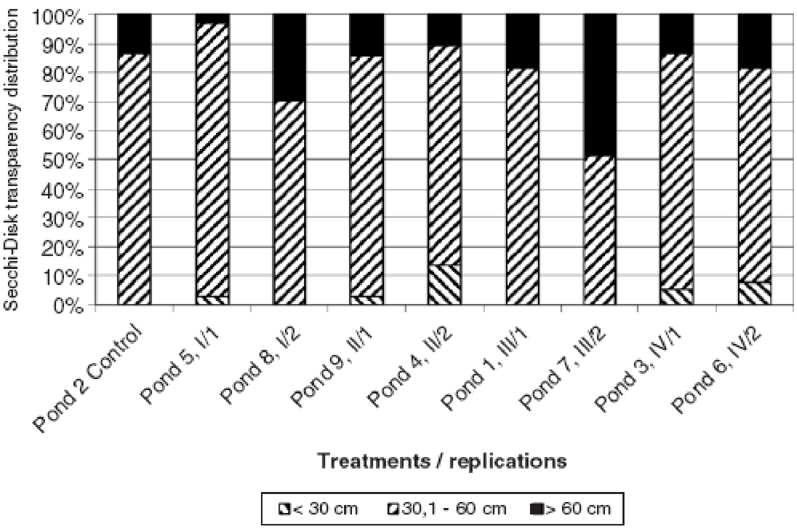

Fig. 2. Water transparency of all ponds was measured daily using Secchi-disk and classified in three classes (<30 cm; between 30.1 and 60 cm; and >60 cm). The data is shown as percentile of days in which water transparency fell in each class.

range (above 5.0 mg/L). Values for pH ranged from 6.2 to 7.2 also within the ideal range for cultured species. The variation between morning and afternoon pH was low. Total ammonia-N values were always under 0.6 mg/L in all ponds.

Variability between pond was observed with alkalinity, hardness and Secchi-disk transparency parameters. Mean alkalinity levels varied from 18 to 31.8 mg $CaCO_3$/L (Table 3); those values are considered low and can affect the primary production of the pond (Boyd, 1982). Total hardness varied from 27.6 to 34.8 mg $CaCO_3$/L.

Eventually, ponds from the same treatment had large variation in transparency; for instance, pond 5 (treatment I replicate 1) had Secchi-disk transparency of 39.6±0.73 cm in the morning measurement and 39.1±0.78 cm afternoon, and pond 8 (treatment I replicate 2) had 55.3±1.4 and 60.7±1.42 cm, respectively. When the distribution of values was analyzed (Fig. 2), the clear superiority of pond 5 was confirmed; only 2.7% of the experimental days it showed mean values of Secchi-disk transparency above to 60 cm and in pond 8 this percentile increases for 29.73%.

3.3. Growth and yield

The initial weight, daily weight gain, final weight, specific growth rate and weight coefficient of variation are expressed in Table 4.

The initial weight of different species was similar, ranging from 1.7 to 2.3 g in CC, 0.5 to 1.7 g in GC, 0.8 to 1.4 g in SC, 1.7 to 2.7 g in BC, 1.4 to 1.6 g in JN and NT. In contrast, the final weight of different species in different treatments showed statistical differences, with a pond effect on growth of different species. Common carp final weights varied from 190.3±5.18 g (treatment I replicate 2) to 515.0±44.0 g (treatment IV replicate 2). The CC from treatment IV (both replicates) had the higher weight in comparison to the other treatments. Grass carp final weights varied from 39.1±2.65 g (treatment I replicate 1) to 93.8±5.26 g (treatment III replicate 2), but when the mean of two replicates was analyzed, the GC from the treatment IV had higher weight. SC final weights ranged from 22.5±2.41 g in control treatment to 56.9±3.32 g in treatment III replicate two; when the mean of two replicates were compared, the SC from the treatment III had higher weight. BC final weights varied from 59.4±2.26 g in treatment I replicate two to 219.6±3.62 g in treatment IV replicate one, which had the higher weight for BC. JN final weights ranged from 85.5±5.0 g in treatment II replicate two to 130.0±5.84 g in treatment III replicate one; but when the mean of two replicates was analyzed, the JN from the treatment IV had higher final weight. Finally, NT final weights varied from 123.7±4.41 g in treatment IV replicate one to 185.2±34.3 g in treatment III replicate two, which had the higher weight for NT.

With a similar pattern, the DWG also varied between replicates of the same treatment, characterizing the same pond effect. DWG for CC ranged from 2.19 to 5.96 g, with the mean DWG for treatment IV higher than for treatment I, but similar to treatment II. The DWG for GC, SC, BC, JN and NT ranged from 0.44 to 1.08 g, 0.25 to 0.65 g, 0.66 to 2.52 g, 0.98 to 1.5 g and 1.42 to 2.14 g, respectively, with no differences between the same treatments.

