UNIVERSIDADE ESTADUAL PAULISTA – UNESP
CENTRO DE AQUICULTURA DA UNESP

Sustentabilidade dos sistemas de produção do lambari-do-rabo-amarelo

Fernando Henrique Agostinho dos Santos Barbosa Gonçalves

JABOTICABAL, SÃO PAULO
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Orientador: Dr. Wagner Cotroni Valenti

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$$Life = \int_{birth}^{death} \frac{happiness}{time} \, \Delta \, time$$

Yes we can!

- OBAMA, B., 2008

Eu acredito!

- DONATO & GONÇALVES, 2016

SUMÁRIO

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RESUMO

Os sistemas de produção de lambari se diferenciam pelo nível de controle da reprodução da espécie. As técnicas utilizadas envolvem desde a reprodução natural até a utilização de laboratório para indução hormonal. Assim, classificamos os sistemas produção de lambari em baixo (LCS), médio (MCS) e alto (HCS) controle. Nosso objetivo é caracterizar os três principais sistemas de produção de lambari do Estado de São Paulo e avaliar a sustentabilidade de cada um. A sustentabilidade foi avaliada por meio de indicadores ambientais, sociais, econômicos e de governança. Visitamos nove propriedades selecionadas de acordo com o nível de controle de produção. Os dados sociais, econômicos e de governança foram obtidos por meio de um questionário semiestruturado e dados secundários obtidos em órgãos públicos. Amostras de água, sedimento, lambaris produzidos e dieta fornecida foram coletadas nas fases inicial e final do ciclo de produção em cada propriedade e analisados no Laboratório de Aquicultura Sustentável, do CAUNESP, no Campus de São Vicente da UNESP. As variáveis obtidas foram comparadas entre os sistemas. Os indicadores foram calculados e transformados em escala de performance. Assim, foram calculados índices de sustentabilidade ambiental, social, econômica e institucional por combinação linear e gerado um índice geral de sustentabilidade para cada sistema. Os sistemas de médio e alto controle de produção foram classificados como Potencialmente Sustentável, com índices de 0.686 e 0.775, respectivamente. O sistema de baixo controle de produção foi classificado como Média Sustentabilidade, com índice de 0.590. A dimensão institucional é o ponto mais fraco da produção de lambari no Estado de São Paulo.

PALAVRAS-CHAVE: *Astyanax lacustris*, sustentabilidade, escala de performance, gases do efeito estufa, equidade social, viabilidade econômica, indicadores de governança.

ABSTRACT

The production systems of lambari differ by the level of control of the reproduction. The techniques used vary from natural reproduction to laboratory use for hormonal induction. Thus, we classify the lambari production systems in low (LCS), medium (MCS) and high (HCS) control. Our objective is to characterize the three main lambari production systems in the São Paulo State and to evaluate the sustainability of each one. The sustainability was assessed by environmental, social, economic and governance indicators. We visited nine properties selected according to their level of control of production. Social, economic and governance data were obtained through a semi-structured questionnaire and secondary data obtained from public agencies. Samples of water, sediment, lambari produced and diet supplied were collected in the initial and final phases of the breeding cycle in each property and analyzed in the Sustainable Aquaculture Laboratory of CAUNESP, at the São Vicente Campus of UNESP. The obtained variables were compared between the systems. The indicators were calculated and transformed into a performance scale. Thus, environmental, social, economic and governance sustainability indexes were calculated by linear combination and generated a general sustainability index for each system. The systems of medium and high control of production were classified as Potentially Sustainable, with indexes of 0.686 and 0.775, respectively. The low production control system was classified as Average Sustainability, with an index of 0.590. The governance is the weakest dimension of lambari production in São Paulo State.

KEY WORDS: *Astyanax lacustris*, sustainability, performance scale, greenhouse gases, social equity, economic viability, governance indicators.

CAPITULO 1

INTRODUÇÃO GERAL

INTRODUÇÃO GERAL

Atualmente, a produção de organismos aquáticos é uma das atividades que apresenta maior crescimento no mundo (FAO, 2016). A aquicultura vem acompanhando o desenvolvimento humano desde tempos remotos. Eventos marcantes de revoluções da aquicultura ao longo da história humana em diversas civilizações foram levantados por Costa-Pierce (2010). No Egito, há 4.000 anos, túmulos revelavam o cultivo de tilápia em tanques de água drenáveis integrados com a agricultura. Na China, o Tratado de Fan Li foi publicado há mais de 2.300 anos durante a dinastia Zhou. Também há evidências da integração de peixes e arroz datada de 8 mil anos. Na Dinastia Tang, o policultivo sofisticado de carpas multiespecíficas já ocorria resultando em aumento de alimentos (peixe e colheitas) por unidade de área. Na Europa, os Etruscos e Romanos há 2.200 anos iniciavam aquicultura na costa do Mar Adriático e a literatura romana relata que peixes em lagoas eram comuns. Na Bolívia, há 2.000 anos, imensos campos agrícolas elevados integravam peixes com irrigação por canais. Há mais de 1.000 anos, o primeiro sistema de aquicultura integrada com agricultura tradicional pode ter sido desenvolvido no Camboja. O conhecimento da trajetória evolutiva reforça a ideia de que as raízes sociais e ecológicas da aquicultura industrial moderna se articulam para promover inovações sustentáveis (Costa-Pierce, 2010). Assim, os ensinamentos dados pela história da aquicultura devem ser considerados para aperfeiçoar os sistemas de produção existentes.

No Brasil, a aquicultura produziu 562,5 mil toneladas em 2015 e a expectativa é de que o segmento cresça 104% até 2025 (FAO, 2016). Das espécies de água doce, chama atenção o crescimento da produção de lambari, espécie nativa de pequeno porte, com ciclo de vida curto e de fácil manejo. A produção brasileira de lambaris foi de 234 toneladas, e movimentou cerca de R$ 1,9 milhões em 2016. O Estado de São Paulo é o maior produtor, responsável pela produção de 74 toneladas de lambaris, correspondendo a 29% da produção nacional (IBGE, 2016). O desenvolvimento da atividade ocorreu principalmente devido à demanda por iscas vivas para a pesca esportiva (Gonçalves *et al*., 2015b). O lambari-do-rabo-amarelo é a principal espécie cultivada no Estado de São Paulo (Valladão *et al.*, 2016; Fonseca et al., 2017). Esta espécie é conhecida como *Astyanax altiparanae* (Garutti & Britski, 2000), mas recentemente foi re-descrita e reconhecida como *Astyanax lacustris* (Lucena & Soares, 2016). Sua produção tem sido ligada à cadeia produtiva do turismo, que contribui significativamente na economia nacional (Gonçalves *et al*., 2015b). Além disso, podem ser criados por pequenos produtores rurais ou urbanos em sistemas familiares de produção, inclusive em locais que apresentam restrições ambientais, como áreas no entorno de unidades de conservação (Lopes *et al.*, 2013). Observa-se ainda o crescimento de vários nichos de mercado, como o de petiscos para consumo humano e o de peixe forrageiro em lojas de aquariofilia e aquários públicos para enriquecimento ambiental e também alimentar espécies carnívoras de maior porte (Silva *et al*., 2011b). Sua utilização como atrator de cardumes para pesca industrial de atuns está em fase inicial de testes após investigações fisiológicas de tolerância à salinidade (Gonçalves *et al.*, 2015a). Assim, produtores de lambari apresentam características da agricultura familiar e acessam mercados específicos e há pouca sobreposição com produtos originários do agronegócio, como por exemplo a tilápia (*Oreochromis niloticus*).

Diversas pesquisas apresentam informações para melhoria da produção da espécie. Para o campo da nutrição, a frequência de alimentação ideal (Hayashi, 2004), os requerimentos de aminoácidos essenciais (Abimorad & Castelani, 2011), a substituição de proteína animal pela de origem vegetal em dietas (Sussel *et al.*, 2014) estão disponíveis. Para o mercado, há a possibilidade do uso de lambari como fonte de ácidos graxos essenciais para alimentação humana e animal (Gonçalves *et al.*, 2014). Estes peixes têm um grande potencial para substituir sardinhas enlatadas (*Sardinella brasiliensis*) e anchovas (*Anchoviella lepidentostole*) no mercado de petiscos (Porto-Foresti *et al.*, 2005). Isso poderia reduzir o impacto sobre as populações naturais dessas espécies, que só estão disponíveis a partir da pesca. Outras vantagens da produção de lambari são a padronização do tamanho, maior rastreabilidade e maior regularidade no fornecimento. Atualmente, os estoques naturais de lambari estão diminuindo devido à pesca excessiva ou poluição. Dessa forma, lambari derivado da produção aquícola é valorizado e agrega valor ambiental por reduzir a pressão de captura sobre populações nativas dos córregos e rios (Gonçalves *et al.*, 2015b). Além disso, a produção de lambari é apontada como um meio de desenvolver comunidades rurais no Brasil por meio do aprimoramento socioeconômico e conservação ambiental (Fonseca *et al*., 2017).

A produção do lambari *Astyanax lacustris* envolve diferentes níveis de intensificação e sofisticação tecnológica que definem os sistemas de produção (Silva *et al.*, 2011a). Os sistemas de produção de lambaris são baseados nos modelos de piscicultura comuns no Brasil e se diferenciam pelo nível de controle da reprodução e povoamento dos jovens nos viveiros. Assim, classificamos os sistemas em baixo, médio e alto controle de produção. As técnicas utilizadas em cada sistema de produção envolvem desde a reprodução natural (baixo controle) até a utilização de laboratório para indução hormonal com extrato hipofisário de carpa (Lopes *et al.*, 2013) no sistema de alto controle. O sistema de médio controle de produção pode utilizar a técnica de indução hormonal, porém aplicada direto nos peixes diretamente nos viveiros para a desova natural, ou seja, sem o controle laboratorial para saber a quantidade de larvas produzida. Além disso, esses produtores podem manter relações comerciais com outros produtores do sistema de alto controle para a aquisição de formas jovens.

O potencial de mercado de lambaris estimulou o aumento do número de produtores nos últimos anos. No entanto, para que os avanços sejam estáveis, é necessário que se adotem os preceitos da sustentabilidade (Valenti, 2008). O aumento da produção de espécies aquáticas traz questões diretamente relacionadas ao seu desenvolvimento sustentável e demanda por estudos de sustentabilidade. Entre elas estão questões relacionadas aos impactos ambientais, viabilidade econômica, equidade social e ao conjunto de arranjos que constituem a governança do setor (Lazard *et al*., 2011). Uma produção planejada com base unicamente no mercado e nas oportunidades financeiras leva a sistemas que não se sustentam ao longo do tempo (Valenti *et al.*, 2010).

Sustentabilidade é uma palavra muito utilizada, muitas vezes de forma não fundamentada para atingir objetivos mercadológicos (Kimpara *et al.*, 2012). Nas últimas décadas, diversos rótulos e logotipos foram utilizados para transmitir informações sobre sustentabilidade em alimentos (Grunert *et al.*, 2014). Há muitas críticas sobre o que significa e como promovê-la. As definições do termo variam de acordo com o grau de importância dada às dimensões econômica, ambiental e social. Há aqueles que se pautam na economia de livre mercado, exploração de recursos e a orientação pelo crescimento da produção. Também há movimentos de conservacionismo dos recursos naturais, com a regulação das atividades econômicas, visando minimizar seu uso. Assumir que a natureza é finita, descartando o crescimento sem limites defendidos pela economia clássica, é a principal característica de uma produção sustentável. Além disso, cada geração tem o dever de deixar para a próxima, uma quantidade de recursos naturais equivalente àquela que recebeu. Essa definição foi apresentada na Agenda 21 e pode ser considerada universal pois vem sendo adaptada pela FAO e outros órgãos internacionais para os vários setores produtivos (Kimpara *et al.*, 2012). Assim, a aquicultura sustentável baseia-se na utilização racional dos recursos financeiros, naturais e humanos no processo de produção. Desse modo, é uma atividade economicamente viável, que propicia melhoria da qualidade de vida das comunidades locais, sem degradar os ecossistemas nos quais se insere (Arana, 1999; Valenti, 2002, 2008). Envolve três componentes: a produção lucrativa, a conservação do meio ambiente e o desenvolvimento social (Valenti, 2000). Estes são essenciais e indissociáveis para que a atividade seja perene.

Para atingir uma aquicultura sustentável, é essencial medir a sustentabilidade dos sistemas de produção usados, das técnicas de manejo e das novas tecnologias que vão sendo geradas e adotadas. Os principais métodos usados para medir a sustentabilidade da aquicultura no mundo são: Análise Emergética, Pegada Ecológica, Análise do Ciclo de Vida, Resiliência e Conjuntos de Indicadores (Kimpara *et al.*, 2012). Cada um tem características próprias (Tabela 1).

Tabela 1 - Comparação entre os métodos empregados para medir a sustentabilidade na aquicultura.

	Análise emergética	Pegada ecológica	Análise da resiliência	Análise do Ciclo de Vida	Conjunto de indicadores
Ênfase na quantificação	Não	Sim	Não	Sim	Sim
Envolvimento dos atores sociais	Não, os resultados são de difícil entendimento	Não, mas permite uma compreensão melhor	Em teoria sim, mas na prática, não	Não	A maioria não, mas eles podem participar da escolha dos indicadores
Componente social	Sim	Não	Sim	Não	Sim, mas não é sempre contemplado
Estudo de interações	Sim	Sim	Sim	Não	Não
Benefício econômico como objetivo principal	Não	Não	Não	Sim	Geralmente sim
Promove o uso eficiente de *inputs* externos	Não	Não	Não	Sim	Sim
Consideração das condições políticas e históricas	Não	Não	Sim	Não	Não

Fonte: Kimpara *et al.*, 2012

Os Conjuntos de Indicadores dão uma visão merística, possibilitando a análise de cada parte do sistema produtivo em separado. Isso permite localizar os pontos fracos para correção. Assim, os indicadores escolhidos devem ser diversificados o suficiente para cobrir todas as facetas da aquicultura. Além disso, devem possibilitar a consolidação em gráficos ou índices combinados que permitam uma interpretação geral. Os dados são de mais fácil obtenção e a interpretação dos resultados é simples e facilmente compreensível (Valenti *et al.*, 2011).

Recentemente, conjuntos de indicadores têm sido desenvolvidos para avaliar a sustentabilidade da aquicultura (EAS, 2005; Boyd *et al.* 2007; EVAD, 2008; Valenti, 2008; Valenti *et al.*, 2011, Lazard *et al.,* 2011, Valenti, 2013). Estes geralmente são distribuídos nas dimensões ambiental, social, econômica e institucional. Os indicadores ambientais estão principalmente focados em aspectos relacionados com a poluição (ex. as concentrações de nutrientes no efluente) e o uso eficiente dos recursos (ex. a eficiência no uso do nitrogênio e fósforo). Os indicadores sociais são ligados a questões como a equitatividade na distribuição de renda, a geração de postos de trabalho (empregos e auto empregos) e a segurança alimentar. Os indicadores econômicos mais utilizados são a renda anual, a taxa interna de retorno, o período de retorno do capital e o valor presente líquido. Os custos referentes às externalidades, no entanto, devem ser incluídos nas equações matemáticas que geram esses indicadores tradicionais. As externalidades são efeitos secundários (positivos ou negativos) de uma atividade econômica. As externalidades negativas surgem quando alguma parte do custo de uma atividade não é assumida pelos produtores ou consumidores do bem ou serviço em questão. A dimensão institucional (Lazard *et al.*, 2011) é medida por indicadores de governança que seguem quatro princípios necessários para o desenvolvimento sustentável da aquicultura. São eles a responsabilidade com ética, eficácia e eficiência dos governos, equidade e previsibilidade do Estado de direito (Hishamunda, *et al.,* 2014). A responsabilidade com ética e a previsibilidade garantem aos empresários que os direitos de propriedade e os contratos serão honrados, enquanto a equidade intergeracional sugere a conservação ecológica. O princípio da eficácia e da eficiência implica que a regulamentação da aquicultura será suficiente sem ser demasiadamente onerosa, e talvez também descentralizada e com participação pública (Hishamunda *et al.*, 2014). Diversas discussões sobre a sustentabilidade da aquicultura são baseadas em um único componente do desenvolvimento sustentável, desconsiderando os demais. Muito pouco trabalho tem sido realizado numa base global e comparativa (Lazard *et al.*, 2011).

Os trabalhos que definiram ou usaram indicadores de sustentabilidade para avaliar a aquicultura encontrados na literatura internacional foram: Dalsgaard *et al.* (1995), Lightfoot *et al.* (1996), Dalsgaard & Oficial (1997), Caffey *et al.* (2001), González *et al.* (2003), Stevenson *et al.* (2005), Boyd *et al.* (2007), Pullin *et al.* (2007), Tipraqsa *et al.* (2007), Dey *et al.* (2007), Bergquist (2007), Evad (2008), Kimpara *et al*. (2012). No Brasil, o grupo de pesquisa do Setor de Carcinicultura do CAUNESP, vem trabalhando no desenvolvimento de indicadores há vários anos (Valenti, 2008; Valenti *et al*., 2011). O presente trabalho integra a Rede de Pesquisa Sustentabilidade na Aquicultura (Edital MCT / CNPq / MEC / CAPES/ CT AGRO / CT HIDRO / FAPS / EMBRAPA No 22/2010 – REPENSA; CNPq Processo 562820/2010-3; FAPESP Processo 10/52210-3) sob a coordenação do Prof. Dr. Wagner Cotroni Valenti, cujo objetivo é definir indicadores e avaliar a sustentabilidade dos sistemas de produção usados na aquicultura do Brasil. A partir da aplicação desses indicadores em fazendas produtoras de lambari, poderemos avaliar a pertinência, eficácia e adequação da produção desses peixes em cada sistema de produção. Além disso, os indicadores irão mostrar um panorama da sustentabilidade de um segmento da aquicultura nacional.

Os estudos de sustentabilidade são recentes e algumas abordagens têm sido pouco exploradas pela comunidade científica devido às dificuldades metodológicas. A sustentabilidade das atividades socioeconômicas ligadas à produção de alimentos é orientada e estimulada por políticas públicas. No Brasil, programas como o ABC (Agricultura de Baixo Carbono), seguem tendências mundiais para adotar uma série de medidas tecnológicas e institucionais para reduzir o uso de carbono e emissão de gases do efeito estufa (Norse, 2012). Iniciativas como estas devem ser adotadas também para a aquicultura. Assim, o presente trabalho apresenta relevância inclusive para subsidiar a elaboração de políticas públicas para o setor produtivo. A proposta encaixa-se perfeitamente nas novas diretrizes da FAO para que a aquicultura seja desenvolvida e analisada com um enfoque ecossistêmico (Soto *et al*, 2008). Dessa maneira, sistemas de produção aquícola ecologicamente planejados e projetados se tornarão mais difundidos porque melhor se encaixam no contexto sócio ecológico de países ricos e pobres. A aquicultura ecológica fornece a base para o desenvolvimento de um novo contrato social para a aquicultura que inclua todas as partes interessadas e tomadores de decisão na conservação e restauração de recursos pesqueiros, agricultura e ecossistemas (Costa-Pierce, 2010).

A consolidação dos métodos utilizados permitirá sua aplicação nas pesquisas desenvolvidas em todos os setores da aquicultura e na avaliação do setor produtivo, auxiliando na tomada de decisões por ocasião da elaboração de políticas públicas. Assim, avaliações da sustentabilidade dos sistemas de produção podem se tornar obrigatórios para colocar os produtos aquícolas brasileiros em mercados diferenciados. Inserido neste contexto, esforços para definir indicadores e avaliar a sustentabilidade dos sistemas de produção usados na aquicultura do Brasil estão em curso.

Embora o cultivo de *A. lacustris* cresça de forma acelerada, não há estudos sobre a sustentabilidade de cada sistema de produção que permita ao produtor tomar decisões acertadas para ter uma atividade lucrativa e perene. Assim, este trabalho tem como objetivo caracterizar detalhadamente cada um desses sistemas, avaliar a sustentabilidade de cada um considerando dimensões ambientais, sociais, econômicas e institucional e compará-los.

APRESENTAÇÃO DO TRABALHO

O presente trabalho foi dividido em quatro capítulos redigidos em inglês sob a forma de artigos científicos. As normas adotadas para a redação são gerais, ainda sem direcionamento para revista específica da área. Com o intuito de caracterizar detalhadamente os sistemas de produção de lambaris no Estado de São Paulo e compará-los sobre os aspectos ambientais, sociais, econômicos e de governança, cada dimensão foi analisada de forma independente expressa em cada capítulo. No entanto, dada a importância da integração dos resultados para interpretação sobre as quatro dimensões estudadas, o último capítulo é dedicado à uma conclusão geral compilando essas informações. Vale ressaltar que devido à semelhança de objetivos de cada trabalho, há semelhanças na condução argumentativa de cada capítulo. Assim, há informações na metodologia que se repetem nos quatro artigos. O presente trabalho foi submetido à Comissão de Ética no Uso de Animais - CEUA do Instituto de Biociências das UNESP, campus do litoral São Vicente, tendo sido aprovada com o protocolo 02/2017.

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CAPÍTULO 2

ENVIRONMENTAL SUSTAINABILITY OF LAMBARI *Astyanax lacustris* PRODUCTION SYSTEMS

ENVIRONMENTAL SUSTAINABILITY OF LAMBARI *Astyanax lacustris* PRODUCTION SYSTEMS

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ABSTRACT

Lambari are small native species, with a short life cycle and easy to produce. The high market potential has instigated an increase in the lambari farms. This study aims to evaluate and compare the environmental sustainability of different lambari production systems performed in the southeast of Brazil. We have grouped the production systems in three types: low (LCS), medium (MCS) and high (HCS). Three farms for each group were analyzed. Samples of water, sediments, greenhouse gases, fish and diets were collected from the nine farms to determine indicators and indexes of environmental sustainability. The MCS showed better performance of indicators of water pollutants and use of natural resources, whereas LCSs showed better indicators of efficiency in the use of resources. The HCS had the better score for global warming potential and sediment pollutant. The high control lambari production system is the most environmentally sustainable with a final score of 0.816. This study also provides an accurate picture of the environmental conditions for Brazilian production of *Astyanax lacustris*. The combination of the set of environmental indicators chosen generated an index able to detect, identify and quantify the main aspects of lambari production systems. These indicators and index are adequate and effective tools to evaluate the environmental sustainability in aquaculture.

Key-words: greenhouse gases, set of indicators, performance scale, sustainability index

1. INTRODUCTION

Aquaculture is one of the fastest growing industries of animal protein in the world (FAO, 2016). In Brazil, aquaculture produced 562,5 tonnes in 2015 and it is expected to grow 104% by 2025 (FAO, 2016). From the freshwater species, the growth of lambari production stands out. In 2015, the production of lambari was 234 tonnes and São Paulo State, the largest producer, was responsible for 29% of the national production (IBGE, 2016). It is in an early stage of development, but has local socioeconomic relevance. The production of lambari in Brazil has been growing, mainly due to the demand for live bait for sport fishing. The main species farmed is the yellow-tailed lambari *Astyanax lacustris* (Fonseca et al. 2017). This species was previously known as *Astyanax altiparanae* (Garutti & Britski, 2000) but was recently re-described (Lucena & Soares, 2016).