The DWG of CC in the present study (2.19 to 5.96 g) was higher than that found by Abdelghany and Ahmad (2002) that reported a DWG for CC of 2.24 to 3.01 g; in contrast, these authors reported a higher DWG for SC (3.61 to 3.71 g) than reported in the present study (0.25 to 0.65 g). However, for NT, the DWG found in this study (1.42 to 2.14 g) was similar to that reported by Abdelghany and Ahmad (2002). The weight evolution in the five days in which weight was recorded (0, 14th, 30th, 65th, 86th day of experiment) is demonstrated in Fig. 4.

For SGR (%/day), no statistical differences were found between groups in each treatments and between different treatments. The SGR for CC, GC, SC, BC, JN and NT varied from 2.271 to 2.781, 1.666 to 2.265, 1.444 to 2.051, 1.606 to 2.276, 2.042 to 2.271 and 2.256 to 2.446, respectively.

In relation to survival rate (Fig. 5), SC showed higher treatment variability than the other species used in this study, ranging from 27.27% in treatment I replicate 1 to 90.91% in treatment I replicate 2. In treatment II and IV, SC survival rate varied from 35.71% to 71.43% and from 28.57% to 71.43%, respectively. Survival rate of BC was also low in treatment III replicate 2 and treatment IV replicate 1. Survival rate of all other species showed acceptable results. Survival rate of CC and GC varied from 96% to 100% and from 69.77% to 100%, respectively, a percentile higher than that reported by Jena et al. (2002) for the same species, and similar to the survival rate (86% to 100%) of CC reported by Zoccarato et al. (1995); in addition, the survival rate of GC (90% to 100%) reported by these authors was higher than reported herein for the same species. Similar results in relation to CC and NT has been observed

Table 3
Alkalinity (A) and total hardness (TH) measured in each experimental pond during all experimental period

Pond	Treatment/ replicate	A and TH (mg $CaCO_3$ l^{-1})	
		A	TH
1	III/1	22.2±1.5 bc	33.6±1.22 a
2	Control	22.2±0.44 bc	29.4±3.14 a
3	IV/1	28.2±2.64 ab	34.8±1.25 a
4	II/2	19.2±1.11 bc	28.2±1.50 a
5	I/1	20.4±1.61 bc	27.6±5.11 a
6	IV/2	31.8±1.11 a	34.8±1.61 a
7	III/2	23.4±2.30 abc	25.2±1.39 a
8	I/2	21.6±0.36 bc	33.0±4.50 a
9	II/1	18.0±0.58 c	29.4±1.22 a

Different small letters in the column indicate statistical differences between pond values (ANOVA followed by Tukey's multiple range test, $P<0.05$) $N=13$.

previously (Abdelghany and Ahmad, 2002) but still higher than those found in the present study for SC.

Besides final yield and final weight of each species, one important parameter to evaluate is the variation of the fish weight (Fréchette, 2005). The WCV for CC was low varying from 5.6% to 11.09%. For the other carp species, the WCV was higher; for GC, SC and BC the WCV ranged from 11.43% to 29.96%, 1.49% to 17.84% and 3.69% to 31.2%, respectively. For JN and NT, the WCV ranged from 11.0% to 18.7% and 6.21% to 18.52%, respectively. To better demonstrate the variability within the same species, the fish harvested were distributed in different weight classes, indicating the percentile distribution of the fish in different weight classes, as show in Fig. 3. For CC, only the treatment II, replicate 1 had two or more weight categories, similar to BC where only the control group fish were classified in two weight categories. In contrast, SC, GC and JN showed higher weight variability with two or more weight classes in all treatments. For NT, fish from treatment IV were allocated in only one weight category in both replicates, in contrast to treatment III in which fish were classified in two or more categories in both replicates.

Concerning the absolute yield data (based on 250 m^2), the higher production of CC was in treatment four, GC higher yield was in treatment III, and SC had extremely low yields in all treatments mostly because of the high mortality rates observed for species. BC higher production was in treatment II, JN and NT had both higher production in treatment III.

The yield/ha during the 86 days of experiment was highly variable for carp species and ranged from 273.2 to 480 kg/ha for CC, from 43.2 to 126.4 kg/ha for GC, from 3.6 to 22.4 kg/ha for SC and from 30.7 to 87.2 kg/ha for BC. JN productivity varied from 80.0 to 136.0 kg/ha and NT yield varied from 79.6 to 224.0 kg/ha. In general, regardless the treatment, the total yield varied from 380.0 to 811.2 kg/ha (Fig. 6).

When analyzed with a growth parameters perspective the most promising polyculture ratio was obtained with treatment IV (15% CC, 30% GC, 5% SC, 10% BC, 20% JN and 20% NT).

The complete exclusion of the CC (treatment III) had no advantages over other treatments. One possible explanation about the favorable effect of CC in polyculture is that pond soil perturbation by the CC increases oxygen transfer to the soil, decreasing the concentration of toxic reduced compounds, allowing a more efficient food recycling and nutrient release from the soil (Ritvo et al., 2004). This major nutrient release seems to be to cooperate for best phyto and zooplankton

Table 4
Initial weight, final weight, daily weight gain, specific growth rate (SGR), weight coefficient of variation (CV), of different groups (ponds) and treatments for common carp (CC), grass carp (GC), silver carp (SC), bighead carp (BC), jundia (JN) and Nile tilapia (NT)

	Species	Treatments/replicate												
		Cont.	I/1	I/2	Mean I	II/1	II/2	Mean II	III/1	III/2	Mean III	IV/1	IV/2	Mean IV
Initial weight (g)	CC	1.9±0.04	2.1±0.04	2.1±0.04	2.1±0.04	1.7±0.04	2.3±0.05	2.0±0.04	–	–	–	2.1±0.05	2.2±0.05	2.1±0.05
	GC	1.7±0.04	1.3±0.03	1.3±0.01	1.3±0.02	1.3±0.02	1.4±0.06	1.3±0.03	1.3±0.02	1.3±0.01	1.3±0.01	1.2±0.03	0.5±0.01	0.8±0.05
	SC	1.3±0.03	1.2±0.03	1.2±0.02	1.2±0.02	1.1±0.01	1.1±0.02	1.1±0.01	0.8±0.01	1.0±0.02	0.9±0.01	0.9±0.02	1.4±0.03	1.1±0.05
	BC	2.4±0.06	1.9±0.04	2.5±0.06	2.2±0.05	2.1±0.04	2.1±0.05	2.1±0.04	2.0±0.01	1.7±0.04	1.8±0.03	2.7±0.07	2.6±0.06	2.6±0.06
	JN	–	–	–	–	1.4±0.06	1.5±0.03	1.4±0.04	1.5±0.03	1.5±0.03	1.5±0.03	1.6±0.04	1.5±0.03	1.5±0.05
	NT	–	–	–	–	–	–	–	1.5±0.04	1.5±0.03	1.5±0.03	1.4±0.04	1.6±0.04	1.5±0.05
Final weight (g) and weight coefficient of variation (WCV, %)	CC	295.8^{C}±12.02	219.5^{D}±3.09	190.3^{D}±5.18	204.88±4.6	426.2^{B}±10.12	325.4^{C}±8.13	375.78±16.41	–	–	–	509.5^{A}±56.5	515.0^{A}±44.0	512.25±15.13
	WCV	9.09	5.6	8.62	10.04	5.82	6.12	15.13	–	–	–	11.09	8.54	9.34
	GC	44.6^{C}±2.29	39.1^{C}±2.65	56.5^{BC}±4.99	47.8±3.4	87.9^{A}±5.54	41.9^{C}±9.3	64.88±6.37	93.8^{A}±5.26	65.8^{BC}±3.79	79.79±4.47	85.1^{AB}±5.32	93.1^{A}±5.78	89.08±3.94
	WCV	11.43	21.48	27.96	31.82	18.89	22.2	41.66	17.7	17.33	25.05	18.8	18.58	18.78
	SC	22.5^{E}±2.41	44.6^{B}±2.5	27.2^{CDE}±1.18	35.95±3.3	28.1^{DE}±2.24	32.3^{C}±1.3	30.18±1.29	37.0^{CD}±3.32	56.9^{A}±3.32	52.17±2.55	46.9^{B}±0.7	52.0^{BC}±2.78	49.4±2.56
	WCV	24.0	12.56	9.49	27.71	17.79	4.02	30.09	17.84	7.73	14.66	1.49	11.92	13.70
	BC	125.0^{F}±17.44	133.1^{C}±5.47	59.4^{D}±2.26	96.21±12.69	77.7^{D}±5.23	123.5^{C}±4.28	100.6±7.62	170.0^{B}±7.5	156.9^{BC}±4.7	163.44±4.71	219.6^{A}±3.62	135.8^{BC}±7.93	177.74±14.56
	WCV	31.2	9.17	8.59	41.71	16.47	8.50	26.24	9.88	6.69	9.11	3.69	13.03	22.53
	JN	–	–	–	–	91.4^{BC}±5.18	85.5^{C}±5.0	88.43±4.26	130.0^{A}±5.84	111.4^{AB}±5.65	120.69±4.64	120.8^{A}±6.57	125.3^{ABC}±8.70	122.75±5.1
	WCV	–	–	–	–	13.89	14.27	16.69	11.0	11.13	13.32	13.33	18.7	13.78
	NT	–	–	–	–	–	–	–	159.8^{AB}±4.89	185.2^{A}±34.3	165.74±4.64	123.7^{C}±4.41	133.7^{BC}±3.39	130.24±3.4
	WCV	–	–	–	–	–	–	–	9.20	18.52	15.43	9.46	6.21	9.41
Daily weight gain (g/day)	CC	3.42	2.53	2.19	2.36^{B}±0.24	4.94	3.76	4.35^{AB}±0.83	–	–	–	5.9	5.96	5.93^{A}±0.04
	GC	0.5	0.44	0.64	0.54±0.14	1.01	0.47	0.74±0.38	1.08	0.75	0.92±0.23	0.98	1.07	1.03±0.06
	SC	0.25	0.5	0.3	0.4±0.14	0.31	0.36	0.34±0.04	0.42	0.65	0.54±0.16	0.49	0.6	0.55±0.08
	BC	1.43	1.52	0.66	1.09±0.61	0.88	1.41	1.15±0.37	1.95	1.8	1.88±0.11	2.52	1.55	2.04±0.69
	JN	–	–	–	–	1.05	0.98	1.02±0.05	1.5	1.28	1.39±0.16	1.39	1.2	1.3±0.13
	NT	–	–	–	–	–	–	–	1.84	2.14	1.99±0.21	1.42	1.54	1.48±0.08
SGR (%/day)	CC	2.557	2.539	2.271	2.41±0.19	2.781	2.498	2.64±0.2	–	–	–	2.773	2.753	2.76±0.01
	GC	1.666	1.715	1.901	1.81±0.13	2.105	1.701	1.9±0.29	2.173	1.989	2.08±0.13	2.156	2.265	2.21±0.08
	SC	1.444	1.842	1.535	1.69±0.22	1.649	1.707	1.68±0.04	1.917	2.051	1.98±0.09	1.948	1.842	1.9±0.07
	BC	1.991	2.135	1.606	1.87±0.37	1.814	2.048	1.93±0.17	2.246	2.276	2.26±0.02	2.229	2.004	2.13±0.16
	JN	–	–	–	–	2.103	2.042	2.07±0.04	2.271	2.188	2.23±0.06	2.193	2.150	2.17±0.03
	NT	–	–	–	–	–	–	–	2.344	2.446	2.4±0.07	2.256	2.232	2.24±0.02