Lambari are small native species, with a short life cycle making them easier to produce. Therefore, they can be bred by small scale rural or urban farms, or even in places that present environmental restrictions, such as areas around conservation centers, reservations or cities (Lopes *et al.*, 2013). Also, the combination of socioeconomic enhancement and environmental conservation using low-trophic level native small fish like lambari is an important tool to develop rural communities in Brazil (Fonseca et al., 2017). Additionally, research shows the possibility of using lambari as a source of essential fatty acids for human and animal feeding (Gonçalves *et al.*, 2014). These fish have a great potential to replace canned sardines (*Sardinella brasiliensis*) and anchovies (*Anchoviella lepidentostole*) in the snack market. This could reduce the impact on the natural populations of those species, which are only available from fisheries. Nowadays, the natural stocks of lambari are decreasing due to overfishing or pollution. Therefore, the contribution to reduce the demand for natural stocks may add value and strengthen the appreciation of lambari derived from aquaculture production (Gonçalves *et al.*, 2015). The production and market potential are large and can proliferate.

The high market potential has instigated an increase in the lambari farms. However, for a stable development, it is necessary to adopt sustainable practices. Production based solely on the current market and financial forecast, leads to systems that are not efficient or sustainable over time (Valenti *et al.*, 2010).

Sustainable aquaculture is based on the rational use of financial, natural and human resources in the production process. In this way, it is an economically viable activity, which improves the quality of life of local communities, without degrading the ecosystems in which it is introduced (Arana, 1999; Valenti, 2002). It involves three components: profitable production, conservation of the environment and social development (Valenti, 2000). Each component is essential and inseparable for the activity to be perennial.

To achieve sustainable aquaculture, it is essential to measure the sustainability of the production systems used, the management techniques and the new technologies that are being generated and adopted. The main methods used to measure the sustainability of aquaculture in the world are: Emergy Analysis, Ecological Footprint, Life Cycle Analysis, Resilience and Set of Indicators (Kimpara *et al.*, 2012). Each one has its own characteristics. The Set of Indicators give a meristic view, making it possible to analyze each part of the production system separately. Thus allowing you to locate the weaknesses and correct them. Therefore, the indicators chosen could be diversified enough to cover all facets of aquaculture. Also, they should allow the consolidation in graphs or indices combined to allow a general interpretation. The data is easier to obtain and the interpretation of the results is simple and easily understood.

Recently, set of indicators have been developed to assess the sustainability of aquaculture (EAS, 2005; Boyd *et al.* 2007, Valenti, 2008, Valenti, *et al.*, 2011 and Valenti, 2013). These are generally distributed in the environmental, social and economic dimensions. Environmental indicators are mainly focused on pollution-related aspects (e.g. nutrient concentrations in the effluent) and the efficient use of resources (e.g. efficiency in the use of nitrogen and phosphorus).

Some studies that defined or used sustainability indicators to evaluate aquaculture found in the international literature are the following: Dalsgaard *et al.* (1995), Lightfoot *et al.* (1996), Dalsgaard & Official (1997), Caffey *et al.* (2001), González *et al.* (2003), Stevenson *et al.* (2005), Boyd *et al.* (2007), Pullin *et al.* (2007), Tipraqsa *et al.* (2007), Dey *et al.* (2007), Bergquist (2007), Evad (2008), Kimpara *et al.* (2012). In Brazil, the research group of the Crustacean Sector of CAUNESP has been working on the development of indicators for several years

(Valenti, 2008; Valenti *et al.*, 2011). From the application of these indicators to lambari farms, we will be able to evaluate the pertinence, effectiveness and adequacy of fish production in each production system. In addition, the indicators will show an overview of the sustainability of a national aquaculture segment.

Sustainability studies are new and some approaches have not been adequately explored by the scientific community due to methodological difficulties. This proposal is designed to follow the new FAO guideline for aquaculture which states that research must be developed and analyzed with an ecosystem approach. The consolidation of the methods used will allow its application for further research in all sectors of aquaculture and in the evaluation of the sector, supporting the decision making process in the elaboration of public policies. Thus, evaluations of the sustainability of production systems may become obligatory to place Brazilian aquaculture products in differentiated markets.

Although cultivation of *A. lacustris* is growing rapidly, there are no studies about environmental sustainability of each production system which allow the producer to make the right decisions to build a perennial business. Thus, this study aims to evaluate the environmental sustainability of each lambari production system of São Paulo State in order to compare them; also, identify which system uses less resources, is more efficient in converting natural resources into biomass and releases less pollutants into the environment; Moreover, check which system is the most appropriate to avoid the increase of the greenhouse effect. With these answers, we show the strengths and weaknesses and point out possible solutions. In addition, evaluate the adequacy of sustainability indicators to compare different systems of aquaculture production.

2. MATERIALS AND METHODS

2.1. FARM SELECTIONS

The culture of the yellow-tail lambari, *Astyanax lacustris*, have been performed using different technological procedures, based on farmer’s empirical practices and previous experiences with other species (Silva *et al.*, 2011a; Fonseca *et al*., 2017). Management strategies differ between farms (Fonseca *et al*., 2017). Thus, we grouped the systems according to the level of control of the stocking and general management practices adopted by farmers:

• Low control systems (LCS): it is a continuous production system, with a minimalistic approach. The males and females are stored in ponds, where all phases of production occur: reproduction, hatching of the larvae and development of the fingerlings until the stage of commercialization. Feeding are supplied 2 times a day with a single kind of extruded commercial diet, grounded to provide smaller pellets. The harvest and sale starts when fish are larger than 5 cm and the breeding fish is offered as a larger bait. The producer's control of stocking density, water quality monitoring, fertilization and intervention level are minimal.

• Medium control systems (MCS): farmers can use the hormonal maturation-induction technique, but applied directly in the breeding fish for spawning inside the ponds. The amount of larvae released by females inside the ponds is unknown. Eventually, these farmers maintain business relationships with hatchery owners for the acquisition of young forms. This is a production control improvement that sets the stocking density of 20/m² until they reach 7 cm for sales. Also, fertilization with poultry manure and diversified feeding 3 times daily are performed. A high protein level powder is provided for the first 30 days of the beginning of the cycle and commercial extruded feed for the rest of the grow-out phase.

• High control systems (HCS): requires a laboratory for inducing spawning and the farmers can quantify the larvae before populating the ponds. The breeding fish are kept in their separated ponds with a density up to 3/m². Reproduction is performed in a laboratory, induced with 6 mg/kg of carp pituitary extract. The eggs are placed in conical incubators for 4 days until the hatched larvae absorb the yolk sac. Then, post-larvae are transferred to fertilized ponds at the average density of 250/m². After 30 days the fish are transferred to other ponds at the average density of 50/m². The farmers have knowledge about water quality monitoring, feeding, liming and fertilization. Poultry manure, chemical fertilizers, urea and rice bran are used for fertilization of the ponds. Feed is provided 3 times a day at all stages. For the beginning of the grow-out phase, a 56% of protein powder diet is provided for the first 30 days. Afterwards, a 3mm pellet and 32% of protein commercial extruded feed is offered for the rest of the grow-out phase. The fish are stocked in ponds in a 120-day grow-out cycle and the farmers access diversified markets to sell 5 to 12 cm lambari.

In the present study, none of the farmers used nurseries. Sportfishing target species has different seasons and its market specificities guides the farmers about the current demand for bait size. Thus, the grow-out period may vary to produce larger or smaller lambari planned to match the season. The replicate technique from nurseries can be adopted by MCS and HCS to control the stocking density in the ponds to reach the lambari size faster according to the market needs.

Initially, we located the farmers of the State of São Paulo based on information from the official State extension and research institutions The farmers were classified according to the three systems described above. We contacted them and three more representative farms of each system were chosen to carry out the work. The productive area of each selected farm are 1.47, 0.85 and 1.5 hectare for LCS, 2.0, 6.2 and 2.5 hectares for MCS and 1.2, 200 and 1.0 hectares for HCS (Figure 1).

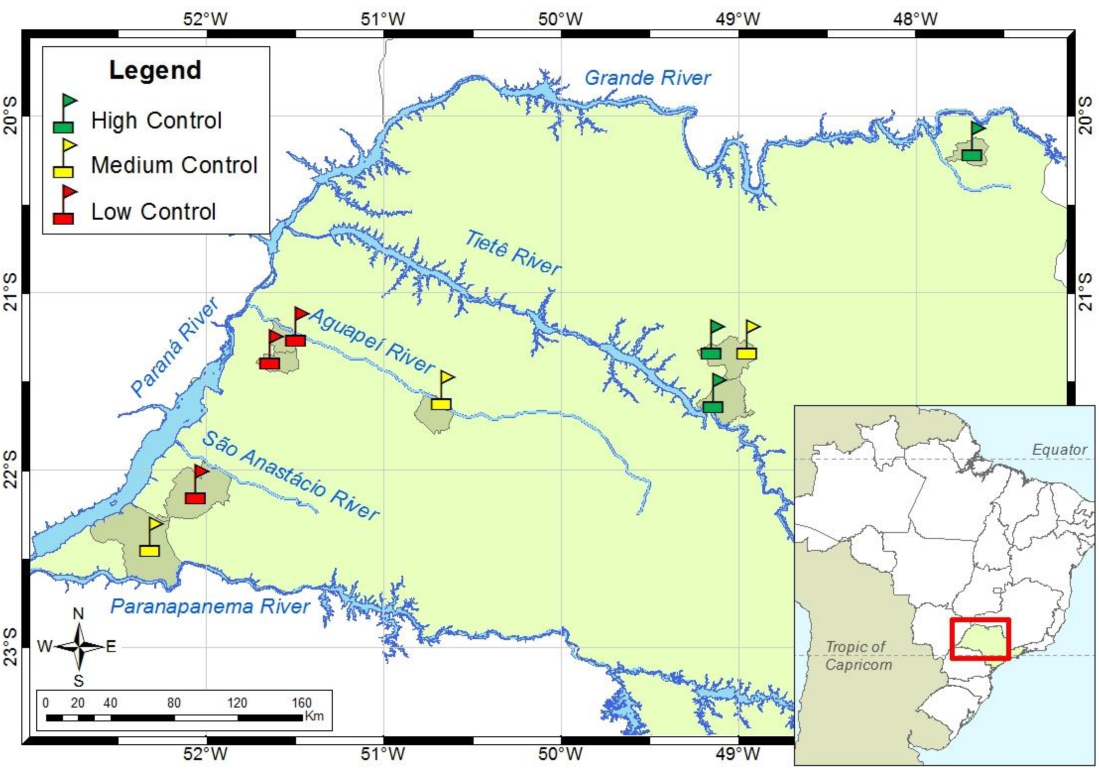


Figure 1 – Location and classification of the selected lambari farms in São Paulo State.

2.2. EXPERIMENTAL DESIGN

We have analyzed the factor production system, with three levels (husbandry types) and three replicates for each level (each farm). We visited each of the nine farms at the beginning and end of the production cycle to obtain the data to calculate the indicators of environmental sustainability. We collected samples of inlet and pond water, effluents, greenhouse gases (CO_2, CH_4, N_2O) emitted and absorbed, sediment accumulated inside the ponds, diet and fish from the beginning (first 30 days) and end (last 90 days) stages of the 120-day grow-out phase. Samples were collected in one pond of each farm; thus, we have obtained three samples of each production system in each phase. These are true replicates because we obtained them from different farms and not from different ponds in the same farm (pseudo replicates). The materials collected were processed by analytical equipment at the Sustainable Aquaculture Laboratory of the Aquaculture Center of Sao Paulo State University - UNESP, at the coastal campus of Sao Vicente, São Paulo.

2.3. ENVIRONMENTAL SUSTAINABILITY

The environmental sustainability analysis was carried out based on the method of the indicators described in EAS (2005), Boyd *et al.* (2007), EVAD (2008), Valenti (2008) and Valenti *et al.* (2011). The indicators used are showed in Table 1, grouped into categories they represent. The use of natural resources was evaluated by indicators that quantify energy, nitrogen, phosphorus, carbon and the area used to produce each tonne of lambari (Boyd *et al.*, 2007; Valenti, 2008; Valenti *et al.*, 2011). The efficiency of resource use was evaluated by indicators that measure the proportion of nitrogen, phosphorus, carbon and energy incorporated in the biomass of the animals (Boyd *et al.*, 2007; Valenti, 2008). The release of pollutants has been measured by means of indicators measuring the nitrogen, phosphorus and organic matter released to the environment in liquid effluents and accumulated in sediment, and the greenhouse gases in carbon dioxide equivalents (CO_2e.) released into the atmosphere to the unit of production (EAS, 2005, Boyd *et al.*, 2007, Valenti, 2008, Valenti *et al.*, 2011). The conservation of genetic diversity and risk for local biodiversity was analyzed from different categories of cultivated animals, to which arbitrary values were assigned: 1 = Local strain in an open or closed system; 2 = Species of the same basin in a closed system; 3 = Species of the same basin in an open system; 4 = Allochthones species, local species with reduced genetic variability, or hybrids (of local or allochthones species) in a closed system; 5 = Allochthones species, local species with reduced genetic variability, or hybrids (of local or allochthones species) in an open system; 6 = Transgenic variety of any species in a closed system; 8 = Transgenic variety of any species in an open system.

Table 1 - Environmental sustainability indicators used to assess lambari *Astyanax lacustris* production systems in Sao Paulo State, Brazil.

Category	Indicator	Formula
Use of natural resources	Use of space (S)	S = used area / total production
	Water dependence (Wd)	Wd = used volume / total production
	Energy use (Eu)	Eu = applied energy / total production
	Nutrients use (C, N e P)	N = mass of applied nutrients / total production
Efficiency in use of resources	Efficiency in energy use (EEU)	EEU = recovered energy in the production / applied energy
	Effectively used production (EUP)	EUP = mass of consumed lambari / total mass
	Potential of nutrient retention (PCR, PNR and PPR) - carbon, nitrogen and phosphorus accumulated in lambari	PNR = mass of nutrients in the lambari / total production
	Efficiency in nutrients use (ECU, ENU e EPU)	ENU = mass of nutrients in the lambari / mass of applied nutrients
Release of pollutants and unused by-products	Eutrophic potential (PEN and PEP) - nitrogen and phosphorus loading released into the water	EP = mass of released nutrients in the effluent / total production
	Organic pollution potential (OPP) - organic carbon load released into water	OPP = mass of organic matter released in the effluent / total production
	Potential of sedimentation (PS)	PS = Suspended material load = mass of suspended material released into the effluent / mass of fish produced;
	Global warming potential (GWP) - load of greenhouse gases released into the atmosphere	GWP = mass of CO_2+CH_4+N_2O (CO_2 equivalent) released to atmosphere / total production
	Acidification potential	PA = Sulphide + Sulphate load applied / mass of fish produced
	Nutrient accumulation (PA and NA) - accumulated phosphorus and nitrogen loads in the sediment	NA = mass of nutrients in the sediments / total production
	Organic matter accumulation (OMA) - organic carbon loading accumulated in the sediment	OMA = mass of organic carbon in the sediments / total production
	Particulate matter accumulation (PMA) - Load of accumulated particulate material in sediment	PMA = mass of Particulate matter in the sediment / total production
Conservation of genetic diversity and biodiversity	Risk of cultivated species (RCS) - increasing levels of impact according to the organism cultivated	RCS = {1, 2, 3, 4, 5, 6 or 8}

The data required to calculate the environmental sustainability indicators were obtained by the methods described below.

The biomass of the stocked fish were determined by weighing samples of the beginning and end of the cycle. After the end of grow-out phase, the final average mass was calculated for each system. Information of the pond areas, survival rate, and productivity from the farmers were obtained. The loads of total organic carbon (total dissolved carbon + particulate organic carbon), methane, carbon dioxide, nitrous oxide, total suspended solids, total nitrogen and phosphorus, and energy were measured for water, gases, sediments, lambari, diets and poultry manure. The water usage were calculated considering the time to fill the pond based on the flow rate and daily water exchange rate to determine the inlet, accumulated, outlet water and the volume of each sampled pond. The energy applied in each production system were calculated by summing the energy value spent by the fuels consumption for sales and delivery of the fish, human labor, the electricity spent during the grow-out period, the produced lambari and diets provided. We adopted the values of 34,704 kJ spent per liter of fuel and 2,093 kJ per worked hour for the calorific value spent by the labor, being this value equivalent to heavy work in industrial activities and approximate to the energy consumption in food by the worker (Mello, 1989). The electricity inputs considered when occurred were lights, hydraulic pumps, aeration for laboratory and aerators for fish ponds. Also, the contents of total organic carbon, nitrogen and phosphorus and energy in each biosystem compartment were determined to obtain the values necessary to calculate the indicators, as described below.

A) Lambari and diet:

At the beginning and end of grow-out phase, a sample of 5 to 20 animals and 20 g of diet were collected and weighed for determination of the initial fish mass, the final average individual mass, carbon, nitrogen, phosphorus and energy contents. Samples were kept in a drying oven with forced circulation at 60° C for 48 h until the weight was constant. They were then weighed, grounded up, transferred to plastic tubes and stored in a freezer until analysis. Carbon and nitrogen contents were determined on a CHNS elementar analyzer (Vario Macro Cube, Elementar®) by high temperature combustion, with conversion of the sample into gases and detection by a TCD (Thermal Conductivity Detector) sensor. For the analysis of phosphorus, the samples were submitted to reaction with magnesium nitrate, nitric acid, ammonium hydroxide, acidified molybdate solution, followed by filtration and titration with nitric acid (AOAC, 1995 - method 969.31 A) and spectrophotometer reading (Shimadzu UV 1800®). The energy contained in the fish was evaluated by automatic calorimetric combustion (C-2000, IKA®) and the results are expressed as KJ/g DM (DM = dry mass).

B) In water:

Samples of inlet and accumulated water in the ponds and effluent water were collected at the beginning and end of the grow-out period for the determination of total suspended solids, total carbon, total nitrogen and total phosphorus. Total suspended solids were measured according to APHA (2005 - method 2540 D). This method consists of filtering a known volume through a Whatman GF/F glass fiber filter and subjecting them to oven drying at 103-105° C. Carbon and total nitrogen were determined by catalytic combustion oxidation using a Vario TOC Select (Elementar®). For the determination of total phosphorus, the samples were submitted to a previous digestion, according to the persulfate digestion method (APHA, 2005 - method 4500-P B5), in order that the compounds associated with the organic matter are released as orthophosphate. Later, the orthophosphate was measured by the method of starch chloride (APHA, 2005 - method 4500-P D), using a digital spectrophotometer (Shimadzu UV 1800®).

C) In the sediment:

The sediment generated in the ponds were measured with the installation of tripton samplers. These were made with six 1.876 L PVC tubes, with 9.7 cm diameter and 25.4 cm long that covers a 450 cm² area. Two collections were performed, in the initial and final phase of the grow-out period. Each sediment sample was weighed and the values of dry weight, carbon content, total nitrogen, total phosphorus and energy were obtained. The dry matter was determined by drying at 95-100°C according to the methodology described in AOAC (1995, method 934.01). The total carbon and nitrogen content were evaluated according to the methodology described for lambari in item "A". Total phosphorus was determined according to the metavanadate colorimetry method applied on samples previously incinerated in the muffle for four hours at 550 ° C (Michelsen, 1957). The mass of sediments obtained in the tripton sampler area were extrapolated for the pond areas of each farm for the grow-out period.

D) In the gases

The release of CO_2, CH_4 and N_2O into the atmosphere can occur by bubbling and emanation, i.e. diffusion gas exchanges at the water-air interface (Matvienko *et al.*, 2000). To capture the bubbles, funnels suspended by floats were installed on the surface of the pond. The funnel has 36 cm of diameter, by 35 cm of height. At the end of the funnel, a 250 mL bottle was connected, where the bubbles were retained over the course of 24 hours. After this period, the containers were taken to the laboratory for chromatographic analysis. The diffusion at the water-air interface were evaluated by the equilibrium method, in which confined portions of air are allowed to partially equilibrate with the gas dissolved in water for periods of 0, 1, 2 and 4 minutes using diffusion chamber. Then, these portions of air (samples) were conditioned in 12 mL gasometrical borosilicate vials (LABCO) for later analysis by gas chromatography. The amount of CO_2, CH_4 and N_2O were determined by means of a gas chromatograph with TCD detector - Shimadzu GC-2014® and ECD-Eletron Captor Detector.

2.4. DATA ANALYSIS

Each indicator was analyzed between treatments using One-Way ANOVA followed by Tukey as the post-hoc test. Arcsine transformation was used on the data when it was in percentages. The obtained variables were compared between systems by multivariate exploratory data analysis. Data were standardized to perform Cluster (using Euclidean distance and UPGMA - Unweighted Pair Group Method using Arithmetic averages) and Principal Components Analysis (PCA).

Each indicator was converted into a performance scale (Bellen, 2008, Valenti, 2008), with scores ranging from 0 to 1 and expressed in multidimensional diagrams. The treatment with the best indicator value (more sustainable when compared to the others) was arbitrarily scored as 1, and the others were determined by proportion. Thus, the indicators were grouped into 6 categories:

(a) Use of resources; (b) Efficiency of resources use; (c) Water pollutants; (d) Sediment pollutants; (e) Greenhouse gases emissions; (f) Conservation of genetic diversity and biodiversity. A sustainability sub-index was computed for each category by the average of their respective indicators. Only the category (e) and (f) represents the value of its unique indicator. The Environmental Sustainability Index was determined by the average of the 6 sub-indicators for each system. The environmental indicators of the lambari production systems were classified by how sustainable they are according to the range of the performance scale (Valenti, 2008) as shown in Table 2.

Table 2 – Performance scale used in the classification of sustainability for the lambari production systems of Sao Paulo State.

Range	Classification
0.000 - 0.200	Not sustainable
0.201 - 0.400	Low sustainability
0.401 - 0.600	Medium sustainability
0.601 - 0.800	Potentially sustainable
0.801 - 1.000	Sustainable

Adapted from Valenti (2008)

3. RESULTS

The management strategies observed for lambari production systems are summarized in Table 3. These production factors and features also describes in detail the status of the production systems studied. In terms of productive efficiency, the MCS and HCS presented better FCR and larger productivity. The survival rate is unknown in the LCS and also for some crops of MCS. When the MCS obtain young forms from hatcheries, this production system present higher survivor rate then HCS due its smaller productive area able to invest in anti-bird net.

Table 3 – Production factors and management practices of lambari *Astyanax lacustris* production systems.