Different capital letters after the means indicate significant differences between columns (Anova, Tukey or Student's *T* test, $P < 0.05$).

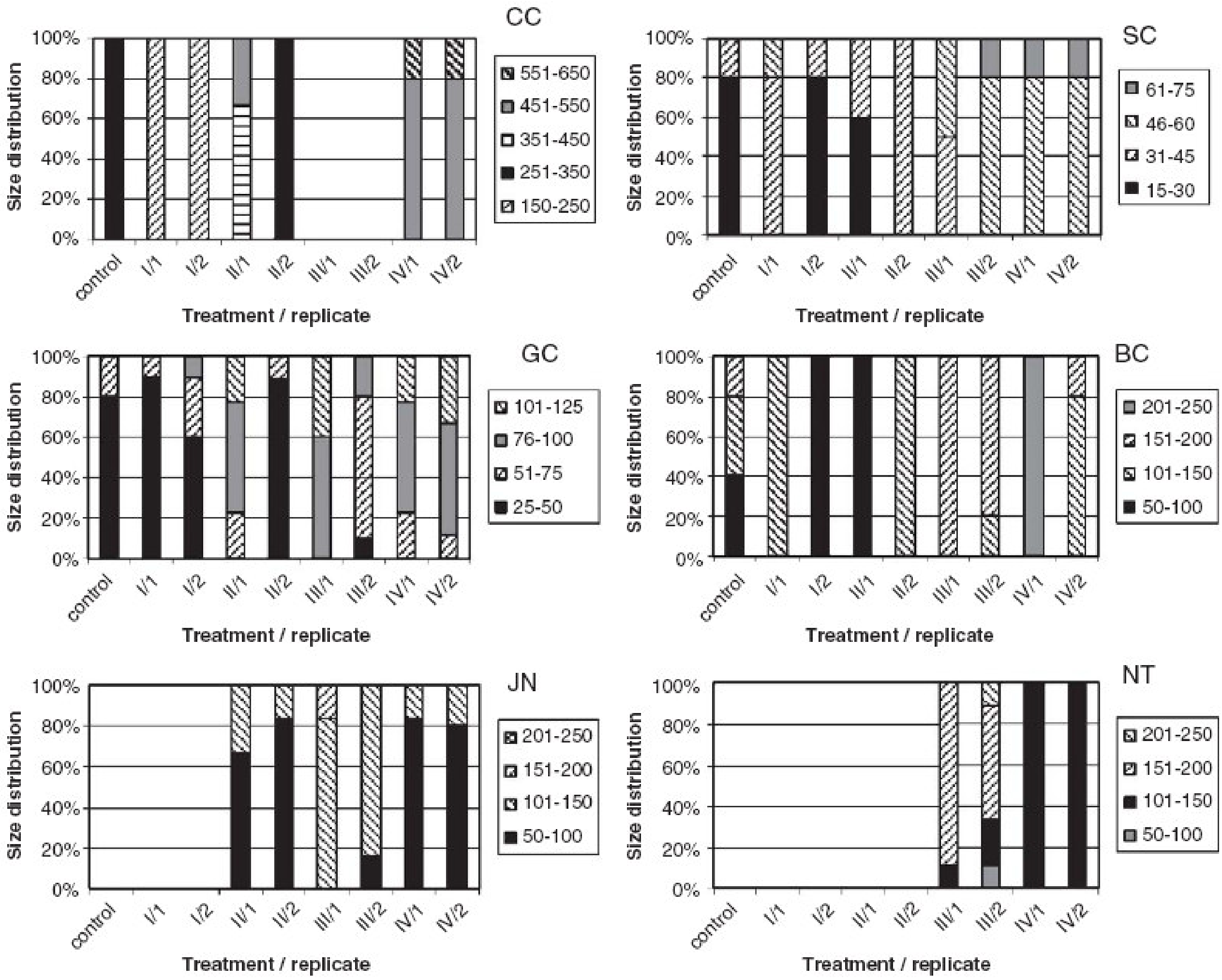

Fig. 3. Percentile distribution of harvested fish in different weight classes in each treatment. Fish from control group was classified in 4 weight classes and fish from the treatments were classified in 5 weight classes.

levels and few days with Secchi-disk transparence above 60 cm. Moreover, the reduction of CC percentile (from 35% in treatment I to 20% and 15% in treatments II and IV, respectively) increases the total yield of the treatment. Lutz (2003) attempted to the fact that stocking CC in high rates may cause excessive turbidity due stirring of the mud, which in turn can rescue the plankton availability for SC and vegetation of GC.

The superiority of the pond 5 transparency (treatment I replicate 1) over pond 8 (treatment I replicate 2) was reflected in the fW of the filtrating species. In pond 5, the fW of SC, a phytoplankton filtrating specie, was 44.6± 2.5 g, statistically higher than the fW (27.2±1.18 g) achieved by SC from pond 8. A more pronounced difference was observed with BC, a zooplankton filtrating species that achieved 133.1±5.47 g in pond 5 in constrast to 59.4±2.26 g achieved in pond 8. This pattern was also observed with DWG: SC had DWG of 0.5 g/day in pond 5 and 0.3 g/day in pond 8; BC had DWG of 1.52 g/day in pond 5 and 0.66 g/day in pond 8; for SGR, SC achieved 1.842%/day in pond 5 and 1.535%/day in pond 8; BC achieved SGR of 2.135%/day in pond 5 and 1.606%/day in pond 8. Abdelghany and Ahmad (2002) found SGR values for SC higher than found in the present study.

This effect of transparency levels of pond 5 (treatment I replicate 1) on fW, DWG and SGR was hard to access due to the very low survival rate of the filtrating species, specially SC, in the this pond (27.27%) in contrast to pond 8 (treatment 1 replicate 2—90.91%). The high mortality rate of SC reduced dramatically the number of fish that consumed plankton, increasing food availability to surviving fish that consequently achieved higher values in weight parameters.

According to Kestmont (1995) the growth and yield of each species may be higher in polyculture than in