Production factors	LCS	MCS	HCS
Reproduction/Hatchery	Natural without control	Induced in the pond	Induced and controlled in lab
Production period (days)	120	120	120
Crops/year	3	3	3
Total pond area (ha)	0.85 - 1.50	1.50 - 6.20	1.05 - 200
Fertilization regime	Poultry manure	Poultry manure	Poultry manure; Chemical fertilizer
Stocking seed	larvae	larvae	fry
Stocking density - Beginning	N/A	N/A-250[a]	250
Stocking density - Grow-out[b]	9	17-25	30
Water exchange (%/day)	3.7	7.0	5.8
Diet protein content (%)	28	56-32	56-32
Feeding frequency	2/day	3/day	3/day
Feed conversion ratio (FCR)	1.83	2.02	1.57
Survival (%)[c]	N/A	N/A-67[a]	56
Final fish length (cm)[f]	8	9.33	9.66
Final fish weight (g)[f]	10	16	18
Sale price (US$[e]/unit)	0.07	0.08	0.08
Sale price (US$[e]/Kg[f])	6.98	5.52	5.42
Productivity (t/ha)	1.8	6.09	6.94

[a] In case young forms origins from hatchery
[b] Estimated though the declared production obtained by interview
[c] Estimated though the declared initial stocking density
[d] The final fish size is dependent to the farm location to access different sport fishing targets
[e] US$ 1.00 = R$ 3.20, Feb, 2017
[f] Converted considering the price by unit and final weight of fish

The concentration of nutrients in water and comparisons among the studied systems are shown in Table 4. The LCS presented high values that differ from the HCS for nitrogen and dissolved organic carbon concentration in the inlet at the beginning of the cycle. At the end of the cycle, the higher concentration of dissolved organic carbon for the accumulated water in the pond differs the LCS from MCS and HCS. In the beginning of the cycle, the average concentrations of nutrients are lower for inlet and higher for outlet water. The exception is the suspended solids for LCS that showed lower concentration in the outlet water as compared to the inlet water. In the end of the cycle, concentrations of nutrients are higher than at the beginning of the cycle. However, a few exceptions like the nitrogen concentration in the end of the cycle of LCS, showed lower concentration in outlet water than inlet water.

Table 4 - Variation of the concentration of nitrogen (mg/L), phosphorus (µg/L), dissolved organic carbon (mg/L) and suspended solids (mg/L) in water throughout the beginning and end of the cycle of different production systems of lambari *Astyanax lacustris* of São Paulo State, Brazil. Values are represented by mean ± standard deviation. Different letters in the same line indicate significant differences between treatments (P<0.05) for the respective period of the cycle (lower case letters for the beginning and upper case letter for the end). The absence of letters means that there is no difference to the respective item.

Nutrient	Water	LCS		MCS		HCS	
		Beginning	End	Beginning	End	Beginning	End
Nitrogen	Inlet	0.98 ± 0.18[a]	1.73 ± 0.40	0.77± 0.15 [ab]	0.53 ± 0.35	0.51 ± 0.10 [b]	1.46 ± 1.84
	Pond	1.16 ± 0.51	1.81 ± 0.54	0.82 ± 0.33	1.02 ± 0.45	1.09 ± 0.16	1.03 ± 0.07
	Outlet	1.25 ± 0.67	1.71 ± 0.51	1.02 ± 0.10	0.82 ± 0.32	0.95 ± 0.15	1.81 ± 1.18
Phosphorus	Inlet	0.05 ± 0.03	0.17 ± 0.09	0.14 ± 0.08	0.06 ± 0.05	0.10 ± 0.09	0.19 ± 0.18
	Pond	0.14 ± 0.10	0.25 ± 0.21	0.14 ± 0.05	0.22 ± 0.08	0.22 ± 0.05	0.33 ± 0.02
	Outlet	0.16 ± 0.13	0.20 ± 0.10	0.24 ± 0.15	0.20 ± 0.02	0.60 ± 0.39	0.23 ± 0.09
Dissolved Organic Carbon	Inlet	4.71 ± 1.17[a]	6.88 ± 2.00	2.74 ± 0.72[ab]	2.20 ± 0.39	2.27 ± 0.72[b]	5.71 ± 6.36
	Pond	4.95 ± 2.17	7.35 ± 2.36[x]	2.97 ± 0.70	3.05 ± 1.06[y]	3.65 ± 1.03	3.26 ± 0.54 [y]
	Outlet	4.93 ± 2.06	7.33 ± 2.29	3.40 ± 1.02	2.83 ± 0.63	3.29 ± 0.88	6.41 ± 4.60
Suspended Solids	Inlet	107.0±156.1	39.1±6.6	30.2±18.1	20.7±14.9	22.5±14.5	59.9±82.1
	Pond	147.4±197.2	200.6±271.7	29.5±14.0	56.5±21.1	49.6±50.7	59.0±51.8
	Outlet	70.8±61.1	204.3±268.4	37.7±11.0	74.3±52.9	150.4±208.0	41.2±31.2

The average values of sedimentation rate were seven times larger in the LCS, as compared to MCS and 4.8 times larger than the HCS (Table 5). One LCS farm presented larger sediment accumulation in its ponds increasing the standard deviation, especially in beginning of the cycle. On the other hand, the average concentration of nutrients in the sediment was lower in LCS compared to the HCS.

Table 5 – Variation of sedimentation rate (g/m²/day), nitrogen concentration (%), phosphorus (%), carbon (%) and sulfur (%) in sediment material throughout the beginning and end of the cycle of different production systems of lambari *Astyanax lacustris* of São Paulo State, Brazil. Values are represented by mean ± standard deviation. Different letters in the same line indicate significant differences between treatments (P<0.05) for the respective period of the cycle (lower case letters for the beginning and upper case letter for the end). The absence of letters means that there is no difference to the respective item.

	LCS		MCS		HCS	
	Beginning	End	Beginning	End	Beginning	End
Sedimentation rate	722±1382	198±251	101±102	206±208	150±212	113±68
Nitrogen	0.79±0.21	0.88±0.49	1.09±0.45	0.80±0.29	1.04±0.43	1.09±0.36
Phosphorus	0.16±0.03	0.20±0.12	0.57±0.28	0.33±0.15	0.50±0.34	0.28±0.11
Carbon	6.35±1.68	6.85±2.42	8.41±4.05	6.05±2.84	7.55±3.75	14.97±8.49
Sulfur	0.59±0.23	0.56±0.15	1.22±1.28	0.78±0.55	0.97±0.35	3.08±2.71

The beginning and end of cycle of LCS and the end of cycle of HCS showed negative results for diffusion gas exchanges at the water-air interface (Table 6). This demonstrated an absorption of carbon dioxide equivalents by the average proportion between day and night transfer rates of greenhouse gases. Bubbling emissions were higher in the MCS. Also, the HCS carbon dioxide bubble emanation rate differs from MCS rate for the beginning of the cycle.

Table 6 - Variation of the transfer rates of greenhouse gases (mg/m²/day) throughout the beginning and end of the cycle of different production systems of lambari *Astyanax lacustris* of São Paulo State, Brazil. Values are represented by mean ± standard deviation. CH_4 = methane; CO_2 = carbon dioxide; N_2O = nitrous oxide. Different letters in the same line indicate significant differences between treatments ($P<0.05$) for the respective period of the cycle (lower case letters for the beginning and upper case letter for the end). The absence of letters means that there is no difference to the respective item.

Source	GHG	LCS		MCS		HCS	
		Beginning	End	Beginning	End	Beginning	End
Diffusion	CO_2	-2577±2328	109±1382	1126±825	1112±3351	-109±1575	-1010±1411
	CH_4	116.15*	5.49*	51.41±91.39	-45.75±35.18	56.54±90.34	79±126
	N_2O	-53±115	-39±385	105±160	4.71±1010	555±1044	-72*
	CO_2e	-17231	-11973	34905	1611	173217	-6805
Bubble Emanation	CO_2	2.30±1.45^{ab}	1.70±2.14	7.04±7.31^{a}	2.31±2.02	0.59±0.73^{b}	0.37±0.59
	CH_4	0.50±1.00	2.32±2.99	1.55±2.24	4.42±3.96	0.84±2.20	0.91±1.91
	N_2O	0.12±0.23	0.09±0.05	0.17±0.13	0.07±0.08	0.04±0.02	0.05±0.07
	CO_2e	50.07	78.65	91.40	115.73	31.31	34.60

Negative values represent absorption
* Loss of replicates

The concentration of nitrogen, carbon, phosphorus, sulfur and also energy from the body composition of the lambari are expressed in Table 7. The beginning of the cycle the LCS fish differ from MCS and HCS in the nitrogen composition. The LCS produces lambari with a final average weight of 10 g, the MCS 16 g and the HCS 18 g. Thus, some results of body composition could vary according to the size of sampled fish.

Table 7 - Variation of nitrogen (%), carbon (%), phosphorus (%), sulfur (%) and energy (MJ/kg) concentrations in the animals at the beginning and end of the cycle of different production systems of lambari *Astyanax lacustris* of São Paulo State, Brazil. Values are represented by mean ± standard deviation. Different letters in the same line indicate significant differences between treatments (P<0.05) for the respective period of the cycle lower case letters for the beginning and Upper case letter for the end). The absence of letters means that there is no difference to the respective item.

	LCS		MCS		HCS	
Lambari	Beginning	End	Beginning	End	Beginning	End
Nitrogen	7.27±0.12[a]	8.75±1.55	9.28±0.75[b]	8.31±0.48	10.68±0.46[b]	9.48±1.44
Phosphorus	3.86±0.15	3.86±0.07	3.43±0.53	3.84±0.02	3.95*	3.86±0.12
Carbon	42.82±0.62	39.12±7.21	47.40±5.16	42.46±4.30	43.53±0.67	46.65±2.57
Sulfur	0.64±0.21	0.84±0.10	1.21±0.60	1.24±0.65	1.47±0.20	1.51±0.20
Energy	20.45±2.37	20.79±3.16	24.24±0.75	22.69±0.85	20.64±0.14	22.16±2.08

* Loss of replicates

The concentration of nitrogen of the diets used by the farmers were different between production systems. The LCS differed from MCS and HCS with lower values in the beginning of the cycle. In the end of the cycle, the LCS differ with lower level just from the HCS (Table 8). The LCS used just one kind of diet during the entire cycle, while the MCS and HCS varied the diet according to the stage of development.

Table 8 – Variation of nitrogen (%), carbon (%), phosphorus (%), sulfur (%) and energy (MJ/kg) concentrations in the provided diet at the beginning and end of the cycle of different production systems of lambari *Astyanax lacustris* of São Paulo State, Brazil. Values are represented by mean ± standard deviation. Different letters in the same line indicate significant differences between treatments (P<0.05) for the respective period of the cycle lower case letters for the beginning and upper case letter for the end). The absence of letters means that there is no difference to the respective item.

	LCS		MCS		HCS	
Diet	Beginning	End	Beginning	End	Beginning	End
Nitrogen	5.14±0.62[a]	5.14±0.62[A]	8.51±0.14[b]	6.23±1.01[AB]	8.43±0.12[b]	7.45±1.04[B]
Phosphorus	3.65±0.04	3.65±0.04	2.82±1.83	2.97±1.07	3.64±0.17	3.20±0.26
Carbon	40.21±0.66	40.21±0.66	45.19±6.48	42.72±2.53	41.92±2.43	51.78±12.17
Sulfur	2.63±0.94	2.63±0.94	3.59±1.22	3.26±1.22	4.36±0.53	2.32±0.80
Energy	16.44±0.97	20.79±0.97	17.95±3.55	17.93±1.23	18.45±0.46	18.66±0.46

The annual values of the environmental variables contented in Table 9 were calculated per area (hectare). The productivity of the LCS was more than three times lower than the other systems. On the other hand, the load of nutrients in the water was higher for the MCS and HCS. The average rate of Greenhouse gases was negative in the LCS and HCS, revealing absorption of carbon dioxide equivalents per hectare.

Table 9 - Total annual values of the variables used to calculate the indicators of environmental sustainability of different production systems of lambari *Astyanax lacustris* of São Paulo State, Brazil. Values are represented by mean ± standard deviation. Different letters in the same line indicate significant differences between treatments (P<0.05). The absence of letters means that there is no difference to the respective item.

Variable	LCS	MCS	HCS
Area used (ha)	1.27±0.37	3.57±2.29	67.42±114.82
Energy applied (MJ/year/ha)*	141.5±86.9	670.2±289.0	1901.0±2144.8
Total production (t/ha)	1.80±1.06	6.09±2.57	6.94±4.40
Energy recovered (MJ/year/ha)*	50.8±43.0	161392±76266	173745±122326
Unconsumed mass (t/ha)	0.00±0.00	0.00±0.00	0.00±0.00
Nitrogen in water (t/ha)	2.40±0.99	7.25±7.80	47.06±78.60
Phosphorus in water (t/ha)	0.33±0.31	1.08±0.76	13.79±23.15
Organic carbon in water (t/ha)	7.05±5.05	18.71±15.67	142.58±237.00
Total carbon in water (t/ha)	15.17±3.61	39.54±35.45	245.90±408.41
Greenhouse gases (t/ha CO_2e)	-47.59±344.98	36.14±793.07	-25.62±50.20
Organic carbon in sediment (t/ha)	224.72±216.57	118.61±82.01	243.22±176.96
Particulate matter in the sediment (t/ha)*	2373.5±3999.5	218.4±206.3	329.6±286.5
Nitrogen in sediment (t/ha)	26.17±22.76	14.92±9.81	21.13±8.47
Phosphorus in sediment (t/ha)	0.55±0.51	0.63±0.46	0.35±0.30
Nitrogen in adult fish (kg/ha)	87.51±75.13	278.88±107.62	358.04±197.99
Phosphorus in adult fish (kg/ha)	38.82±29.76	131.20±55.90	148.60±90.11
Organic carbon in adult fish (kg/ha)	363.26±275.07	1406.88±502.36	1812.10±1157.74
Phosphorus in fingerlings (kg/ha)	2.02±1.60	2.73±0.77	5.30**
Nitrogen in fingerlings (kg/ha)	38.91±32.28	72.37±7.93	63.25±70.46
Organic carbon in fingerlings (kg/ha)	229.17±189.82	375.26±89.10	258.61±291.39

* Multiply by 1000
** Loss of replicates

The environmental sustainability indicators are divided in categories (Table 10). The LCS differ from MCS and HCS for the indicators use of space, water dependence, reflecting lower productivity. However, LCS present better values for phosphorus retention potential, differing from MCS and HCS. The load of the nutrients nitrogen and phosphorus released as the effluents to produce 1 tonne of lambari was up to six times higher in the HCS compared with the LCS. The HCS had a lower impact on global warming due to a lower emission of greenhouse gases per production units. For sediment, the LCS had the highest average rates of nitrogen, phosphorus, carbon and particulate matter. Also, the LCS presented high levels for acidification potential from the concentration of sulfur from solid samples.

Table 10 - Indicators of environmental sustainability of different production systems of lambari *Astyanax lacustris* of São Paulo State, Brazil. Values are represented by mean ± standard deviation. Different letters in the same line indicate significant differences between treatments (P<0.05). The absence of letters means that there is no difference to the respective item.

Indicators	LCS	MCS	HCS
Use of natural resources			
Use of Space (m^2/kg)	6.8±3.3[a]	1.9±1.1[b]	1.8±0.9[b]
Use of Space (ha/t)	0.68±0.33[a]	0.19±0.11[b]	0.18±0.09[b]
Water Dependence (m^3/kg)	34.2±4.2[a]	10.2±5.2[b]	8.7±5.0[b]
Energy use (MJ/t)*	107±28.3	164±106	370±472
Carbon use (t/t)	11.07±6.30	7.43±5.15	58.90±98.43
Nitrogen use (t/t)	1.85±1.37	1.26±0.91	11.27±18.96
Phosphorus use (t/t)	0.32±0.35	0.24±0.14	3.31±5.54
Efficiency in the use of resources			
Efficiency in energy use (%)	12.93±21.98	0.31±0.27	0.28±0.26
Retention potential - C (kg/t)	137.1±89.9	69.7±35.2	119.8±103.0
Retention potential - N (kg/t)	52.2±35.4	41.1±6.0	44.7±8.2
Retention potential - P (kg/t)	1.36±0.35[a]	0.20±0.15[b]	0.21±0.21[b]
Efficiency of Carbon use (%)	2.24±2.67	2.31±3.07	6.06±5.60
Efficiency of Nitrogen use (%)	6.75±8.53	7.39±8.58	10.18±9.91
Efficiency of Phosphorus use (%)	0.80±0.53	0.11±0.09	0.18±0.18
Production actually used (%)	100±0	100±0	100±0
Release of pollutants and unused by-products			
Eutrophication potential - N (kg/t)	2.12±2.09	1.17±0.71	0.90±0.23
Eutrophication potential - P (kg/t)	16.33±11.69	6.37±5.60	7.72±9.74
Siltation potential (t/t)	2.79±3.44	0.25±0.19	0.25±0.20
Global warming potential (tCO_2e/t)	42.6±242.5	51.8±174.0	33.3±63.3
Organic pollution potential (kg/t)	67.2±46.5	18.6±12.7	28.5±37.7
Acidification potential (kg/t)	25.99±22.76	6.25±3.14	10.47±6.40
Nitrogen accumulation (kg/t)	22.68±25.55	2.48±1.02	4.16±2.72
Phosphorus accumulation (kg/t)	0.26±0.22	0.10±0.04	0.06±0.07
Organic Matter accumulation (t/t)*	100±162	6.19±5.65	17.95±22.94
Particulate Matter accumulation (t/t)*	810±1317	31.4±23.7	71±82
Conservation of genetic diversity and biodiversity			
Risk of Cultivated Species	1	1	1

* Multiply by 1000

The cluster analysis did not recovered the groups defined a priori for the production systems (Figure 2). However, partial groups can be observed for MCS and LCS.

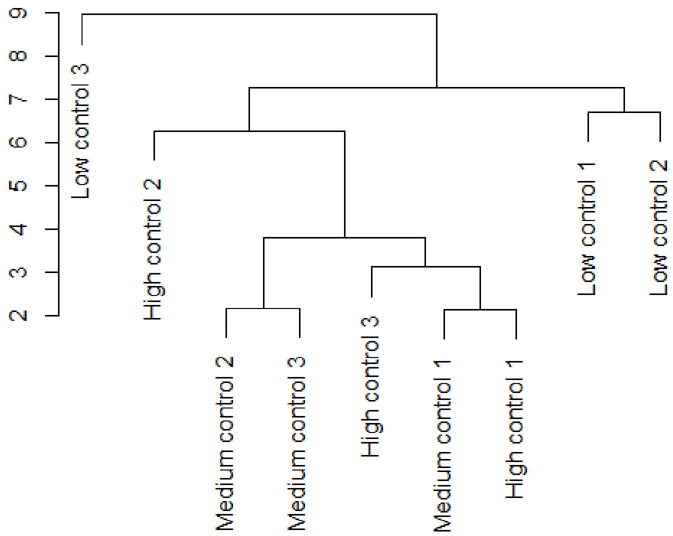


Figure 2. Dendrogram of dissimilarity of environmental sustainability indicators of lambari production systems (Euclidean distance)

The environmental sustainability indicators submitted to the Principal Components Analysis (PCA) are not able to show which components could generate patterns for clustering of cohesive groups (Figure 3).

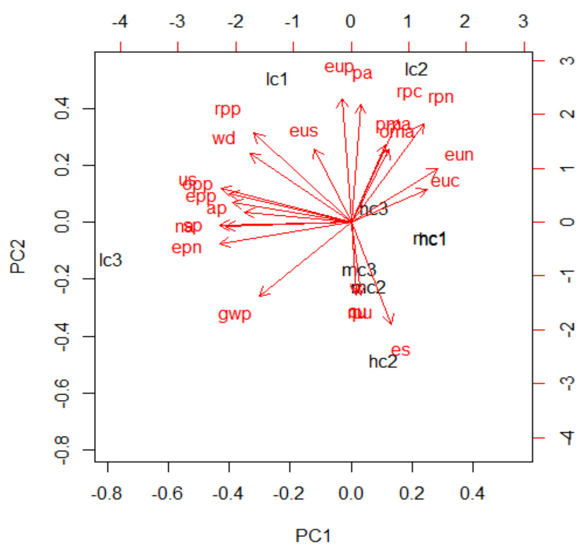
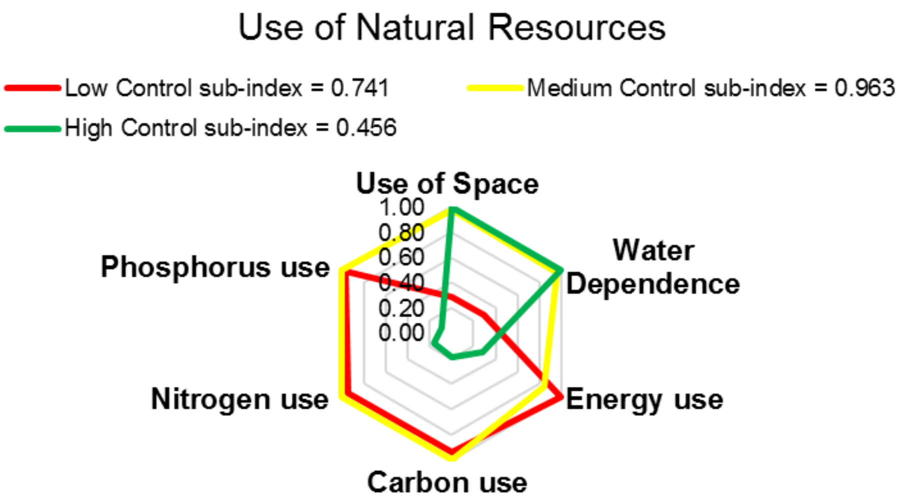


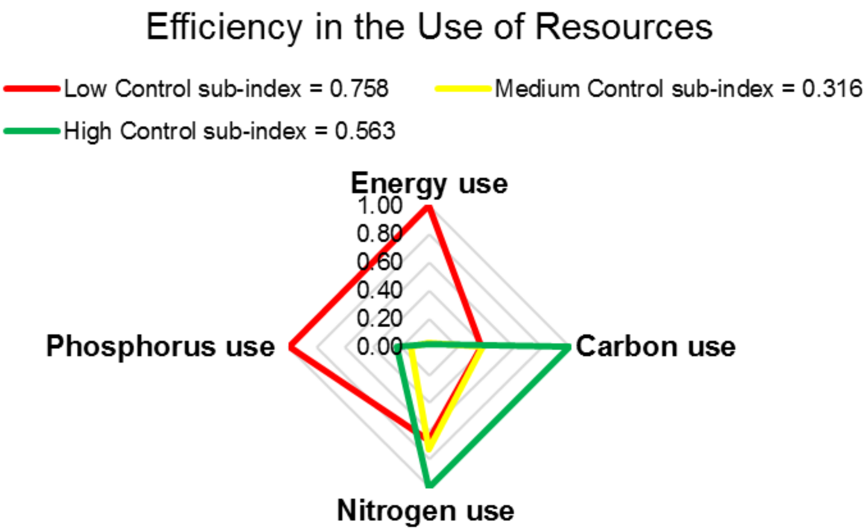
Figure 3. Principal components Analysis (PCA) for environmental sustainability indicators of lambari production systems in São Paulo State. lc=low control; mc=medium control; hc=high control; us=use of space; wd=water dependence; eu=energy use; cu=carbon use; nu=nitrogen use; pu= phosphorus use; eue=efficiency in the use of energy; rpc=retention potential – c; rpn=retention potential – n; rpp=retention potential – p; euc=efficiency in the use of carbon; eun=efficiency in the use of nitrogen; eup=efficiency in the use of phosphorus; epn=eutrophication potential – n; epp=eutrophication potential – p; opp=organic pollution potential; ap=acidification potential; gwp=global warming potential; sp=sedimentation potential; na=nitrogen accumulation; pa=phosphorus accumulation; oma=organic matter accumulation; pma=particulate matter accumulation; rcs=risk of cultivated species

The MCS had a better performance in two categories of environmental indicators, represented by Figure 4a-4c for use of natural resources and water pollutants, respectively. For the category of efficiency in the use of resources, the LCS had a better score (Figure 4b). For the category of sediment pollutant, the HCS had the better score, closely followed by the MCS, while the LCS showed a inferior performance (figure 4d).

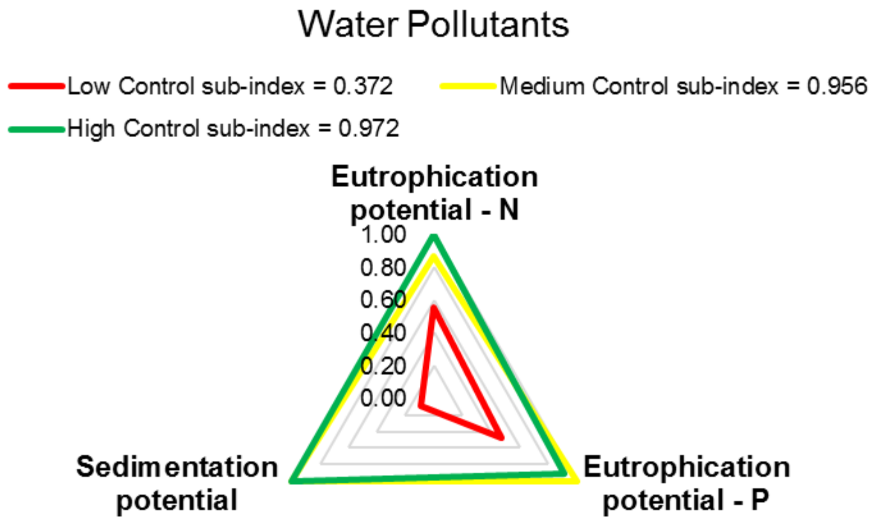
a)



b)



c)



d)

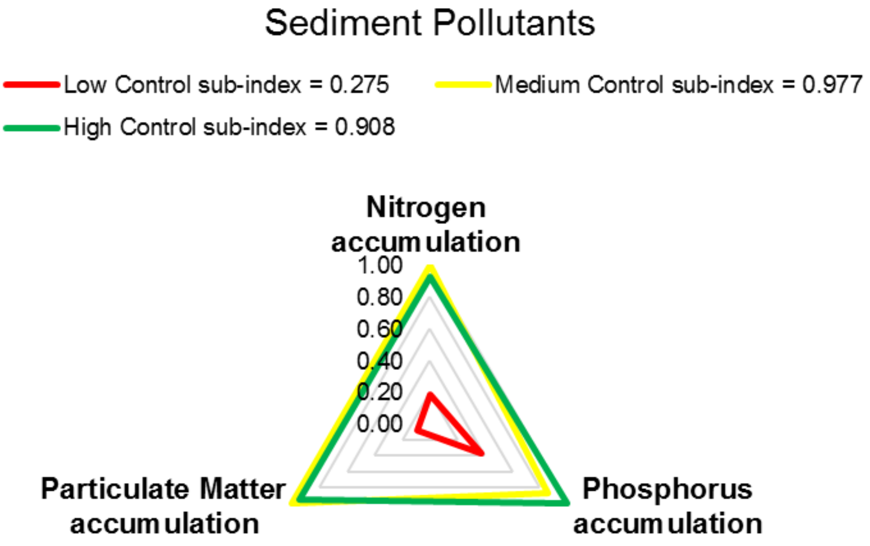


Figure 4. Indicators of environmental sustainability obtained for each category: (a) Use of Natural Resources; (b) Efficiency in Resources Use; (c) Water Pollutants; (d) Sediment Pollutants, with their respective sub-index for each treatment.

The construction of the final environmental sustainability index considered the results of each category of the set of environmental indicators below (Table 11). This final result indicates that the HCS and MCS more similarities and more environmentally sustainable than LCS. Thus, the production systems are classified as medium sustainability for LCS and potentially sustainability for MCS and HCS.

Table 11 – Environmental Sustainability Index of different production systems of lambari *Astyanax lacustris*.

Sub Index	LCS	MCS	HCS
Use of Natural Resources	0.741	0.963	0.456
Efficiency in the Use of Resources	0.758	0.316	0.563
Water Pollutants	0.372	0.956	0.972
GHG Emissions	0.820	0.643	1.000
Sediment Pollutants	0.275	0.977	0.908
Biodiversity	1.000	1.000	1.000
Final Score	**0.661**	**0.809**	**0.817**

For each category of the set of environmental indicators, we can picture the negative and positive aspects of the lambari productions systems through the environmental sustainability index (Figure 5).

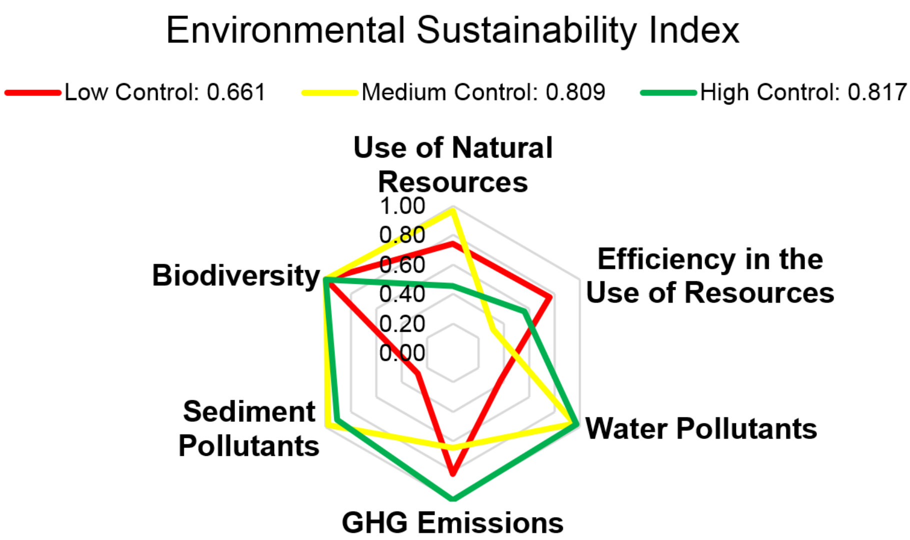


Figure 5 – Environmental Sustainability Index

The environmental sustainability index of the lambari production systems presented the final score to be classified as sustainable for the MCS and HCS. However, the LCS with an inferior score, was classified as potentially sustainable.

4. DISCUSSION

Management practices and strategies vary wildly between lambari farms (Fonseca *et al.* 2017). Farmers of a same production systems have specificities such as experiences, location and access to inputs that expresses in different results with large variability and standard deviations. Thus, the exploratory data analysis did not identified differences between the production systems. The LCS presented lower productivity compared to MCS and HCS (Table 3). The lower productivity affected all the indicators because of the lack of efficiency in the production. Therefore, lower production results in lower environmental performance expressed by the sustainability indicators. The release of pollutants is the weakness of the LCS in the environmental dimension, especially in the water and sediments categories classified as low sustainability. This is the major factor that differ LCS from MCS and HCS. However, LCS presented the best efficiency in the use of natural resources, especially in the use of nutrients from water, fertilizers and diets. The MCS and HCS had close values and performances. The proximity established between MCS and HCS to obtain young forms also provides the sharing of experiences and management strategies. Feeding frequency, diet composition, fertilization are some points of similarity, which are related to their capacity to learn new practices and techniques through courses they were able to participate. These allowed the MCS and HCS to be classified as sustainable for pollutants release. The exception is the greenhouse gases emissions for MCS, classified as potentially sustainability.

The productivity as the strengths of the MCS and HCS improves their performance on the sustainability indicators and categories scores as well as it is the weakness of the LCS. Fonseca *et al*., (2017) pointed the poor management practices exist and current science-based information is still insufficient to provide technology to match rural farmer realities or needs. Although the LCS may look as a startup for the business in an extensive approach, the farmers are longer in the industry and they are closed to adopt new techniques, especially for the reproduction through hormonal induction in laboratory. This technology demands investments and knowledge that may be difficult for successful adoption considering that the LCS farmer’s education level is lower than MCS and HCS. Thus, simple alternative strategies are needed to improve systems’ efficiencies (Fonseca *et al*., 2017).

The main source of nutrient inputs into the systems are inlet water, fertilizers and diets. The sampled farms showed variations in the characteristics of each item. The inlet water was, many times, very clean, from water springs. However, HCS farms use nutrient rich waters from reservoirs. The use of eutrophic water for aquaculture is beneficial to improve primary productivity (Kimpara *et al*., 2011) but it must be paired with better management practices (BMPs) (Edwards, 2015). Conversely, the production of *A. lacustris* through LCS and MCS use less nutrients than *Deuteron iguape* in a public aquaculture farm located in the Atlantic rain forest in the south coast of Sao Paulo State, Brazil (Fonseca *et al*., 2017). Also, *D. iguape* impacts the water and sediments with wildly higher loads of nitrogen and phosphorus per kg of produced fish compared with all of the *A. lacustris* production systems. The only exception is the HCS, that uses 20 to 28 times more carbon to produce a tonne of *A. lacustris* compared to *D. iguape*. The production of *D. iguape* is an alternative for vulnerable rural communities and the target is local sales or food security (Fonseca *et al*., 2017). Thus, their productivity is lower, even with higher levels of nutrients, and the environmental indicators for this species resulted in higher impact per production attesting the need of BMPs proposed by Edwards (2015).

For the pollutants category, the LCS releases 3.6 times more phosphorous in the water than tilapia cage culture in a reservoir in the northeast Brazil (Moura *et al*., 2016). However, MCS and HCS releases loads of nitrogen and phosphorus comparable to laboratorial experimental conditions of prawn-tilapia integrated multi-trophic aquaculture system (Proença, 2013). Therefore, the LCS has less management in the ponds, which results in larger amount of suspended solids in the water at the end of the cycle; thereby increasing the siltation potential. To mitigate this, the addition of substrates may reduce the impact on the receiving waterbodies from the phosphorus in the sediment and effluents (David *et al*., 2017).

According to the effluent standards for aquaculture stated by the Global Aquaculture Alliance, the concentration of phosphorus and total suspended solids should be kept to 0.3 and 50 mg/L, respectively (Boyd, 2003). The effluent generated per lambari production had adequate phosphorus concentration levels in all the systems, except in the beginning of the cycle of the HCS. This may be related to the mix of manure and chemical fertilizers which was added at the beginning of the cycle to increase the primary production. Although the rates of total suspended solids were higher than recommended, they were adequate in the outlet waters at the beginning of the MCS and at the end of the HCS. The use of water per production was higher for LCS, impacting its relation with natural resources use. The daily water addition rate to replace water loss by seepage and evaporation were 3.69, 6.97, 5.75% for the LCS, MCS and HCS, respectively. The use of water for pellet-fed pond aquaculture system are 11.5 m³ per kg of fresh weight produced fish (Verdegem *et al*., 2006), is comparable to MCS and HCS, but the LCS used 34 m³ per kg of lambari.

Farmers of the LCS use the same diet for the whole grow-out phase, usually specific to other species such as tilapia. The size of the pellet is not suitable for lambari, so wasted nutrients became effluents. Conversely, farmers of the HCS use a different diet. Although it is not specific for the species, it was more suitable for the different sizes of lambari during the grow-out phase. The feed conversion ratio had small differences for LCS, MCS and HCS (1.83, 2.02, 1.57), and the average final weight of the fish was 10, 16 and 18 g, respectively. The LCS has less efficiency during the feeding period than the other two systems, but is still an improvement over natural sources of food where the fish have greater consumption of plankton. The MCS had less efficiency in feeding than the HCS. The composition of the diets varied, especially in the MCS, where one of the farmers added Silkworm bran to the regular commercial diet. Although this mix contained high protein levels, the bran’s lack of floatation created a difficulty in consumption for the fish. Additionally, the lack of information about population and stocking density in the LCS may have caused problems with proper nutrient supply in fertilization and feeding. In the beginning of the cycle, the fertilization of the ponds is necessary to stimulate the primary productivity, an essential natural food for post-larvae. For this, chicken manure is the most used nutrient source due to its relatively lower price and the availability of poultry farms in the region. Other inputs used for this purpose were chemical fertilizer, urea and rice bran. All of this contributed to the organic-rich sediment accumulation and an increase in anaerobic decomposition causing higher levels of bubbling emissions in the MCS.

The diffusive methane emissions in each system indicated the decomposition of the wasted nutrients from feed. CH_4 has low solubility and lack of ionic form that could be retained by the reaction with free radicals, so it escapes from the dissolved state into gas bubbles (Tokida *et al.*, 2013). The MCS absorbed CH_4 at the end of the cycle. N_2O was absorbed during the whole LCS cycle and at the end of the HCS cycle. The mechanisms to explain the reductions of nitrous oxide emissions is simply due solubility of nitrous oxide in the water by physical absorption (Webb, 1923). The absorption of CO_2 through photosynthesis and CH_4 and N_2O through diffusion in the water-air interface reduces the CO_2 equivalents. CH_4 and N_2O are 21 and 310 times, respectively, more aggressive to global warming than CO_2 (IPCC, 2007). The production of *Astyanax lacustris* in LCS, MCS and HCS emit 42.61, 51.75 and 33.29 tonnes of CO_2e per tonne of lambari produced, respectively. Due the absorption of N_2O by diffusion in the HCS, the global warming potential presented the best score because of the productivity of the ponds. In comparison, the loads of carbon dioxide equivalents are negative for *Deuterodon iguape* (Fonseca *et al*., 2017) and prawn-tilapia IMTA (Proença, 2013), indicating absorption of greenhouse gases. However, the present study considered the levels of N_2O that considerably affects the global warming potential and it lacks studies with this approach for more accurate comparisons because of the difficulties to measure greenhouse gases in the aquaculture field.

Astyanax lacustris occurs in the basin of the Parana river, where the farms are located. The escape of these animals has minimal negative interaction with wild populations through competition, transfer of disease/pathogens, and interbreeding. It is an autochthonous species and has the highest rate for the indicator of conservation of genetic diversity and biodiversity for all the production systems. This indicator is site-specific and autochthonous lambari production should be encouraged in Brazil. Other lambari species such as *Deuterodon iguape* are an alternative even for polyculture systems around conservation areas (Gonçalves *et al.*, 2015). In addition, lambari production is indicated as a means to develop rural communities in Brazil through socioeconomic improvement and environmental conservation (Fonseca et al., 2017).

The environmental indicators show how nutrients are distributed in several components of aquaculture ponds. Also, the information can be used for better management of the systems so as to obtain the maximum nutrient concentration in the biomass of any target animal (David *et al.*, 2017). The greater implementation of better management practices (BMPs) and an ecosystem approach to aquaculture (EAA) are essential for development of environmentally sustainable aquaculture (Edwards, 2015).

The set of indicators are adequate and effective tools to evaluate the environmental sustainability in aquaculture. It was able to identify the strengths and weaknesses of the production systems. However, the choices and interpretations of sub-indexes emphasize the subjectivity in the construction of the environmental index. The use of six categories of sub-indexes could be reduced to four since the release of pollutants join together the data for water, sediment and atmosphere loads in a singles sub-index. It is recommended that other combinations and manipulations of the sub-indexes are utilized to compare the differences in further studies. In addition, it is necessary to define environmental sustainability reference values for indicators differentiated by species to base the determination of the sustainability index as well for each dimension. As soon as there are such reference values, the environmental sustainability classification of each production system may be different. The performance scale calculation would be comparative between reference values for the environmental dimension and no longer in relation to the best performing production system as presented. The indicators showed great variability, partly due to the type of management adopted by lambari production systems, great variation in the size of the farms and also for limitations in the number of replicates used in this study. These factors may be affecting the groups during the cluster analysis. The partial clustering for LCS and MCS may be associated to the similarities in the management of those farms, especially in the use of diets and in the inefficiency in the use of nutrients. It is recommended to carry out studies that contemplate more number of farms and systems of production for better statistical analysis.

All three production systems of lambari have high environmental sustainability, especially the MCS and HCS. However, the LCS needs improvement of its productivity and application of BMPs considering the feeding, water quality monitoring, breeding and simple solutions for avoiding release pollutants. Technical support is strongly recommended. Unfortunately, Brazil has few public or private technical assistance services specific for aquaculture. It is even more rare in rural settlements, where LCS and MCS are located. This study also provides a picture of the environmental conditions for Brazilian production of *Astyanax lacustris*. The farms in this study are a good sampling, representative of the whole country's current most common production systems in operation from the smallest rural settlements to the larger full scale productions. Furthermore, these samples reported production 3.8 times larger than the official national production report (IBGE, 2016).

5. CONCLUSIONS

We conclude that the HCS and MCS are sustainable production systems. The use of technology for better control of breeding and productivity benefitted its pollutant emissions and the HCS scored to be the most environmentally sustainable of the São Paulo State. However, the LCS is classified as potentially sustainable due its lower scores for the loads of nutrients per kg of fish for water and sediments pollutants. The productivity is the factor that differ the production systems affecting the calculation of the indicators. Technical assistance is recommended for mitigation of the lack of good practices in maintenance of the ponds and control of the population in the LCS through simple solutions.

The performance scale was able to display the strengths and weakness of each treatment in a descriptive approach when the statistical analysis faced large variability of values caused by different management practices. Thus, this tool could not identify differences between productions systems. During the research, the combination of the set of environmental indicators chosen generated an index able to detect, identify and quantify the main aspects of lambari production systems. Additionally, information about the social, economic and governance of aquaculture production systems must be compared and integrated to achieve an efficient sustainability index.

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CAPÍTULO 3

SOCIAL SUSTAINABILITY OF LAMBARI *Astyanax lacustris* PRODUCTION SYSTEMS

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ABSTRACT

Investigations about the social factors of aquatic species are essential for pertinent sustainable development of the aquaculture industry considering the small scale producers and local communities. This study aims to evaluate the social sustainability of the lambari *A. lacustris* using a set of indicators. We interviewed nine farmers to obtain the necessary data to calculate the social indicators for lambari production systems, classified according their levels of control of production in low (LCS), medium (MCS) and high (HCS). The indicators were grouped in four categories: The principle of equity and the income distribution, equality of opportunities, jobs creation and benefits for local communities. The HCS was socially sustainable. It performed better for equity and income distribution, equality of opportunities and benefits for local communities. Both the LCS and MCS were classified as potentially sustainable. The production of lambari through the LCS opened opportunities for self-employment. However, social organization may improve the social benefits of the industry through association and cooperatives, increasing the inclusion of more workers by direct and/or indirect jobs.

Keywords: Sustainability, social index, lambari, performance scale.

1. INTRODUCTION

Poverty reduction has been a central goal for developing countries and one of the millennium goals of the United Nations (UN, 2015). To achieve a sustainable and solidary model of development, multiple policy, economic and social actions are essential for the construction of an equitable, fair and emancipatory society (FAO, 2017). In Brazil, the political crises and the economic recession has resulted in 12.9 million unemployed citizens (IBGE, 2017). The current scenario, characterized by unemployment, laxity, poverty and exclusion, requires bold changes in the social policies, with progressive movement in the areas of work organization which will impact the whole social structure related to diversity in the work force (Singer, 2006).

Aquaculture is indicated as a potential industry to alleviate poverty (Belton *et al.*, 2012). It is one of the fastest growing industries of animal protein in the world (FAO, 2016). Conversely, there is some question about the relationship between aquaculture and poverty reduction (Bené *et al.* 2016). Power imbalances in the value chain are important and small-scale producers often receive the least benefit (Ardjosoediro & Neven, 2008). The lack of specific information about the socioeconomic scenario of aquaculture industry generates inadequate public policies and unsustainable practices (Lazard *et al.*, 2011). Thus, investigations about the social factors of aquatic species are essential for appropriate sustainable development of the aquaculture industry, which considers the small scale producers and local communities.

From the freshwater species from Brazilian aquaculture, the growth of lambari production stands out. Lambari is a low-trophic level native small fish pointed as a tool able to develop poor rural communities in Brazil that combines socioeconomic enhancement and environmental conservation (Fonseca *et al.*, 2017). It can be produced by small scale family farmers in places that present environmental restrictions, such as areas around conservation centers (Lopes *et al.*, 2013). São Paulo State, the largest producer, was responsible for 29% of the national production of 234 tonnes that moved around US$[1] 604,064.68 (IBGE, 2016). The main species farmed is the yellow-tailed lambari *Astyanax lacustris*

[1] Dollar quotation: R$3.20 - May, 2017

(Fonseca *et al*., 2017). This species was previously known as *Astyanax altiparanae* (Garutti & Britski, 2000) but was recently re-described (Lucena & Soares, 2016). The lambari production in Brazil has been growing, mainly due to the demand for live bait for sport fishing, contributing to the national economy though the tourism industry (Silva et al., 2011a). However, there are several market niches potentials to develop such as snacks for human consumption and forage fish in aquarium stores and public aquariums (Silva *et al.*, 2011b). Thus, production and market potential are large and stimulate to increase the number of lambari farms. However, for progress to be stabilized, it is necessary to adopt sustainable practices. Production based solely on the current market and financial forecast, leads to systems that are not efficient or sustainable over time (Valenti *et al.*, 2010).

Sustainable aquaculture is based on the rational use of financial, natural and human resources in the production process. In this way, it is an economically viable activity, which improves the quality of life of local communities, without degrading the ecosystems in which it is introduced (Arana, 1999; Valenti, 2002). It involves three components: profitable production, conservation of the environment and social development (Valenti, 2000). Each component is essential and inseparable for the activity to be perennial. To achieve sustainable aquaculture, it is essential to measure the sustainability of the production systems used, the management techniques and the new technologies that are being generated and adopted. Between several methods for measure the sustainability, the Set of Indicators give a meristic view, making it possible to analyze each part of the production system separately. This allows you to locate the weaknesses and correct them. Additionally, they should allow for the consolidation of information into graphs or index which may be combined to allow for a more general interpretation. The data is easier to obtain and the interpretation of the results is simple and easily understood.

Recently, set of indicators have been developed to assess the sustainability of aquaculture (EAS, 2005; Boyd *et al.* 2007; Valenti, 2008, Valenti, *et al.*, 2011 and Valenti, 2013). These are generally distributed in the environmental, social and economic dimensions. Social indicators are linked to issues such as equitable distribution of income, job creation (jobs and self-employment), and food security. From the application of these indicators to lambari farms, we will be able to evaluate the social pertinence, effectiveness and adequacy of lambari production in each production system. Also, the indicators will show an overview of the sustainability of a national aquaculture segment.

Although production of *A. lacustris* is growing rapidly, there are no studies about social sustainability of each production system in order to contribute to the regulation of public policies which encourage an inclusive and perennial business. Thus, this study aims to evaluate the social sustainability of each lambari production system of São Paulo State and to compare them. With this data, we show the strengths and weaknesses and point out possible solutions. In addition, we evaluate the adequacy of sustainability indicators to compare different systems of aquaculture production.