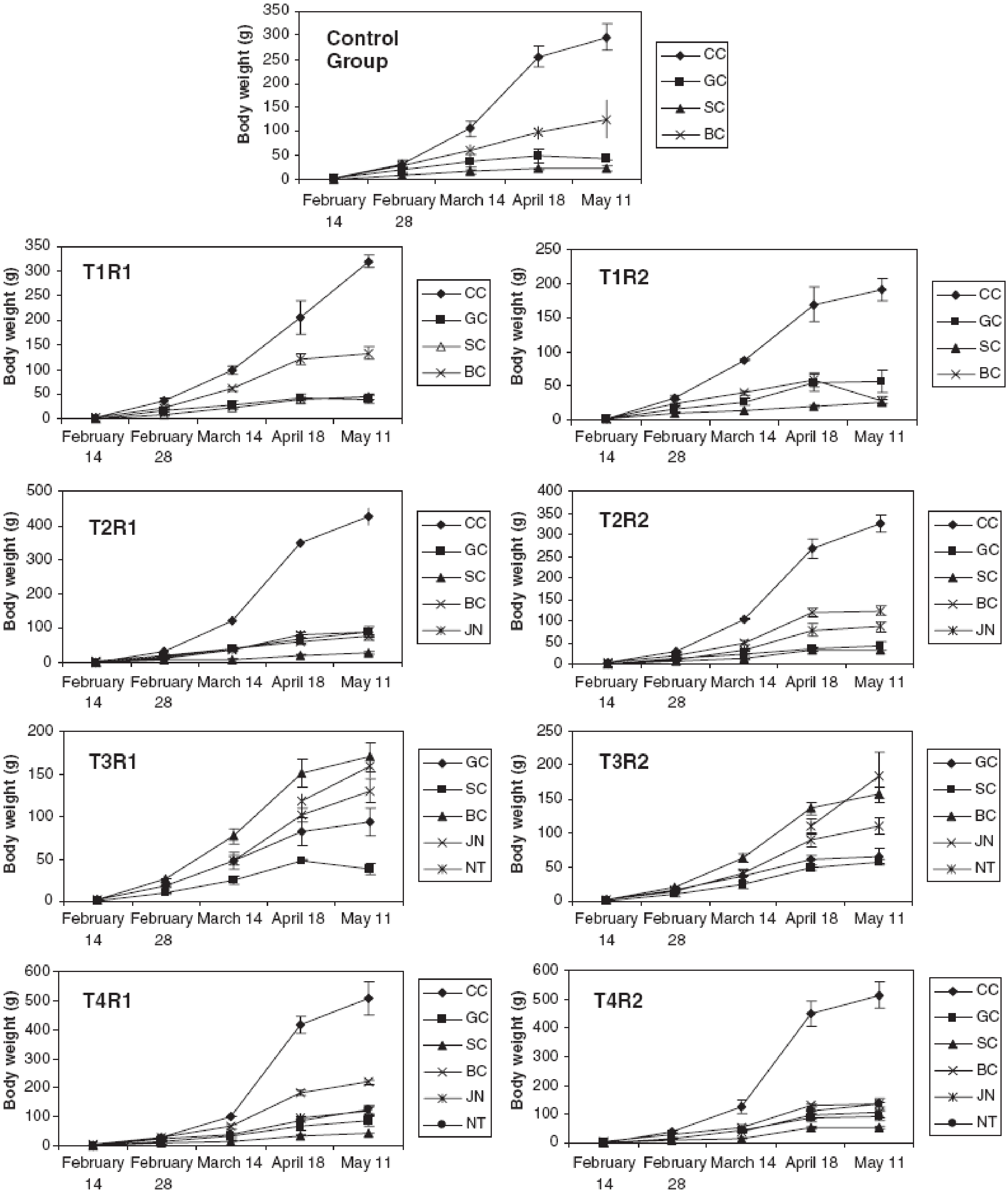

Fig. 4. Evolution of the mean body weight of each fish species in each treatment, evaluated at specific times during the experiment.

monoculture because of positive interactions among species. As explained by Milstein (1992), SC fecal pellets rich in partially digested phytoplankton are eaten by the common carp, which otherwise would not utilize these algae. By stirring up the mud, the CC recycles nutrients into the water column and improves the