2. MATERIALS AND METHODS

2.1. FARMS SELECTION PROCESS

The production of the yellow-tail lambari, *Astyanax lacustris*, involves different levels of intensification and technological sophistication (Silva *et al.*, 2011a). For the present study, based on the country's current most common production systems in operation, we grouped the farms in Low Control System (LCS), Medium Control System (MCS) and High Control System (HCS), according to the criteria defined in Gonçalves & Valenti, (Chapter 2).

Initially, we located the farmers of the State of São Paulo based on information from extension agents. The farmers were classified according to the three systems described above. We contacted them and three more representative farms of each system were chosen (Figure 1) to carry out the work.

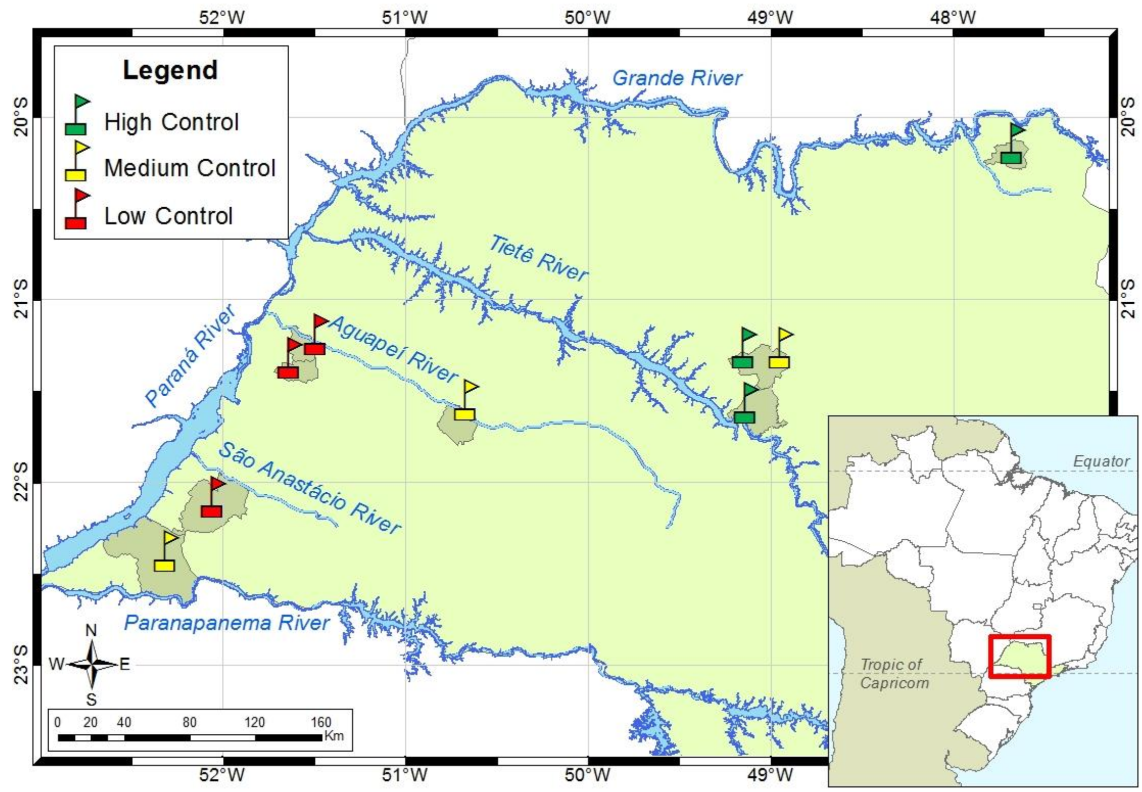


Figure 1 – Location and classification of the selected farms in Sao Paulo State.

2.2. EXPERIMENTAL DESIGN

We have analyzed the factor production system, with three levels (husbandry types) and three replicates for each level (each farm). We interviewed nine farmers to obtain the necessary data to calculate the indicators and determine the social sustainability of the lambari production systems using semi-structured questionnaires. These are true replicates because we obtained from different farmers.

2.3. SOCIAL SUSTAINABILITY INDICATORS

The social sustainability was evaluated considering four aspects: The principle of equality and the income distribution, equality of opportunities, the generation of jobs and benefits for local communities. The principle of equity considered the individual remuneration of the labor, including the entrepreneur, percentage of the cost of production (or breakeven price) that corresponds to the labor remuneration, including family labor. The income distribution shows the relationship between the amount paid as wages + charges + social benefits (i.e. company health plan) and profit generated. The indicator shows for each US$ dollars of the entrepreneur's profit how many US$ dollars are distributed to the workers. The remuneration of labor can also be expressed in units of production, considering the mass of fish produced.

The generation of jobs measures direct, indirect jobs by total amount invested and proportion of self-employment jobs. The equality of opportunities measures the social inclusion considering the five main ethnic groups in Brazil: White, Brown, Black, Yellow and Indigenous. We also considered the age groups as young (10 to 19 years), adults (20 to 39), middle age (40 to 59) and old (> 60). The data on the social composition of the local population (racial, age and gender) were obtained from the IBGE database (IBGE, 2016) and the number of jobs occupied by the local population in the farms.

The benefits for local communities measured the relationship between production, workers, local market, community activities, health and education conditions, and the fixation of income. The proportion of jobs generated that allowed recruitment among the local population, considering their culture, level of education and skills. It also considered the purchases of inputs, products, equipment, etc., that were made in the local market, except for labor. The indicator Workplace Safety (WS) quantifies accident prevention procedures. We analyzed 15 items that represent equipment, actions and practices that give security to the worker, as the following: Use of life vest; Use of sun protection goggles; Use of protective goggles against mud, scales, etc.; Use of a pigmented glove; Use of waterproof and non-slip boots; Use of own clothes to stay in the sun or rain; Use of equipment that alleviates physical exertion; Use of adequate lighting in places; Use of appropriate electrical and hydraulic installation; Use of machines, equipment, implements, furniture and tools that provide good conditions for posture, visualization, movement and operation; Use of machines and equipment by a qualified professional; Use of protective apron when necessary; Guaranteed rest breaks for activities that are performed while (or necessitate) standing up; Well-equipped and easily accessible first-aid kit; Indication of any danger areas.

Table 2 - Social sustainability indicators used to assess lambari *Astyanax lacustris* production systems.

Indicator	Formula
Principle of equality and Income distribution	
Wage equality	WE = 1- (Standard deviation of wages / Average of wages)
Proportional labor cost	PLC = Remuneration of labor (includes family labor) / cost of production
Income distribution	ID = wages + charges + social benefits / Profit
Remuneration per production	RP = amount paid in remuneration of labor / mass of produced fish
Equality of opportunities	
Racial inclusion	RI = Racial composition of the jobs / racial composition of the local population
Gender inclusion	GI = Generic composition of the jobs / generic composition of the local population
Age inclusion	AI = Age composition of the jobs / age group of the local population
Labor per area	LA = man-hours per year / occupied area
Labor per production	LP = man-hours/ mass of produced fish
Job creation	
Generating direct jobs	GDJ = number of jobs and direct self-employment / investment
Job creation	JG = number of jobs and direct self-employment + indirect / investment
Self-employment proportion	SEP = number of self-employed / total number of jobs
Benefits for local communities	
Use of local labor	ULL = jobs suitable for local labor / total number of jobs
Income fixation	IF = acquisitions in the local market / total acquisitions
Local consumption	LC = production consumed in the local market / total production
Access to health programs	AHP = Employees and owners with health plans / Total employees and owners
Education	E = Employees who study / Total employees
Employee tenure	ET = average time spent by each worker in the aquaculture (in years)
Community participation	CP = Workers who participate in community activities / Total workers
Workplace safety	WS = Equipment, actions and practices that give security to the worker present in the enterprise / Total analyzed items

The data needed to calculate the social indicators (Table 2) were primary and secondary. The primary data were obtained from the farms through direct interviews with the owners, administrators, technicians and employees, using a semi-structured questionnaire. The secondary data were obtained through research carried out with public agencies, which maintains the records of the property and the region, such as the Brazilian Geography and Statistics Institute (IBGE), data files of the extinct Ministry of Fisheries and Aquaculture (MPA), State Secretariats of Aquaculture and / or Agrarian Development, Prefectures among others. All monetary values were converted from Brazilian Reais to US dollars, based on the average trading price of the dollar in May 2017 (US$ 1.00 = R$ 3.20).

2.4. DATA ANALYSIS

The obtained variables were compared between systems by multivariate exploratory data analysis. Data was standardized to perform Cluster (using euclidian distance and UPGMA - Unweighted Pair Group Method using Arithmetic averages) and Principal Components Analysis (PCA).

Each indicator was converted into a performance scale (Bellen, 2008, Valenti, 2008), with scores ranging from 0 to 1 and expressed in multidimensional diagrams. The process with the best indicator value (more sustainable when compared to the others) was arbitrarily scored as 1, and the others were determined proportionally. Thus, the indicators were grouped into 4 categories: (a) Principle of equity and income distribution; (b) Equality of opportunities; (c) Jobs generation; (d) Benefits for local communities. A sustainability sub-index was computed for each category by the average of their respective indicators. The Social Sustainability Index was determined by the average of the indicators of the four sub-indexes for each system. The social indicators of the lambari production systems were classified by how sustainable they are according to the range of the performance scale (Valenti, 2008) as shown in Table 3.

Table 3 – Performance scale used in the classification of sustainability for the lambari production systems of Sao Paulo State.

Range	**Classification**
0.000 - 0.200	Not sustainable
0.201 - 0.400	Low sustainability
0.401 - 0.600	Medium sustainability
0.601 - 0.800	Potentially sustainable
0.801 - 1.000	Sustainable

Adapted from Valenti (2008)

3. RESULTS

The social indicators of the lambari productions systems are presented in Table 4. The MCS presented the best indicator of wage equity at 58.5%. The income distribution of the HCS was $1.01 and the remuneration per production, $1.76. There is a strong difference compared to the LCS, $0.27 and $3.07, respectively. The LCS remunerated US$ 30.00 for each 1,000 fish produced, 1.8 times more than the MCS. Compared to the MCS and HCS, the LCS required more labor per kilogram of fish produced, 0.49 (MH/kg). Conversely, for the relation of labor per area, it required 807.49 MHY/m² less than the MCS and HCS, that required 1302 and 1444, respectively. The farmers of the LCS have been in the business longer, 2.5 and 4 times more time than the HCS and MCS, respectively. The income fixation in the cities was greater for the LCS, estimated in 60%. For the other production systems this rate was 53 and 43% for MCS and HCS, respectively. The production of lambari is not inclusive and generated very few jobs per invested amounts. However, the cost of each direct and indirect job positions generated by each lambari production system were US$ 18,756.55, US$ 29,885.53 and US$ 55,445.28 for LCS, MCS and HCS, respectively.

Table 4 - Indicators of social sustainability in different production systems of lambari *Astyanax lacustris*.

Indicators	**LCS**	**MCS**	**HCS**
Principle of equality and income distribution			
Wage equity (%)	11.07±6.77	58.54±34.25	29.20±41.91
Proportional labor cost (%)	16.54±5.70	9.59±0.67	12.81±5.99
Income distribution ($)	0.27±0.04	0.51±0.38	1.01±0.95
Remuneration per production ($/kg)	3.07±1.51	1.31±0.75	1.76±1.22
Remuneration per production ($/1000)	30.71±15.05	17.45±3.95	24.68±6.47
Equality of opportunities			
Racial inclusion (%)	1.77±0.56	5.11±2.41	11.12±6.61
Gender inclusion (%)	2.49±1.32	5.29±1.15	13.17±5.60
Age inclusion (%)	6.24±3.00	17.20±8.90	24.24±10.46
Labor per area (MHY/m²)	807±279	1302±326	1444±1201
Labor per production (MY/Kg)	0.49±0.13	0.27±0.20	0.20±0.18
Jobs Generation			
Generating direct jobs (Jobs/$)	$2.68E^{-5}$±$0.25E^{-5}$	$2.91E^{-5}$±$2.33E^{-5}$	$2.97E^{-5}$±$2.14E^{-5}$
Job creation (Jobs/$)	$5.36E^{-5}$±$0.49E^{-5}$	$4.55E^{-5}$±$3.29E^{-5}$	$5.85E^{-5}$±$4.69E^{-5}$
Generating direct jobs cost ($/Jobs)	37,513±3,319	52,501±37,274	83,397±103,264
Job creation cost ($/Jobs)	18,757±1,660	29,886±17,062	55,445±74,855
Self-employment proportion (%)	100±0	31±5	38.73±4.89
Benefits for local communities			
Use of local labor (%)	100±0	100±0	100±0
Income fixation (%)	60±0	53±6	43±0
Local consumption (%)	100±0	70±5	47±47
Access to health programs (%)	0±0	22.2±19.2	34±6
Education (%)	0±0	22.2±19.2	34±6
Employee tenure (years)	22±6	5±1	9±4
Community participation (%)	100±0	44±51	24±8
Workplace safety (%)	18±10	36±15	40±12

The cluster analysis (Figure 2) showed that the LCS had elements which differed from the others, with 70% of dissimilarity between the low and medium control groups. Conversely, the MCS and HCS showed no differences between them.

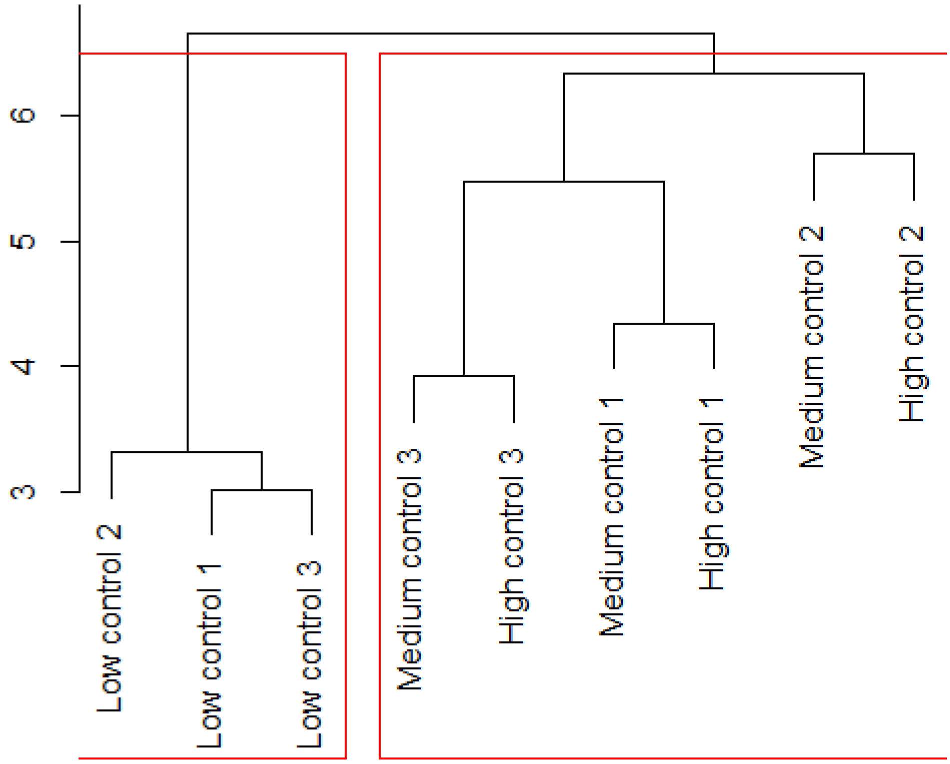


Figure 2. Dendrogram of dissimilarity of social sustainability indicators of lambari production systems (Euclidean distance).

The social sustainability indicators submitted to the Principal Components Analysis (PCA) were able to show which components could generate patterns for clustering of cohesive groups (Figure 3). The indicator use of local labor was not considered in this analysis because all the samples presented the same result, with no variation. That means this data does not help the search for clustering. The LCS is relatively homogeneous and the indicators of employee tenure, self-employment proportion and income fixation were the ones that best explained the grouping for the LCS.

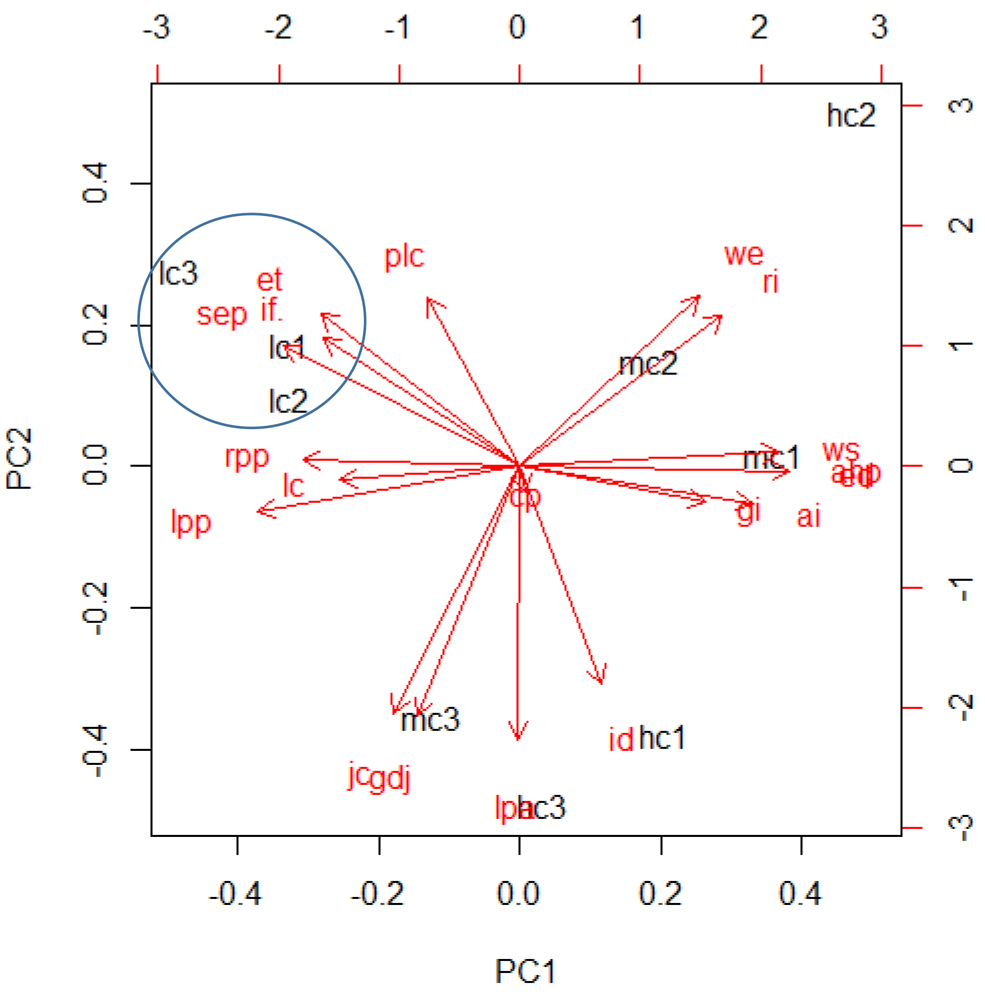
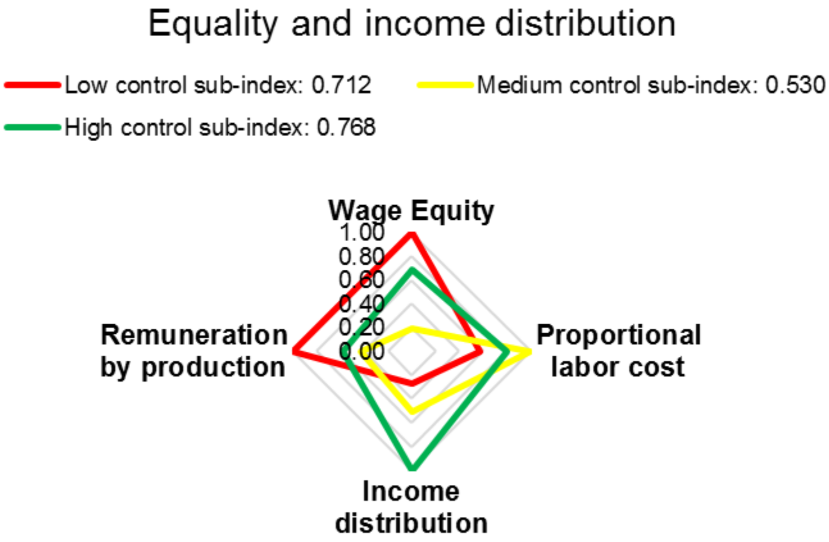


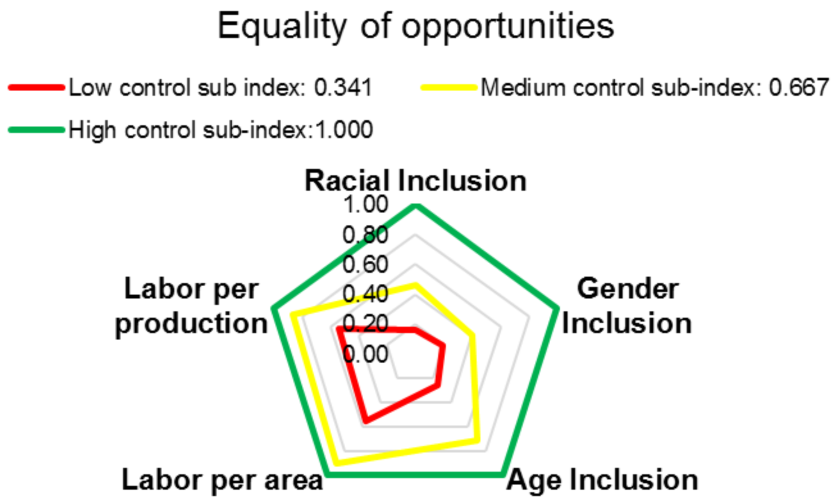
Figure 3. Principal components Analysis (PCA) for social sustainability indicators of lambari production systems in São Paulo State. lc=low control; mc = medium control; hc = high control; we=wage equity; plc=proportional labor cost; ic=income distribution; rpp=remuneration per production; ri=racial inclusion; gi=gender inclusion; ai=age inclusion; lpa=labor per area; lpp=labor per production; gdj=generating direct jobs; jc=job cration; sep=self-employment proportion; if=income fixation; lc=local consumption; ahp=access to health programs; e=education; et=employee tenure; cp=community participation; ws=workplace safety;

The HCS had better performance in the categories of Equity and income distribution, Equality of opportunities and Benefits for local communities (Figure 4a, 4b and 4d). The LCS presented better performance in the category Jobs generation, especially due to the indicator of the self-employed proportion (Figure 4c).

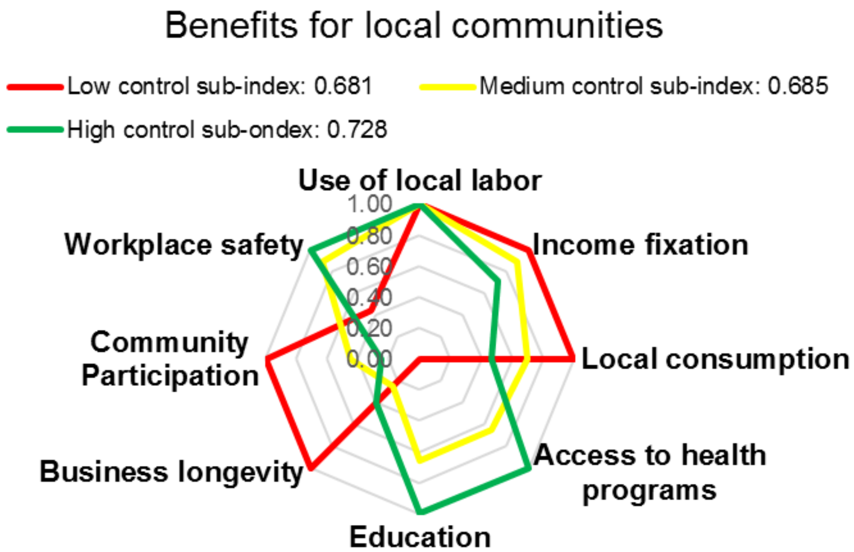
a)


Equality and income distribution
Low control sub-index: 0.712
Medium control sub-index: 0.530
High control sub-index: 0.768
Wage Equity
1.00
0.80
0.60
0.40
0.20
0.00
Proportional labor cost
Income distribution
Remuneration by production

b)


Equality of opportunities
Low control sub index: 0.341
Medium control sub-index: 0.667
High control sub-index:1.000
Racial Inclusion
1.00
0.80
0.60
0.40
0.20
0.00
Gender Inclusion
Age Inclusion
Labor per area
Labor per production

c)


Benefits for local communities
Low control sub-index: 0.681
Medium control sub-index: 0.685
High control sub-ondex: 0.728
Use of local labor
1.00
0.80
0.60
0.40
0.20
0.00
Income fixation
Local consumption
Access to health programs
Education
Business longevity
Community Participation
Workplace safety

d)

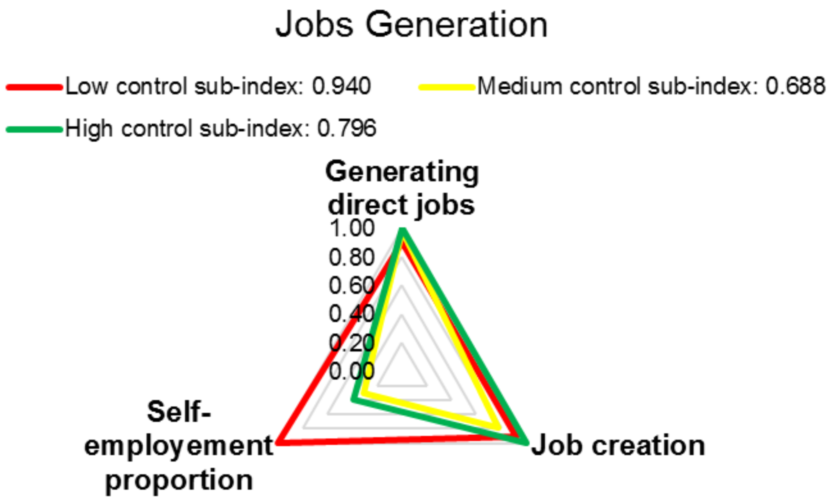


Figure 4 - Indicators of social sustainability obtained for each category: (a) Equality and income distribution; (b) Equality of opportunities; (c) Jobs generation; (d) Benefits for local communities, with their respective sub-index for each system.

The best performance of the HCS in three of four categories of social indicators reflected on the final social sustainability index with the highest score of 0.823 (Figure 5).

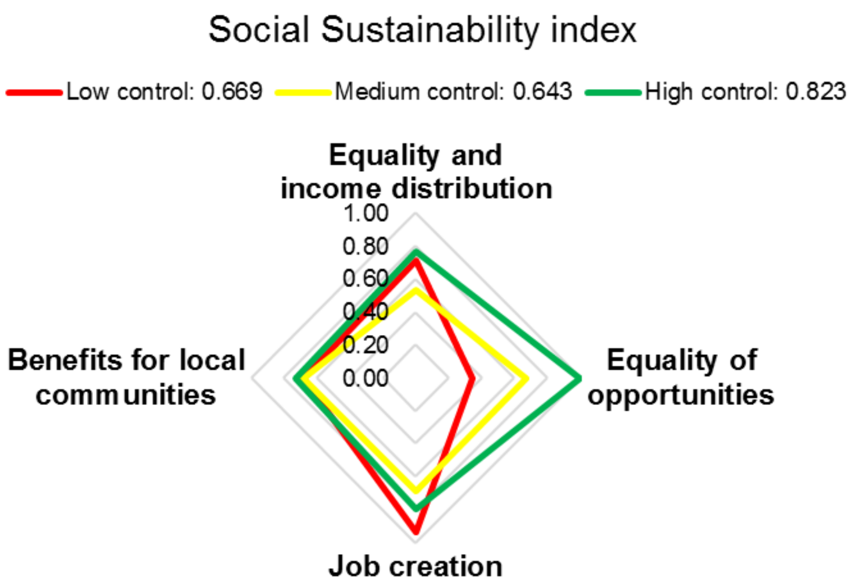


Figure 5. Social Sustainability Index

Table 5 - Social Sustainability Index of the production systems of lambari *Astyanax lacustris*.

Sub-indexes	**LCS**	**MCS**	**HCS**
Equality and income distribution	0.712	0.530	0.768
Equality of opportunities	0.341	0.667	1.000
Jobs creation	0.940	0.688	0.796
Benefits for local communities	0.681	0.685	0.728
Final index	**0.669**	**0.643**	**0.823**

4. DISCUSSION

MCS presented lower equity and income distribution than LCS and HCS and it is classified as medium sustainability for this category. MCS hires unofficial employee with lower payments to supply specific demands, for example for harvesting. However, HCS has formal employees with higher wage. Although the LCS is classified as sustainable for job creation and potentially sustainable for equity and income distribution, it presents low sustainability for equality of opportunities. The reason is that there are no employees hired on these farms, which increases the self-employment proportion. The exploratory analysis of the social indicators (Figures 2 and 3) was able to identify a cohesive group that differ LCS from MCS and HCS by the employee tenure, self-employment proportion and income fixation. The LCS performance on those indicators are related to the limitation on increasing their scale of production, being longer in the business, working by themselves and all the expenses are local. All the production systems are potentially sustainable for benefitting local communities. However, the factor that cause the major differences between the production systems in the social dimension is the number of job positions generated, that affects the social sustainability indicators. The performance scale generated the social sustainability index that classified the LCS and MCS as potentially sustainable and the HCS scored to be classified as sustainable.

Sociologically, the lambari production in São Paulo State is not diverse; they lack racial, gender and age inclusivity. All the owners were white and their wives had other occupations not related to the business. The MCS and HCS presented one brown employee at one farm each. Also, the indicators showed how close (or far) the lambari production systems are from the local community distribution of race, gender and age. However, the HCS had better rates of 11.12, 13.17 and 24.24% for race, gender and age inclusion, respectively, because the farmers hire more employee than LCS and MCS. The region where the lambari farms are located had great immigration movement of white European communities during the post war period. These immigrants started to work with the production of milk, sugarcane, peanuts, oranges and limes. Because of the proximity with big rivers, the sport fishing industry demanded live baits when the lambari production started. Comparing the results with the culture of species, there is more inclusion working with tilapia production in cages, were the rates are 55, 48 and 66% for race, gender and age, respectively (Moura *et al.*, 2016). Thus, the lower number of employees may mask the results of the indicators and affects the inclusion rates. Also, the analysis of the indicators depends on observations during the study in the field. Rural employments have been substituted for mechanical labor. However, the production of lambari are not mechanic based even for the HCS as observed in the indicator labor per area. The LCS presented larger value for the indicator labor per production. The interpretation of this data should indicate that this system is more sustainable because it would incorporate more labor in the farms. However, the LCS farmers has no employees, and the high value of labor hours per production is concentrated in the owners, with no distribution of jobs, which may cause health problem due overworking and affect their quality of life.

The production of lambari presents advantages in the social dimension when evaluating the results with tilapia production in cages (Moura *et al.*, 2016). Lambari culture generates more benefits to local communities than tilapia cage culture in northeast of Brazil. Moura *et al*., (2016) observed that tilapia farmers had lower access to health care and education than HCS lambari farmers. However, the farmers of the LCS presented low education levels. This confirm the importance of the business, able to promote opportunity for productive inclusion for low educated workers. Also, none of the farmers interviewed in the present study have private health insurance. The wealthier farmers from the HCS affirm that the public services of health care are good enough in their region, so they chose not to have a private health insurance. For the smaller scale famers from the LCS, they establish that they can afford it. For the category jobs generation, both species presented a shortcoming for only generating a minor number of direct and indirect jobs, considering the amounts invested in the farms. The use of local labor emphasizes and elevates the social value of the business.

All of the production of the LCS is consumed by the local community, which indicates that the business increases the supply of live bait for the local market. The fish are sold to live bait stores, fishing hotels or directly to sport fishermen. This indicator of consumption reflects the improvements in the indirect job opportunities in the local community provided by the lambari production, since the market is linked to the tourism industry (Silva *et al.*, 2011a). Although the MCS and HCS spread the consumption for other territories and also states, they have great social importance to provide innovations in accessing different market niches such as industrial tuna fishing and snack food.

The HCS is represented by wealthier farmers, with greater economic power. They are able to generate more direct and indirect jobs and presented more stability with retaining employees compared to the MCS. This fact is also strengthened thru the capacity to provide benefits for the employees and for the local communities as shown by some indicators such as access to health programs, education and workplace safety. Also, their income distribution is 3.7 and 1.9 times larger compared to the LCS and MCS, respectively.

The LCS are older in the business and has better capacity to retain workers than MCS and HCS. However, LCS farmers are self-employed workers and includes the smallest scale farms, some of them located on rural settlements, where none of them hire employees. Thus, there is very little workers benefiting from the business. The owners work on the production by themselves, make deals with local day laborers and also may receive help from the consumers for harvesting the fish from the ponds. Their relationship is not merely mercantile. There is trust and reciprocity between them which builds a higher level of social capital (Silva *et al.*, 2007). These relationships also can be improved through some kind of participation in community activities such as the local rural development council, neighbor associations or even church events. The farmers participate in some of these activities and use them as an opportunity to introduce their products for sport fishermen and/or share about their production systems, advantages and struggles of the business to improve governance and innovations for the production systems. However, the social capital may not be a useful predictor of success. It is dependent on the presence of engaged leadership and agreement among members linked to all social and ecological variables (Crona *et al.*, 2017). These activities could be productive for local development when they increase the participation of the community. However, even though the MCS and HCS farmers participate of the social activities, their employees have no involvement in community decisions or social events.

The political crisis and the economic recession of the country resulted in 14.2 million Brazilians being unemployed (IBGE, 2017). The State and private sectors are not offering enough job positions or actively working to open new opportunities to provide income to the population. Lambari production is resilient and provides longevity in the business for the farmers of all production systems. Although the sampled farms presented stability facing the crisis, other farmers from different regions have been ending their activities, especially the ones from the LCS located in remote areas. The smaller scale may reduce the efficiency Thus, solidary economy (Singer, 2006) is necessary as an organizational alternative to promote socio-economic change for those disadvantaged populations. When applied to aquaculture, the solidary economy can improve marketability, avoiding the paralysis of small-scale activities in competition with intensive production of agribusiness. Also, the social organization of farmers though associations or cooperatives may provide improvements in the social indicator as observed with the association of tilapia cages culture farmers in the northeast Brazil (Moura *et al*., 2016).

The social organization of the farmers is individual. However, one farmer from the HCS works with informal groups. Coincidently, this farmer is the biggest lambari producer in Brazil and he has partnerships with 15 smaller farms. Increasing the governance, cooperatives, associations and/or informal groups could help organize and improve the social solidary economy (Kawano, 2013). When social organization of the farmers occurs, collective innovations can happen, increasing the social capital with trust and solidary relations (Singer, 2006). The government must support the strengthening of the solidarity economy. Also, it can strengthen the social reproduction of the business, transferring the (aqua)culture and techniques to next generations. However, the location of lambari farms lacks technical assistance that is essential to improve systems' efficiencies providing simple alternative strategies to match rural farmer realities or needs (Fonseca *et al*., 2017).

The set of indicators were adequate and effective tools to evaluate the social sustainability for lambari production systems and present great applicability for aquaculture sustainability assessment. However, the choices and interpretations of sub-indexes emphasize the subjectivity in the construction of the social sustainability index. For example, the interpretations for the generation of jobs must consider the context that the LCS is inserted, and not just the value given by the indicator. The fact that they are self-employed and are not able to hire employees is an opportunity for poor rural communities in Brazil. Lambari production is a tool to developing Brazilian rural communities combining socioeconomic enhancement and environmental conservation (Fonseca *et al*., 2017).

Lambari is a low-trophic level small fish able to provide an alternative income source through the live bait market for poor communities. It also provides food security and conserving local biodiversity (Fonseca *et al*., 2017). Small fish can be consumed with bones, head and viscera, which are rich in minerals and vitamins and other nutrients such as calcium (Fiedler *at al*., 2016). Thus, as an important tool for sustainable food production and development of rural populations, lambari production systems also benefit local communities providing the farmers livelihood for a better standard of living.

The indicators showed great variability, partly due to great variation in the size of the farms, the number of employees and also for limitations in the number of replicates used in this study. These factors may be affecting the groups during the cluster analysis. The clustering for LCS is due the lack of employees hired by the farmers and self-employment proportion. The MCS and HCS presented similarities in hiring formal labor, generating job positions and both production systems were grouped in the cluster analysis. It is recommended to carry out studies that contemplate more number of farms and systems of production for better statistical analysis.

5. CONCLUSIONS

We conclude that the HCS was socially sustainable. It performed better for equality and income distribution, equality of opportunities and benefits for local communities. Both the LCS and MCS were classified as potentially sustainable. The production of lambari through the LCS opened opportunities for self-employment. However, social organization may improve the social benefits of the industry through association and cooperatives, increasing the inclusion of more workers by direct and/or indirect jobs.

During the research, the combination of the set of social indicators chosen generated an index able to detect, identify and quantify the main aspects of lambari production systems. It is recommended that other combinations and manipulations of the sub-indexes used to compare the differences be tested in further studies. Additionally, information on environmental, economic and institutional dimensions must be compared and integrated to achieve an efficient sustainability index.

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CAPÍTULO 4

ECONOMIC SUSTAINABILITY OF LAMBARI *Astyanax lacustris* PRODUCTION SYSTEMS

ECONOMIC SUSTAINABILITY OF LAMBARI *Astyanax lacustris* PRODUCTION SYSTEMS.

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ABSTRACT

This study aims to evaluate the economic sustainability of different lambari production systems of São Paulo State and compare them, considering the side effects (positive or negative) of the environment during the production. Based on the country's current most common lambari production systems in operation, we defined three types: low control (LCS), medium control (MCS) and high control (HCS). We obtained the data from nine farms in São Paulo State through direct interviews using a semi-structured questionnaire to determine indicators and indexes of economic sustainability divided into four categories. The results show that the HCS had a better performance in efficiency in the use of financial resources and resilience capacity. The LCS had superior score for ability to absorb negative externalities. The capacity for reinvestments was stronger for the MCS. We conclude that the HCS is economically sustainable with a final score of 0.832. The MCS and LCS are classified as potentially sustainable and medium sustainability, respectively. Public policies must encourage sustainable productions considering the valuation of externalities. This study also provides an accurate picture of the economic conditions for Brazilian production of *Astyanax lacustris*. The combination of the set of economic indicators chosen generated an index able to detect, identify and quantify the main aspects of lambari production systems. These indicators and index are adequate and effective tools to evaluate economic sustainability in aquaculture.

Key-words: externalities, set of indicators, performance scale, sustainability index

1. INTRODUCTION

Brazilian aquaculture produced 562,5 tonnes in 2015 and it is expected to grow 104% by 2025 following the world being the fastest growing industries of animal protein (FAO, 2016). From the freshwater species, the growth of lambari production stands out. Lambari is a small native species, with short life cycle and easy to produce. The Brazilian production of lambari was 244 tonnes and moved around US$[2] 512,188.00. São Paulo State, the largest producer, was responsible for 29% of the national production (IBGE, 2015). The main species farmed is the yellow-tailed lambari *Astyanax lacustris* (Fonseca et al. 2017). This species was previously known as *Astyanax altiparanae* (Garutti & Britski, 2000) but was recently re-described (Lucena & Soares, 2016).

The lambari production in Brazil has been growing, mainly due to the demand for live bait for sport fishing, contributing to the national economy though the tourism industry (Silva et al., 2011a). However, there are several market niches potentials to develop such as snacks for human consumption and forage fish in aquarium stores and public aquariums (Silva *et al.*, 2011b). There is little competition for space in the market with other species, especially products originating from agribusiness, such as tilapia (*Oreochromis niloticus*). The lambari use as attractor for industrial tuna fishing has been tested by the private sector after investigations for its salinity tolerance (Gonçalves et al., 2015a). Also, lambari can be used as a source of essential fatty acids for human and animal feeding (Gonçalves *et al.*, 2014) and great potential to replace canned sardines (*Sardinella brasiliensis*) and anchovies (*Anchoviella lepidentostole*) in the snack market (Porto-Foresti, *et al*., 2005). This could reduce the impact on the natural populations of those species, which are only available from fisheries. Nowadays, the natural stocks of lambari are decreasing due to overfishing or pollution. Therefore, the contribution to reduce the demand for natural stocks may add value and strengthen the appreciation of lambari derived from aquaculture production (Gonçalves *et al.*, 2015). Thus, production and market potential are large and can proliferate.

[2] Dollar quotation: R$3.20 - May, 2017

The market potential of lambari has instigated an increase in the number of farmers in the business. However, for progress to be stabilized, it is necessary to adopt sustainable practices. Production based solely on the current market and financial forecast, leads to systems that are not efficient or sustainable over time (Valenti *et al.*, 2010). Sustainable aquaculture is based on the rational use of financial, natural and human resources in the production process. In this way, it is an economically viable activity, which improves the quality of life of local communities, without degrading the ecosystems in which it is introduced (Arana, 1999; Valenti, 2002). It involves three components: profitable production, conservation of the environment and social development (Valenti, 2000). Each component is essential and inseparable for the activity to be perennial.

To achieve sustainable aquaculture, it is essential to measure the sustainability of the production systems used, the management techniques and the new technologies that are being generated and adopted. The Set of Indicators give a meristic view, making it possible to analyze each part of the production system separately. This allows you to locate the weaknesses and correct them. In addition, they should allow the consolidation in graphs or indices combined to allow a general interpretation. The data is easier to obtain and the interpretation of the results is simple and easily understood. The most used economic indicators are the annual income, the internal rate of return, the period of return of capital and the net present value (Shang, 1990). For analyses of sustainability, the costs of externalities, however, should be included in the mathematical equations that generate these traditional indicators. Externalities are side effects (positive or negative) of an economic activity. Negative externalities arise when some part of the cost of an activity is not borne by the producers or consumers of the good or service in question. From the application of these indicators to lambari farms, we will be able to evaluate the pertinence, effectiveness and adequacy of fish production in each production system. In addition, the indicators will show an overview of the sustainability of a national aquaculture segment.

Although production of *A. lacustris* is growing rapidly, there are no studies about economic sustainability of each production system. Economic indicators can guide fish farmers to make decisions to have a perennial business. Their knowledge can also be an important tool to adjust production technology compared to the market price of the product (Gonçalves *et al*., 2015b). Thus, this study aims to evaluate the economic sustainability of each lambari production system of São Paulo State and to compare costs of production, the minimum selling price and the economic viability of each system. With these answers, we show the strengths and weaknesses and point out possible solutions. In addition, evaluate the adequacy of sustainability indicators to compare different systems of aquaculture production.

2. MATERIALS AND METHODS

2.1. FARMS SELECTION PROCESS

The production of the yellow-tail lambari, *Astyanax lacustris*, involves different levels of intensification and technological sophistication (Silva *et al.*, 2011a). The cycle may vary according to the size of bait the current market needs. For the present study, we considered 120 days of cycle and based on the country's current most common production systems in operation, we defined three basic types:

The production of the yellow-tail lambari, *Astyanax lacustris*, involves different levels of intensification and technological sophistication (Silva *et al.*, 2011a). For the present study, based on the country's current most common production systems in operation, we grouped the farms in Low Control System (LCS), Medium Control System (MCS) and High Control System (HCS), according to the criteria defined in Gonçalves & Valenti, (Chapter 2).

Initially, we located the farmers of the State of São Paulo based on information from extension agents. The farmers were classified according to the three systems described above. We contacted them and three more representative farms of each system were chosen (Figure 1) to carry out the work.

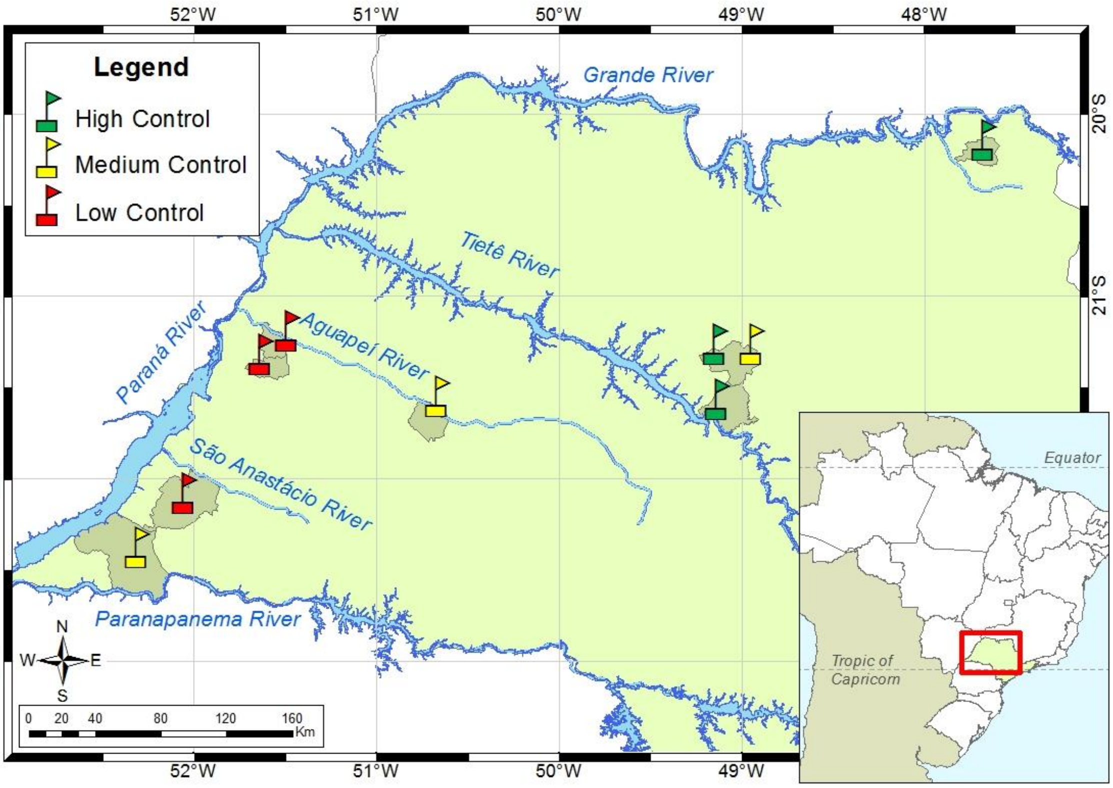


Figure 1 – Location and classification of the selected farms in Sao Paulo State.