development of filamentous algae, thereby increasing phytoplankton production that will be consumed by SC. In our experiment, the presence of CC had positive effects on all zootechnical parameters of all species used.

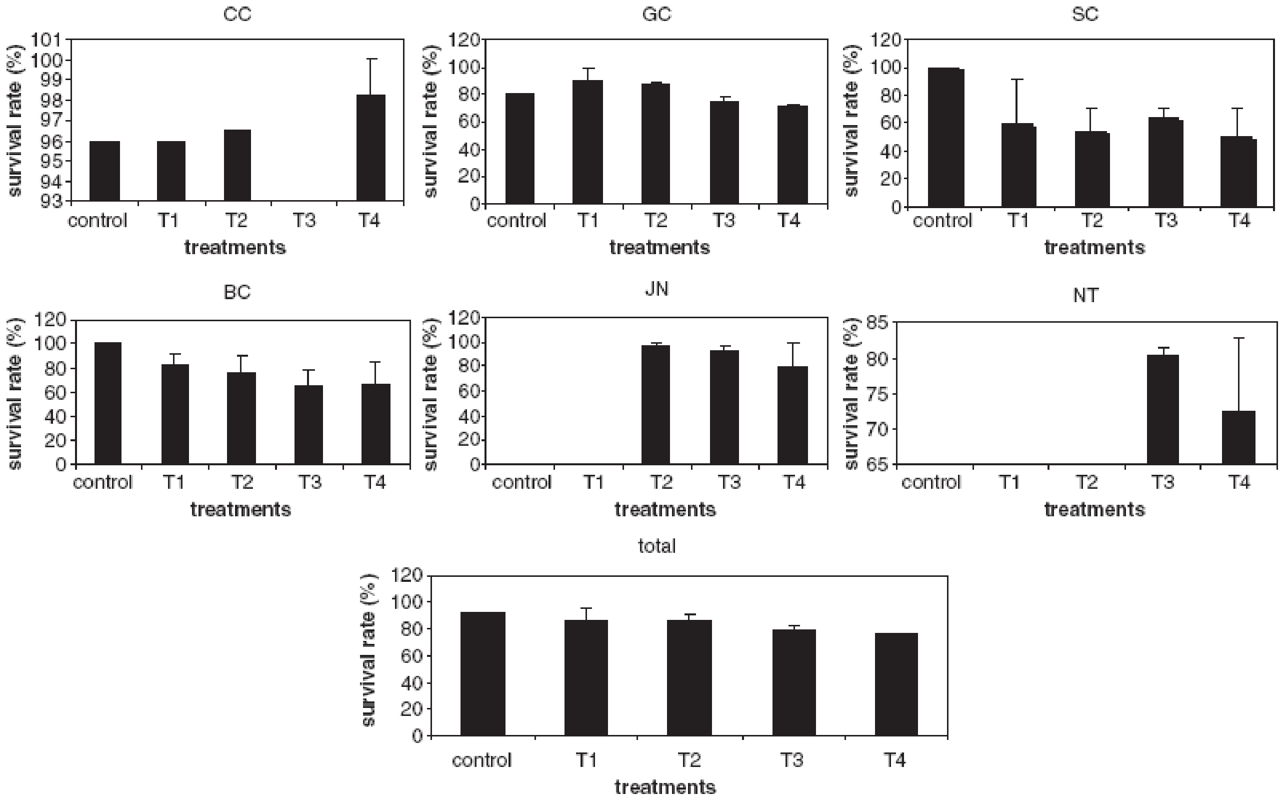

Fig. 5. Survival rate (%) of each species in each treatment and total survival rate of the treatment. Data is expressed as mean ± SEM. Common carp (CC), grass carp (GC), silver carp (SC), bighead carp (BC), jundia (JN) and Nile tilapia (NT).