2.2. EXPERIMENTAL DESIGN

We have analyzed the factor production system, with three levels (husbandry types) and three replicates for each level (each farm). We interviewed nine farmers to obtain the necessary data to calculate the indicators and determine the social sustainability of the lambari production systems using semi-structured questionnaires. These are true replicates because we obtained from different farmers.

2.3. ECONOMIC SUSTAINABILITY INDICATORS

The economic indicators were defined to reflect four aspects: The efficiency in the use of financial resources; the ability of resilience, that is, the ability to deal with future uncertainties and generate enough income to keep the producer on the business; the capacity to absorb the cost of the negative externalities, that is, the indicators must show if the income generated is real or if it comes from negative externalities, whose costs are not paid by the enterprise but by society or the environment; The ability to generate resources for reinvestments, that is, the indicators show if the activity generates its own resources for investment and growth.

All expenses were estimated, considering the initial investments for equipment, labor during construction and also the annual operating costs defined for each lambari production system. Gross revenues were determined considering the sale price per unit, according to size classes and productivity obtained in each system. The data needed to calculate the economic indicators were primary and secondary. The primary data was obtained from the farms through direct interviews with the owners, administrators, technicians and employees, using a semi-structured questionnaire. The secondary data was obtained through research carried out with public agencies, which maintains the records of the property and the region, such as IBGE, Ministry of Fisheries and Aquaculture (MPA), State Secretariats of Aquaculture and / or Agrarian Development, Prefectures between others. All monetary values were converted from Brazilian Reais to US dollars, based on the average trading price of the dollar for the quotation of May 2017 (US$ 1.00 = R$ 3.20).

For the category “efficiency in the use of financial resources” we used the following indicators (Table 2): The Income-Investment Ratio measures the income generated per unit of capital invested. Ventures with lower initial investment and that generate the same net income are more sustainable, since they correspond to a more efficient use of capital resources. For this category, we also used traditional economic indicators such as the Internal Rate of Return (IRR), Pay-back Period (PBP), Benefit-cost ratio (BCR) and Net Present Value (NPV) and Profit (P) (Shang, 1990) considering the inclusion of externalities (Valenti *et al*. 2011). The Internal Rate of Return takes into account the variation of capital over time. This indicator can be considered as the interest rate received for an investment over a given period within regular intervals where payments are made to cover all the costs of creating and proceeds from the sale of the product. When evaluating a project by Internal Rate of Return, it appears that it is economically viable only when the rate exceeds a specified interest rate. The minimum annual interest rate of attractiveness considered in this study was 13%, equivalent to the interest received on cash investments based on the SELIC (Special System of Settlement and Custody), which is released by the Brazilian

Monetary Policy Committee (COPOM). Demarcated by SELIC is that are set interest rates charged by financial market. Besides IRR, Net Present Value (NPV) is the present value of series of future revenues for a period, discounted using the interest rate, subtracted from net investment. The Pay-back Period (PBP) is defined as the number of years required for the company to recover the initial capital invested in the project. The Benefit / Cost Ratio (RBC) consider the relationship between annual net benefit in year (gross revenue minus operating expenses) and the capital invested in year (initial investment plus reinvestments). This indicator also considers the project horizon fixed in 20 years and discount rate based on the hurdle rate of attractiveness. The Profit (P) corresponds to Gross Revenue (GR) minus Total Cost of Production (TC) (Fixed costs + variable costs); P = GR-TC. Annual Income corresponds to the Gross Revenue (GR), deducting the Operating Expenses of production (OE), Depreciation (D), and Taxes (T), that is, all corresponds to Profit Plus the Cost of Opportunity, Taxes and Fees. The opportunity cost includes: owner's compensation, interest on fixed capital, and current, and land remuneration; AI = GR-OE-D-T.

To understand the “resilience capacity” category, we used the indicators of business longevity, that corresponds to the time (in years) that each farm is engaged in aquaculture, the average longevity of the farms. The risk rate measures the proportion of risk factors for lambari production systems present in the farms. We considered 17 factors that raise the risks and negative impacts on lambari production systems:

1. Lack of Business Plan in the installation planning phase.

2. The owner does not have technical and / or administrative training.

3. Administrative deficiencies, especially in logistics and problem solving.

4. Lack of well-established trade flow for the product, i.e. needs to open the market.

5. Farm is installed in protection areas or other inappropriate location, subject to floods, urban, rural and industrial pollution, etc.

6. Lack of responsible technician part-time or full-time.

7. Little experience or high turnover of technicians.

8. Employees not trained and does not outsource services to improve production and management or to solve problems.

9. The farm and technical advisors are not able to deal with diseases.

10. Lack of access to technical, economic and market information.

11. Inexistence of night and weekend supervision.

12. Lack of surveillance or security systems against theft.

13. Intensive system practice, which use many inputs and energy and operate close to the support capacity of the production system.

14. Lack of emergency systems to prevent disruption of electricity supply on farms that rely on this energy to operate vital equipment such as aerators.

15. Institutional instability: there are continuous changes in the legal rules and in the development, regulation and supervision agencies.

16. Agglomeration: there is proximity to other farms producing the same organism, which generates the use of the same environmental services and produces the same type of pollution.

17. The farm faces conflicts with the local community and / or NGOs.

TR = 1 - (number of risk factors present / number of factors analyzed)

For the same category we also considered the diversification of products and markets. The product diversity indicator measure the number of products offered by the farms like other agricultural products and / or services. The market diversity measures the number of markets that absorb production like wholesalers, fishing hotels and restaurants, respectively.

To determine the ability to absorb the cost of the negative externalities we considered the load of nitrogen, phosphorus, carbon and carbon dioxide equivalent retained, absorbed or emitted in the farms. We quantified these data to obtain environmental sustainability indicators for complementary study (Chapter 2). Thus, negative externalities are the losses caused to the environment (Pigou, 1963) in US$ per unit of production. Positive externalities measure the environmental services performed by the productions systems, such as retention of P and N in the produced biomass and absorption of greenhouse gases (CO_2e) from the atmosphere. It's also expressed in $ per unit of production. Based on these data, we calculated the externalities considering the following prices: Carbon US$ 30.00 per tonnes; Nitrogen US$ 20.00 per kg; Phosphorus US$4.00 per kg (Chopin *et al.*, 2012); CO_2e US$5.44 per tonne (Investing.com).

The capacity to generate resources for reinvestments were evaluated by the indicator Capital Generated reinvested, as the relation reinvestments / total investment. The sustainability of each lambari production system were evaluated by the proportion of invested capital that has been generated in the system itself.

Table 2 - Economic sustainability indicators used to assess lambari *Astyanax lacustris* production systems in Sao Paulo State, Brazil.

Indicator	Description
Efficiency in the use of financial resources	
Net Income-Investment Ratio	Annual Income / Initial Investment
Internal Rate of Return*	Shang, 1990; Jolly & Clonts, 1993
Payback Period*	Shang, 1990; Jolly & Clonts, 1993
Benefit Cost Ratio*	Shang, 1990; Jolly & Clonts, 1993
Net present value*	Shang, 1990; Jolly & Clonts, 1993
Profit *	Gross revenue minus total production costs
Annual Income	Profit plus the Cost of Opportunity, Taxes and Fees.
Resilience capacity	
Business longevity	Average life expectancy of companies
Risk rate	Risk factors observed/ total risk factor analyzed
Product Diversity	Number of products offered by the enterprise
Market Diversity	Number of markets that absorb production
Ability to absorb the cost of the negative externalities	
Negative Externalities	Pigou, 1963; Valenti *et al*, 2011
Positive Externalities	Environmental services performed by production
Capacity to generate resources for reinvestments	
Capital Generated Reinvested	Reinvestments / total investment

* The externalities are considered

2.4. ANALYSIS OF RESULTS

The obtained variables were compared between systems by multivariate exploratory data analysis. Data was standardized to perform Cluster (using Euclidian distance and UPGMA - Unweighted Pair Group Method using Arithmetic averages) and Principal Components Analysis (PCA).

Each indicator was converted into a performance scale (Bellen, 2008, Valenti, 2008), with scores ranging from 0 to 1 and expressed in multidimensional diagrams. The treatment with the best indicator value (more sustainable when compared to the others) was arbitrary scored as 1, and the others were determined by proportion. Thus, the indicators were grouped into four categories: (a) Efficiency in the use of financial resources; (b) Resilience capacity; (c) Ability to absorb the cost of negative externalities; (d) Capacity to generate resources for reinvestments; Sub-indexes were computed for each category by the average of their respective indicators. Only the category (e) represents the value of its unique indicator. The Economic Sustainability Index was determined by the average of the four sub-indexes for each system. The economic indicators of the lambari production systems were classified by how sustainable they are according to the range of the performance scale (Valenti, 2008) as shown in Table 3.

Table 3 – Performance scale used in the classification of sustainability for the lambari production systems of Sao Paulo State.

Range	**Classification**
0.000 - 0.200	Not sustainable
0.201 - 0.400	Low sustainability
0.401 - 0.600	Medium sustainability
0.601 - 0.800	Potentially sustainable
0.801 - 1.000	Sustainable

Adapted from Valenti (2008)

3. RESULTS

The production factors and features of the lambari production systems are described in Table 4. The better productive performance for FCR and productivity in the MCS and HCS reflected in the average production cost per kilogram. The survivor rate is unknown in the LCS and also for some crops of MCS. Once the MCS obtain young forms from hatcheries, this production system present higher survivor rate then HCS due its smaller productive area able to invest in anti-bird net.

Table 4 – Production factors and management practices of lambari *Astyanax lacustris* production systems.

Production factors	**LCS**	**MCS**	**HCS**
Reproduction/Hatchery	Natural without control	Induced in the pond	Induced and controlled in lab
Production period (days)	120	120	120
Crops/year	3	3	3
Total pond area	0.85 - 1.50	1.50 - 6.20	1.05 - 200
Fertilization regime	Poultry manure	Poultry manure	Poultry manure; Chemical fertilizer
Stocking seed	larvae	larvae	fry
Stocking density - Beginning	N/A	N/A-250[a]	250
Stocking density - Grow-out[b]	9	17-25	30
Water temperature (°C)	25-33	28-35	18-31
Water exchange (%/day)	3.69	6.97	5.75
Dissolved oxygen (mg/l)	4-6	3-6	3-7
Diet protein content (%)	28	56-32	56-32
Feeding frequency	2/day	3/day	3/day
Feed conversion ratio (FCR)	1.83	2.02	1.57
Feed prices (US$/kg)	0.61±0.06	0.50±0.06	0.78±0.23
Survival (%)[c]	N/A	N/A-67[a]	56
Final fish length (cm)	8	9.33	9.66
Final fish weight (g)	10	16	18
Total production costs (US$[d]/unit)	0.06	0.06	0.07
Total production costs (US$[d]/kg[e])	5.79	4.28	4.57
Sale price (US$[d]/unit)	0.07	0.08	0.08
Sale price (US$[d]/kg[e])	6.98	5.52	5.42
Productivity (t/ha)	1.8	6.09	6.94

[a] In case young forms origins from hatchery
[b] Estimated though the declared production
[c] Estimated though the declared initial stocking density
[d] US$ 1.00 = R$ 3.20, Feb, 2017
[e] Converted considering the price by unit and final weight of fish

The indicators of economic sustainability are presents divided in four categories (Table 5). The HCS showed the larger values of annual income. It can be up to 82 and 17 times larger than LCS and MCS, respectively. The total pond area has the larger variation for HCS and presents a scale effect on the indicators. However, considering the large variability in the total pond areas of the farms, the values of annual income per hectare are US$ 5,928.76, US$ 11,237.53 and US$ 8,298.86 for LCS, MCS and HCS, respectively. The farmers of the MCS have been working in the business for less time than the farmers from the others production systems. However, they presented an Internal Rate of Return (IRR) close to the HCS. The LCS was more efficient to absorb negative externalities due environmental services calculated at the positive externalities.

Table 5 - Indicators of economic sustainability of different production systems of lambari *Astyanax lacustris*.

Indicators	Low Control	Medium Control	High Control
Efficiency in the use of financial resources			
Income-Investment Ratio (%)	18±14	33±13	47±59
Internal Rate of Return (%)	17.6±12.7	24.61±10.7	28.6±29.2
Payback Period (years)	8.3±7.0	5.3±2.0	6.9±2.6
Benefit Cost (US$)	2.00±1.23	3.40±1.15	4.60±5.25
Net present value (US$)	33,990±43,793	207,116±138,178	4,434,793±7,633,674
Profit (US$)	3,082±4,968	22,345±15,800	445,385±764,532
Annual Income (US$)	6,706±4,727	32,490±18,815	549,289±934,990
Resilience capacity			
Business longevity (years)	22.0±6.1	8.0±4.2	18.3±9.4
Risk rate	0.18±0.10	0.36±0.15	0.40±0.12
Product Diversity	3.3±1.1	3.0±1.0	2.3±1.5
Market Diversity	2.7±0.6	3.0±1.7	3.3±0.6
Ability to absorb the cost of the negative externalities			
Negative Externalities (US$/t)	690±1,088	526±714	246±309
Positive Externalities (US$/t)	1,404±1,040	1,019±314	914±193
Capacity to generate resources for reinvestments			
Capital reinvested (US$)	575±49	6,488±6,787	4,186±3,660

The cluster analysis did not recovered the groups defined a priori for the production systems due a larger variability of the economic indicators (Figure 2). However, partial grouping can be idenfied to LCS and HCS.

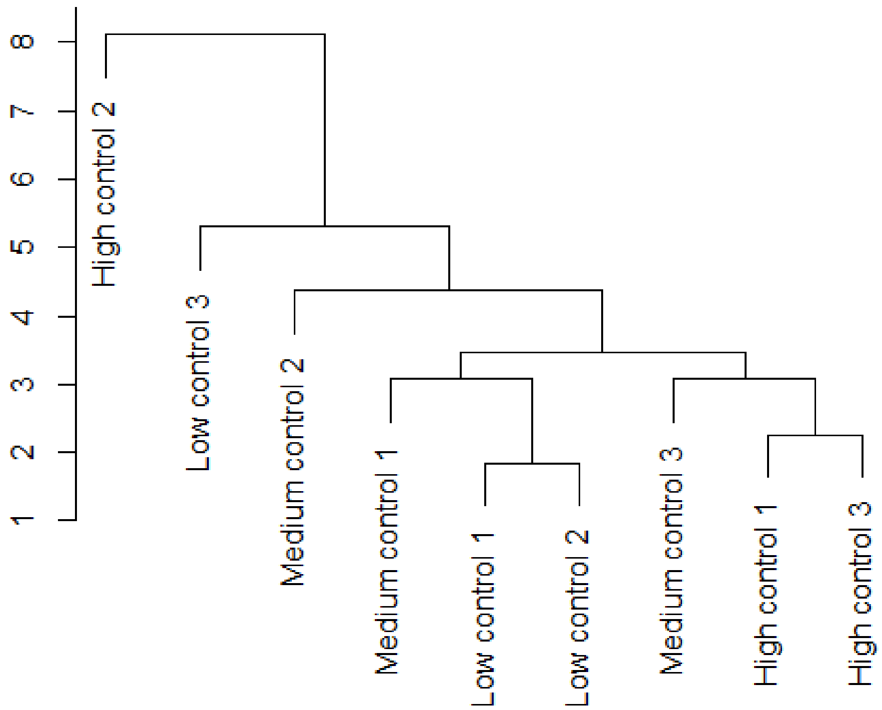


Figure 2. Dendrogram of dissimilarity of economic sustainability indicators of lambari production systems (Euclidean distance)

The economic sustainability indicators submitted to the Principal Components Analysis (PCA) are not able to show which components could generate patterns for clustering of cohesive groups (Figure 3).

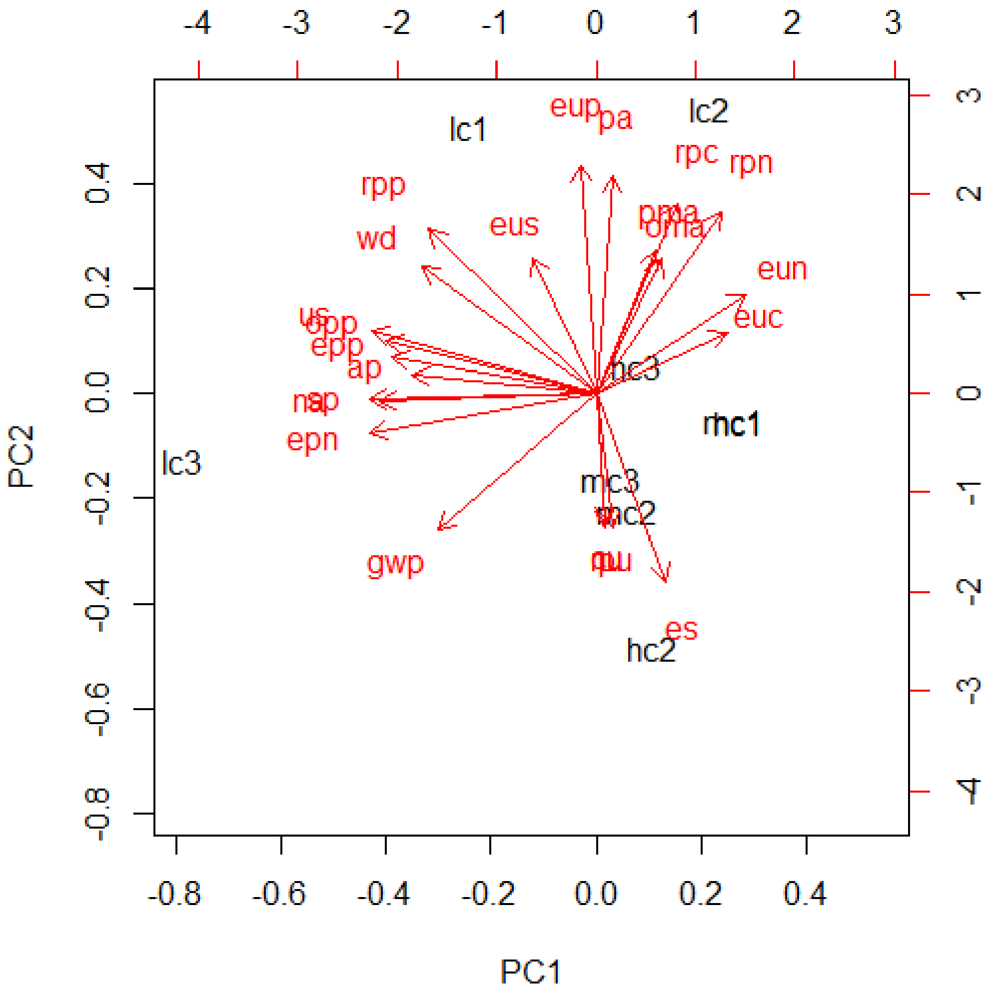
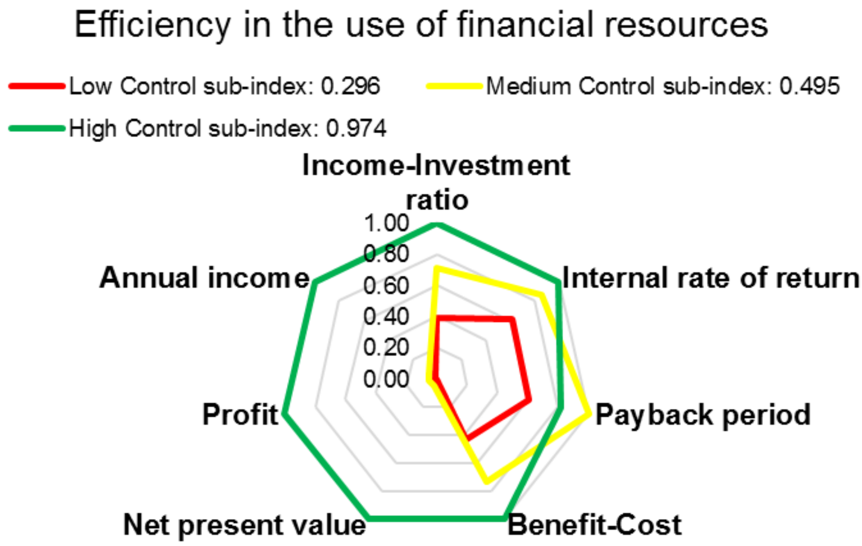


Figure 3. Principal components Analysis (PCA) for economic sustainability indicators of lambari production systems in São Paulo State. lc=low control; mc=medium control; hc=high control; iir=income-investment ratio; irr=internal rate of return; pp=payback period; bcr= benefit cost ratio; npv=net present value; p=profit; ai=annual income; rr=risk rate; pd=product diversity; md=markets diversity; lb=longevity in the business; ne=negative externalities; pe=positive externalities; cgr=capital generated reinvested.

The HCS had the best performance in six of the seven items for “efficiency in the use of financial resources” (Figure 4a). It also had the best score for their “resilience capacity” (Figure 4b). The categories “ability to absorb the cost of the negative externalities” and “capacity to generate resources for reinvestments” has few elements to be shown in multidimensional figures. Although, the LCS and MCS presented the best performances for these categories, respectively (Table 5).

a)



b)

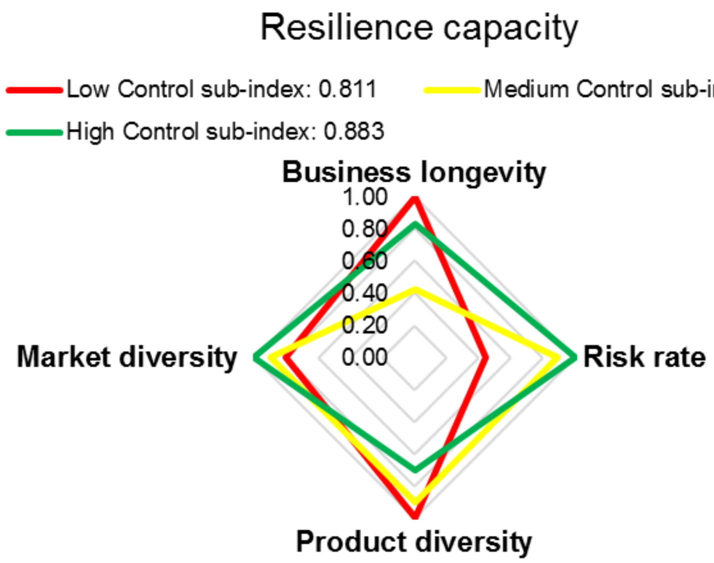


Figure 4. Indicators of sustainability obtained for each category (a) Efficiency in the use of financial resources; (b) Resilience capacity, with their respective sub-index for each treatment.