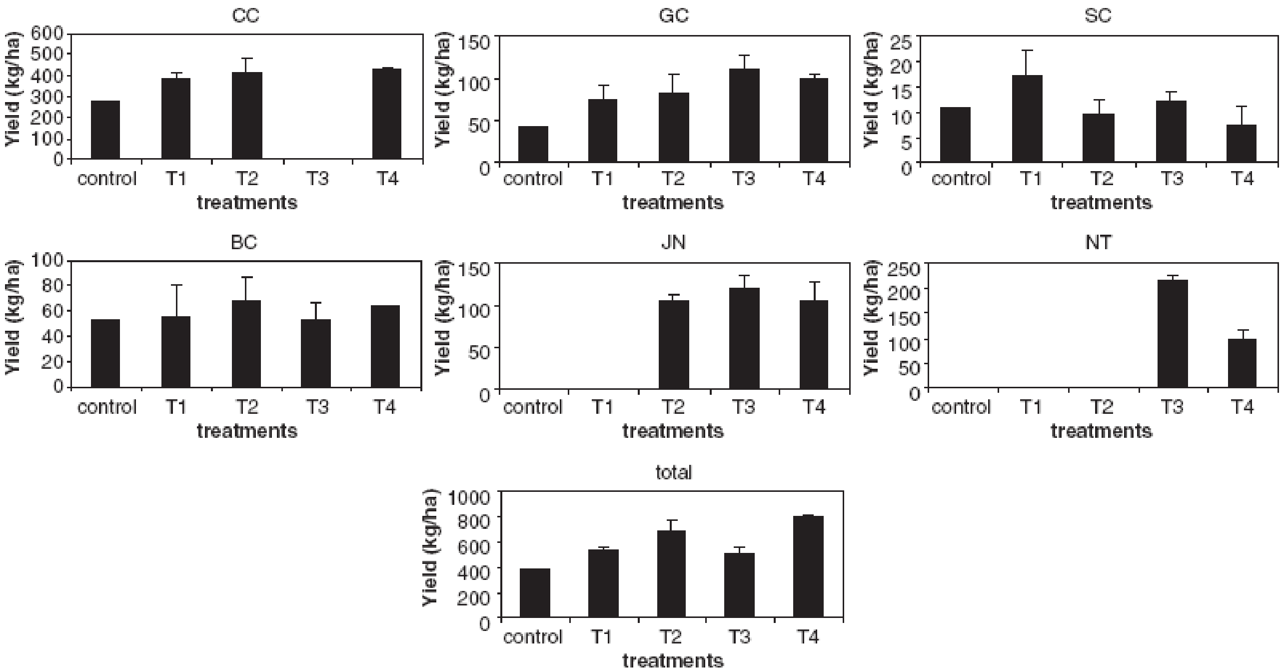

Fig. 6. Yield (kg/ha) of each species in each treatment and total yield of the treatment. Data is expressed as mean ± SEM. Common carp (CC), grass carp (GC), silver carp (SC), bighead carp (BC), jundia (JN) and Nile tilapia (NT).

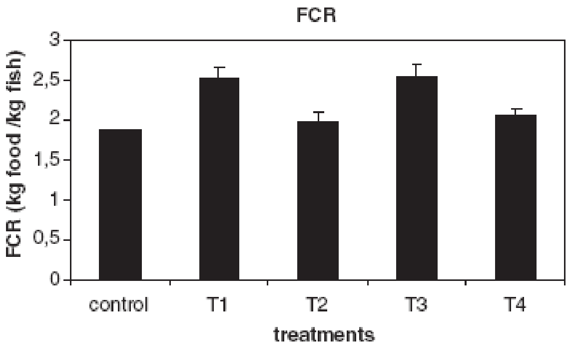

Fig. 7. Food conversion rate (FCR, kg food consumed/kg fish produced) of each species in each treatment and total FCR of the treatment. Data is expressed as mean±SEM. Common carp (CC), grass carp (GC), silver carp (SC), bighead carp (BC), jundia (JN) and Nile tilapia (NT).

The GC benefit depends more of the quality of the tank regarding the presence of macrophytes (Horváth et al., 1984); this could explain the superiority of GC yield in both replicates of treatment III, that had no CC—that usually prevents seed germination of higher plants—and the macrophytes were predominant in both ponds.

The introduction of jundia (*R. quelen*) in the polycultures tested had no effect over other species. Jundia is an omnivorous native species with preference for animal protein source (Gomes et al., 2000). Since jundia feeds well on artificial food and corn grains, it may show a competition with NT and CC, but no negative effect was verified in these species with the JN introduction. Except for treatment I replicate one, JN survival rates were good, varying from 89.66% to 100%, similar to previously reported by Barcellos et al. (2004) in JN monocultured in cages. JN reached fW varying from 85.5 to 130.0 g, higher than found previously (63.74±3.69 g) for the same period of time (Barcellos et al., 2004). DWG and SGR were also higher than found in other studies (Barcellos et al., 2004; Souza et al., 2005).

Nile tilapia grew better in treatment III which had no CC, probably because these species compete for artificial food. Lutz (2003) reported that the overlapping of food preferences among species may be a problem in polycultures. Moreover, CC achieved best performance in the presence of the NT. Papoutsoglou et al. (1991) also verified that CC and NT achieved better results when cultured together than when cultivated in monoculture system. As reviewed by Kestmont (1995), the association of carp and tilapia may increase the growth of carp. In polyculture systems, only a proper combination of ecologically different species, at adequate densities, will utilize the available resources efficiently due to the maximization of synergistic fish–fish relationships and minimization of antagonistic ones (Milstein, 1992).

Food consumed and food conversion rate (FCR, Fig. 7) varied from 1.87 to 2.70 kg of food per kilogram of fish produced. When compared, the FCR had no difference between treatments, and were higher than those found by Abdelghany and Ahmad (2002) that reported a FCR of 0.46 to 1.37 kg. However, in a carp polyculture analyzed by Jena et al. (2002), FCR varied from 1.47 to 3.16 kg, similar to those reported herein.

An economic analysis was performed, but since the fish in the initial growing season had no market size and the stocking density was not employed in the nursery period, both scenarios of juveniles and whole fish sales had no positive incomes (data not shown).

4. Conclusion

Based on the data presented herein, the most promising polyculture ratio seems to be that used in treatment IV (15% CC, 30% GC, 5% SC, 10% BC, 20% JN and 20% NT) for initial growing season. The reduction of CC ratio and the introduction of NT and JN had positive effects in all growth parameters evaluated.

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CAPÍTULO III

CONCLUSÕES E CONSIDERAÇÕES FINAIS

Conclusões

1) O policultivo com 5000 alevinos por hectare permite melhor desempenho zootécnico em relação ao policultivo com a densidade tradicional (2500 alevinos por hectare).

2) A substituição parcial da carpa húngara pelo jundiá apresenta efeito positivo, resultando em aumento dos parâmetros de produção avaliados.

3) A exclusão completa da carpa húngara não refletiu bom resultado, onde os valores encontrados de rendimento foram abaixo daqueles onde a espécie estava presente.

4) A substituição parcial da carpa húngara pelo jundiá e das carpas filtradoras (prateada e cabeça-grande) pela tilápia-do-Nilo apresentou os melhores resultados.

Considerações finais

O policultivo proposto, composto pelas seis espécies, nas condições em que foi testado, apresentou melhor desempenho zootécnico em relação ao tradicional policultivo praticado no Rio Grande do Sul. Portanto, parece ser uma real e factível alternativa para o cultivo de peixes no Estado.

Esta linha de pesquisa deve e está sendo continuada a partir deste trabalho, com o objetivo de elucidar algumas questões importantes, como determinar as taxas ideais de substituição parcial de carpas húngaras por jundiás e de carpas filtradoras por tilápias.

A importância da determinação das taxas de substituição, reside no fato da diversidade de micro climas existente na região sul do Brasil. Regiões mais quentes favoreceriam os policultivos nos quais houvesse percentuais maiores de introdução da tilápia-do-Nilo.

Outro fator que poderá influenciar a decisão pela taxa de substituição mais adequada é a disponibilidade de alevinos de algumas das espécies utilizadas. Regiões onde determinada espécie fosse de difícil aquisição, determinariam introdução da mesma em percentuais menores.

Por fim, uma microrregião onde houvesse melhor aceitação de uma espécie de carpa específica, determinaria a escolha por um modelo onde o cultivo dessa espécie fosse em percentuais maiores.

CAPÍTULO IV

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APÊNDICES

NORMAS DA REVISTA

AQUACULTURE

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Guide for Authors

Types of contribution

1. Original Research Papers (Regular Papers)
2. Review Articles
3. Short Communications
4. Technical Papers
5. Letters to the Editor
6. Book Reviews

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Benzie, J.A.H., Ballment, E., Frusher, S., 1993. Genetic structure of *Penaeus monodon* in Australia: concordant results from mtDNA and allozymes. In: Gall, G.A.E., Chen, H. (Eds.), Genetics in Aquaculture IV. Proceedings of the Fourth International Symposium, 29 April-3 May 1991, Wuhan, China. Aquaculture 111, 89–93.

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Gaugh, Jr., H.G., 1992. Statistical Analysis of Regional Yield Trials. Elsevier, Amsterdam, 278 pp.

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