The efficiency in the use of financial resources presented low sustainability for the LCS. The construction of the final economic sustainability index considered the results of each category of the set of economic indicators below (Table 6). This final result establishes that the HCS is sustainable, with a final score of 0.832.

Table 6 – Economic Sustainability Index of the production systems of lambari *Astyanax lacustris*.

Sub-index	**LCS**	**MCS**	**HCS**
Efficiency in the use of financial resources	0.296	0.495	0.974
Resilience capacity	0.811	0.778	0.883
Ability to absorb negative externalities	0.881	0.807	0.825
Capacity for reinvestments	0.089	1.000	0.645
Final Score	**0.519**	**0.770**	**0.832**

For each category of the set of economic indicators, we can see the weaknesses and strengths of the lambari productions systems through the economic sustainability index (Figure 3).

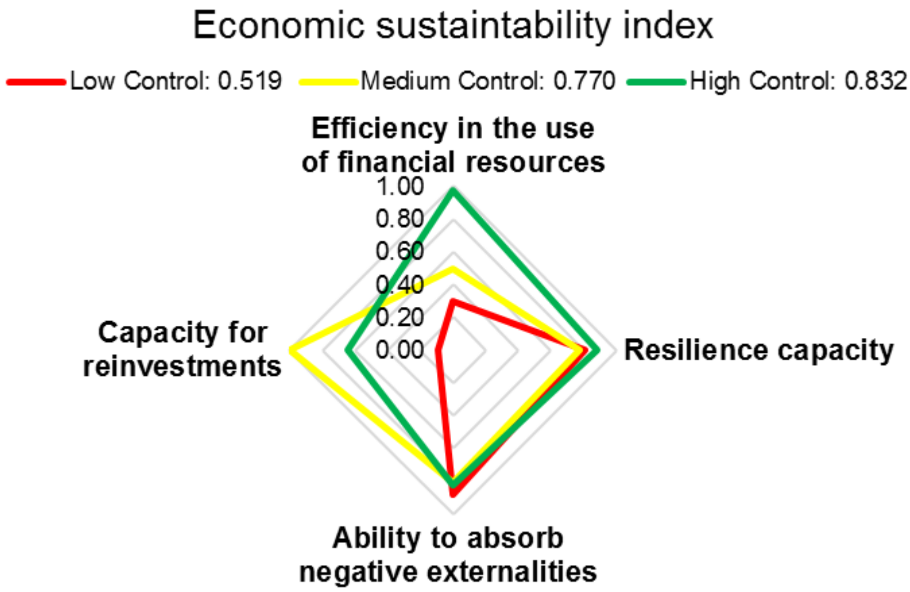


Figure 5 – Economic Sustainability Index

4. DISCUSSION

The present study considered the real conditions of the current lambari production systems and describes the economic situation of lambari production in Brazil. The HCS was more efficient in the use of financial resources. However, its production costs were higher than MCS. The production of lambari *Deuterodon iguape* in cages inside tilapia ponds presented production cost of US$ 6.67/kg (Gonçalves *et al*., 2015b), which is 56% higher than MCS. For the internal rate of return (IRR) the polyculture system was 61%, 32.4% better than the HCS. The production of tilapia in cages in the northeast of Brazil also presented better economic efficiency, and presented 52% of IRR (Moura *et al*., 2016). However, all the lambari production systems are economic feasible because they present

IRR higher than the minimum annual interest rate of attractiveness stipulated to 13%. Additionally, lambari production present the advantage to provide income faster than other species such as tilapia due the 120-days grow-out cycle (Gonçalves *et al*, 2015). The LCS and HCS are sustainable for resilience capacity. For this category, LCS farmers are almost 3 times longer in the business than the farmers of the MCS, classified as potentially sustainable. Also, the HCS farmers were able to guarantee lower risk rates than MCS and LCS due its better management capacity and to provide security equipment for the employees. All the production systems are classified as sustainable for absorbing externalities of the production. However, the LCS are not sustainable for reinvestments compared to MCS and HCS.

Management practices and strategies vary wildly between lambari farms (Fonseca *et al.* 2017). Farms that use the same production systems have specificities such as the owners' experiences, location and access to supplies and others, which results in large variability and standard deviations. However, we highlighted important features that are comparable and able to identify the strengths and weaknesses for each production system. The productivity is the major factor that differ the production systems. The LCS presented lower productivity compared to MCS and HCS (Table 3). This affects all the indicators, because they are calculated considering the production. However, MCS and HCS had close values and performances. The proximity established between MCS and HCS to obtain young forms also provides the sharing of experiences and management strategies. Feeding frequency, diet composition, fertilization are some points of similarity, which are related to their capacity to learn new practices and techniques through courses they were able to participate.

The productivity as the strengths of the MCS and HCS improves their performance on the economic indicators and categories scores as well as it is the weakness of the LCS. The production cost was 35% higher for LCS compared to MCS caused by lower productivity. Fonseca *et al*., (2017) pointed the poor management practices exist and current science-based information is still insufficient to provide technology to match rural farmer realities or needs. Although the LCS may look as a startup for the business in an extensive approach, the farmers are longer in the industry and they are resistant to adopt new techniques, especially for the reproduction through hormonal induction in laboratory. This technology demands investments and knowledge that may be difficult for successful adoption considering that the LCS farmer's education level is lower than MCS and HCS. Thus, simple alternative strategies are needed to improve systems' efficiencies (Fonseca *et al*., 2017).

The farmers of the HCS had higher operational costs than the farmers from the other systems because of higher expenses with labor. The contribution of the supplies in the operational cost was 71, 77 and 63% for LCS, MCS and HCS, respectively. Sabbag et al. (2011) observed that the inputs impact 74% of the operational costs on a LCS lambari farm. Additionally, the investments with infrastructure, equipment for the hatchery and operations with the reproduction laboratory for HCS had 6.9 years of payback period. It is more than double of time to recover the invested capital compared to tilapia production in cages, which had 3.22 years (Moura *et al*., 2016). However, the average productive area in the HCS is up to 52 times larger than the LCS. Large-scale production reduces the operational costs in relation to the total cost of production and increases the financial efficiency. Also, one of the sampled farms of the HCS (Buritizal) is considered the biggest lambari farm in Brazil. Its productive area is 200 times larger than the average of 1.0 ha in São Paulo State (São Paulo, 2008). Its economic results are significantly higher in comparison to the other farms, increasing the average scores of indexes of the HCS.

All the sampled farms are multifunctional, offering other products and services. However, we considered the income based exclusively on the lambari production for the calculation of the economic indicators. The farms are located in areas where the annual per capita income is between US$ 885.04 and US$ 3,428.85, where the average for São Paulo State is US$ 5,557.50 (IBGE, 2015). The annual income of all lambari production systems was 1.2, 5.8 and 98.8 times larger for LCS, MCS and HCS, respectively, than the average annual per capita income for São Paulo State. Just the lambari production is sufficient to give the owners and their families an acceptable standard of life in the region and that guarantees longevity in the business. Other products, like milk, cattle, fruits, vegetables and services like restaurants, bait stores and sport fishing parks are offered by the farmers to diversify the income of the families that works on lambari production. The HCS had less products diversity, but it accessed more markets. This means that HCS farms are more specialized in one product, in this case, live lambari for bait. The LCS and MCS are smaller scale farms compared to HCS farms. The income from lambari sales is preferred to attend the sport fishing industry though its consumers. This is the most profitable market that the lambari farmers have access. However, in some cases, the production of lambari is also a mean to promote food security for rural poor people in Brazil (Fonseca *et al*., 2017). Usually, the consumption of lambari is whole with the head and bones, which may provide calcium. Even though information about lambari as a nutrient source is underestimated, small indigenous fish consumed whole have a large potential to contribute to micronutrient intake (Fiedler *et al*., 2016). However, the production of lambari to promote food security does not occur for the farmers of this present study. To sale lambari for fishermen, hotels at fishing parks and bait stores guarantee the economic sustainability even for smaller farmers from LCS that are able to purchase their nutritional needs.

The demands of live bait for sport fishing can vary in each season and/or region. It can determine the size of lambari to the local market and also the distribution of farmers. When the fishing season is closed for the management of native species reproduction, the fishermen are allowed to capture introduced species in watersheds such as African cat fish, black bass, tilapia, tucunaré, pescada do Piauí and hybrids. During this period, sport fishermen can use 8 to 12 cm lambari to capture “tucunaré” (*Cichla spp.*), in reservoirs in the Tietê river. Also, lambari 5 to 7 cm can be used to capture “pescada do Piauí” (*Plagioscion squamosissimus*) in the Parana and Paranapanema rivers (Figure 1) (Silva *et al.*, 2011). In the United States the market for baitfish has greatest demand for small minnows in the spring. The golden shiners (*Notemigonus crysoleucas*) the spawned one spring must be kept small throughout the year for sale the following spring (Stone *et al*., 2016). Small farmers from the LCSs produce smaller lambari. The average final weight of lambari was 10, 16 and 18 g for the LCS, MCS and HCS, respectively. The total cost to produce 1 g of lambari is 54% higher for LCS than for MCS and HCS. Despite the economic disparity in production potential between the HCS and MCS, the LCS has experienced more longevity in the business (Table 2). This is due to the strong relationship between the smaller scale farmers and the consumers which is based on trust and loyalty (Silva *et al.*, 2011a).

The demand for processed lambari for snacks is estimated in 120,000 kg per month in São Paulo State, but just half of this is attended by captured fish in reservoirs (Dr. F. Sussel, personal communication). Lambari captured from natural stocks has disadvantages for snacks in terms of quality, size, flavor and crunchiness. The coast of the State has a strong snack market with *Anchoviella lepidentostole* from fisheries in beach kiosks and restaurants. Additionally, lambari from aquaculture production is well received in those commercial places and is an alternative to supply this demand during closed fishing season. (Silva *et al.* 2011b). This potential for snacks had never been developed on a commercial scale due the difficulties in processing. Recently, the private sector developed a specific machine able to process 250 kg of lambari per day. The cost of investment for purchasing this machine is US$11,875.00 and it improves the efficiency of processing by 12.5 times compared to the rate of 20 kg of lambari per day without any equipment. This possibility opens new market niches for farmers of all production systems. However, post-production elements must be organized for adequate processing, distribution and commercialization, marketing to reach the final consumer (Valenti & Moraes-Valenti, 2010). New investments, collaborative work between farmers and technical assistance are essential to reinforce the processed lambari market chain. Another potential market niche is the tuna fishing industry. Nowadays only the biggest farmer of the HCS accesses this market niche. The demand for one single fishing vessel can be up to 800,000 units of lambari per fishing expedition. The use as attractor for tuna schools is possible due the tolerance of the lambari to marine salinity for enough time to perform the fishery. Also, reports about the efficiency of lambari use for this proposal compared to sardines create a huge potential for direct sales to the tuna fisheries industry (Gonçalves *et al.*, 2015a).

The major risks observed of the lambari production systems are the lack of business plan, access of technical, economic and market information and technical assistance. HCS have a greater economic power to invest in services, security and technological improvements to reduce the risk rates. Some of the farms were located in rural settlements and had a lower financial capacity to invest in structure to avoid risks. The access to financial support programs along with technical assistance for the application of technologies, access to information and good practices can help small farmers to improve their production and economic efficiency. This could enable them to profitably access other market niches and may increase their resilience when facing economic, environmental, social and institutional difficulties. Thus, the HCS had stronger resilience capacity and its results but closed followed by the LCS.

Weather conditions may affect the water supply and may offer risk to the production. During 2014, São Paulo State experienced a severe dry season that made all the farmers reduce production for saving water. The river's water levels significantly decreased, many fish died due to lack of dissolved oxygen and concentrated pollutants. In the following year, the rain season recovered the water sources to supply the farms but the rivers and reservoirs remained low. Because this water level made it easier to catch fish, the sport fishing demand for live bait increased, thus benefiting lambari sales. Although the market was favorable, the larger scale farmers from the HCS struggled to supply the demand with the remain effects of the dry season. In Bangladesh, natural disasters showed the poor people were more vulnerable and suffered significantly higher economic, physical and structural damage. However, this high vulnerability did not necessarily lead to low resilience, as these individuals exhibited a greater ability to withstand the shock compared to their non-poor neighbors (Akter & Mallick, 2013).

The retention of P and N in the produced biomass and absorption of greenhouse gases (CO_2e) from the atmosphere were measure for all sampled farms in complementary study (Chapter 2) of the environmental sustainability. The benefits of the positive externalities during the production decreased the costs of production in 22.32, 9.29 and 5.38% for LCS, MCS and HCS, respectively. The production of lambari were able to absorb negative externalities and offer environmental services, retaining nutrients and greenhouse gases. Other species such as tilapia and white shrimp in Thailand presented impacts with externalities with models to improve planning and increase awareness of the comparative performance of different types of aquaculture (Ferreira *et al.*, 2014). Fish farmers have an incentive to produce responsibly, and are more likely to internalize environmental externalities than many other activities because environmental damage directly affects their own output. From enlightened self-interest, farmers themselves have an incentive to reduce pollution. The use of antibiotics in Norwegian salmon farming has fallen dramatically since 1987 and is now almost insignificant. Its use was a negative environmental externality but also a threat to the image of (and markets for) Norwegian farmed salmon (Bjørndal *et al.*, 2003).

Examining the externalities in production systems introduces further implications for development of public polices which consider the concept of nutrient trading credits (Chopin, 2013). It is an important tool to regulate sustainable production systems. Economic advantages from these credits may encourage farmers and entrepreneurs from different sectors to adopt good practices of production and increase positive externalities or even provide incentive to decrease negative externalities. Ecosystem services must be considered in these efforts as well for developing new aquaculture systems. Some of the externalities of monoculture systems are internalized and increase the overall sustainability, long-term profitability and resilience of aquaculture farms (Chopin *et al.*, 2010). The Brazilian lambari production can incorporate integrated multi-trophic aquaculture (IMTA) strategies. IMTA systems combine species from different trophic levels or complementary ecosystem functions in the same aquaculture system (Chopin, 2013). Studies considering IMTA with lambari and amazon-river prawn and also other species are in course to compare indicator and indexes. These systems are economic attractive and it adoption improve sustainability. Other alternatives such as the production of lambari in cages into tilapia ponds are economic feasible and present other advantages. This production system excludes agonistic encounters, reducing competition between the species, favoring productivity and the use of cages facilitates the handling for farmers (Gonçalves et al., 2015b).

The set of indicators were adequate and effective to evaluate the economic sustainability in lambari production systems. This tool also presents a great applicability for economic sustainability assessment for other aquaculture production systems, considering the externalities. However, the choices and interpretations of sub-indexes emphasize the subjectivity in the construction of the economic index. The MCS and HCS presented the highest economic sustainability and according to the performance scale they were classified as potentially sustainable and sustainable, respectively. However, considering some of economic indicators like profit, annual income and capacity for reinvestments per hectare or per production, the large-scale production contributes for the economic difference between LCS and the other two production systems. To turn the data more comparable, the adoption of economic indicators divided per hectare or production may offer different interpretation of the results that can be useful for other applications. Nonetheless, sensibility is necessary to avoid distortions in the results. For example, the low productivity of LCS provides lower production. Since you divide your economic indicator by a smaller denominator, results a greater value. Thus, the LCS would be presented as the most economic sustainable production system.

The indicators showed great variability, partly due to the differences in productivity, great variation in the size of the farms and also for limitations in the number of replicates used in this study. These factors may be affecting the groups during the cluster analysis. The partial clustering for LCS and HCS may be associated to the similarities of each of their financial performance. The HCS did not grouped all the tree replicates because of the presence of the farm from Buritizal, that presented higher economic performance. It is recommended to carry out studies that contemplate more number of farms and systems of production for better statistical analysis.

Technical support is strongly recommended, especially for the LCS farms, for improvement in the use of financial resources and system efficiencies. Simple solutions and strategies must be developed to match the farmer necessities. Our findings also provide a picture of the economic conditions for Brazilian production of *Astyanax lacustris*. The farms in this study are a good sampling, representative of the whole country's current most common production systems in operation from the smallest rural settlements to the larger full scale productions. Furthermore, these samples reported total gross revenue by production US$3,441,515.62, which is 5.7 times larger than official national production report (IBGE, 2016).

5. CONCLUSIONS

We conclude that the HCS is the most economic sustainable system to produce lambari of the São Paulo State. It presented the greater efficiency in the use of financial resources and superior resilience capacity and its score is classified as sustainable according to the performance scale. The MCS presented better capacity for reinvestments and it is classified as potentially sustainable. All the production systems were classified as sustainable for being able to absorb part of the negative impacts from production. This is an opportunity for public policies to encourage sustainable productions considering the valuation of externalities.

The combination of the set of economic indicators chosen generated an index able to detect, identify and quantify the main aspects of lambari production systems. However, it is recommended that other combinations and manipulations of the sub-indexes used to compare the differences be tested in further studies. Additionally, information about environmental, social and institutional dimensions must be compared and integrated to achieve an efficient sustainability index.

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CAPÍTULO 5

INSTITUTIONAL SUSTAINABILITY OF LAMBARI *Astyanax lacustris* PRODUCTION SYSTEMS

INSTITUTIONAL SUSTAINABILITY OF LAMBARI *Astyanax lacustris* PRODUCTION SYSTEMS

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ABSTRACT

Set of indicator for measuring sustainability can be useful tool for analyzing governance, making public policy, building scientific knowledge, and even influencing ruling elites. Although cultivation of *A. lacustris* is growing rapidly, there are no studies about governance of the industry and each production system. We interviewed nine farmers to obtain the necessary data to calculate the governance indicators for lambari production systems, which were classified according to their levels of control of production in low (LCS), medium (MCS) and high (HCS). The indicators were grouped in three types of governance: hierarchical, market and participatory. The LCS had a better score in the category market governance. However, the HCS had a better performance in two of three categories of governance indicators for hierarchical and participatory governance, respectively. This is reflected at the score in the governace index. The HCS presented better governance and it is classified as potentially sustainable for the institutional dimension. Also, analyzing the trajectory of lambari production development, the existence of the HCS is the result of good hierarchical and participatory governance. The market governance guides the lambari production. However, the participatory governance is able to improve sustainability through specialized technical assistance. The combination of the set of indicators for local assessment with other theoretical background for global analysis provides an adequate picture of the institutional sustainability and to propose solutions that are essential for the sustainability of aquaculture.

Keywords: Community participation, public policies, solidary economy, social capital.

1. INTRODUCTION

The escalation of production of aquatic species carries issues related directly to its sustainable development and demand sustainability studies. In Brazil, the production of lambari *Astyanax lacustris* (Lucena & Soares, 2016) is growing, mainly due to the demand for live baits for sport fishing (Gonçalves *et al.,* 2015). The market potential of lambari has instigated an increase in the number of farms. Scientists, politicians and other stakeholders of aquaculture have neglected the importance of a multidisciplinary approach to the aquaculture production chain (Valenti & Moraes-Valenti, 2010) to adopt sustainable practices. Amongst these, there are issues related to the environmental impacts, economic feasibility and social equity and to the set of arrangements constituting the sector's governance (Lazard *et al.*, 2011). Governance is defined as including ''the state's institutional arrangements; the processes for formulating policy, decision making, and implementation; information flows within government; and the overall relationship between citizens and government" (Woods, 2000). Also, good governance involves promotion of transparency, accountability, efficiency, fairness, participation and ownership. These values translate into a broad objective to improve political accountability, participation, an effective rule of law, transparency, and flows of information between governments and their citizens" (Woods 2000). Thus, governance is a system of rules based on interpersonal relations and laws, creating conditions for the consolidation of aquaculture sustainability.

Production based solely on the current market and financial forecast, leads to systems that are not efficient or sustainable over time (Valenti *et al.*, 2010). To achieve sustainable aquaculture, it is essential to measure the sustainability of the used production systems, the management techniques and the new technologies that are being generated and adopted. Indicators can capture multiple facts or dimensions of a complex, multi-dimensional concept in a way that facilitates straightforward evaluation and comparison. Such measures can be useful tools for analyzing governance, making public policy, building scientific knowledge, and even influencing ruling elites (Gisselquist, 2014; Mitra, 2013). Several discussions of aquaculture sustainability are based on a single component of sustainable development. Very little work has been undertaken on a global and comparative basis (Lazard et al, 2011). This fact reemphasizes that governance is a complex and multi-layered concept, which makes it difficult to summarize into a single indicator. Thus governance indicators are 'composite' indicators. They try to capture the varied dimensions involved in the concept of 'good governance' as envisaged by agencies, organizations and scholars interested in the topic (Mitra, 2013). The "governance tools" aims to harmonize human and ecological well-being by internalizing externalities that result from short-sighted behavior. It is based on the principles of governance for aquaculture that are accountability, effectiveness / efficiency, equity and predictability (Hishamunda *et al.*, 2014).

The institutional dimension (Lazard et al., 2011) is measured by governance indicators that can be grouped in three types of governance: hierarchical, market and participatory. Hierarchical governance refers to the traditional concept of "government" with elites and top-down decision-making. It is more common in societies where there has been a tradition of centralized authoritarian control. Market governance leaves aquaculture mainly to supply and demand forces. Its goals are enhancing industry profitability and competitiveness. It is common in Europe and in countries where one of the priorities of governments is foreign-exchange earnings. The participatory governance extends from industry self-regulation using codes of practice, comanagement of the sector with industry representatives and government regulators, to community partnerships. It is being increasingly applied in aquaculture, especially where democratic values are widespread (Hishamunda *et al.*, 2014). From the application of governance indicators to the lambari industry, we can evaluate the pertinence, effectiveness and adequacy of the assessment methods for production systems. Also, the indicators show an overview of the sustainability of a national aquaculture segment.

Governance studies are new and some approaches have not been adequately explored by the scientific community due to methodological lack of standards (Gisselquist, 2014). The application of governance assessment for aquaculture industry follow FAO guidelines for aquaculture which states that research must be developed and analyzed with a multidisciplinary ecosystem approach (FAO, 2016). The consolidation of the methods used will allow its application in further research in all sectors of aquaculture and in the evaluation of the industry, supporting in the decision making process in the elaboration of public policies. Thus, evaluations of the sustainability of production systems considering the governance as the institutional dimension may become obligatory to place Brazilian aquaculture products in differentiated markets.

Although cultivation of *A. lacustris* is growing rapidly, there are no studies about governance of the industry and each production system that allow the farmers a perennial business. Thus, this study aims to define a set of indicators of governance for lambari production systems of São Paulo State and to compare them. With these answers, we show the strengths and weaknesses and point out possible solutions. In addition, evaluate the adequacy of governance indicators to compare different systems of aquaculture production.

2. MATERIALS AND METHODS

2.1. FARMS SELECTION PROCESS

The production of the yellow-tail lambari, *Astyanax lacustris*, involves different levels of intensification and technological sophistication (Silva *et al.*, 2011a). For the present study, based on the country's current most common production systems in operation, we grouped the farms in Low Control System (LCS), Medium Control System (MCS) and High Control System (HCS), according to the criteria defined in Gonçalves & Valenti, (Chapter 2).

Initially, we located the farmers of the State of São Paulo based on information from extension agents. The farmers were classified according to the three systems described above. We contacted them and three more representative farms of each system were chosen (Figure 1) to carry out the work.

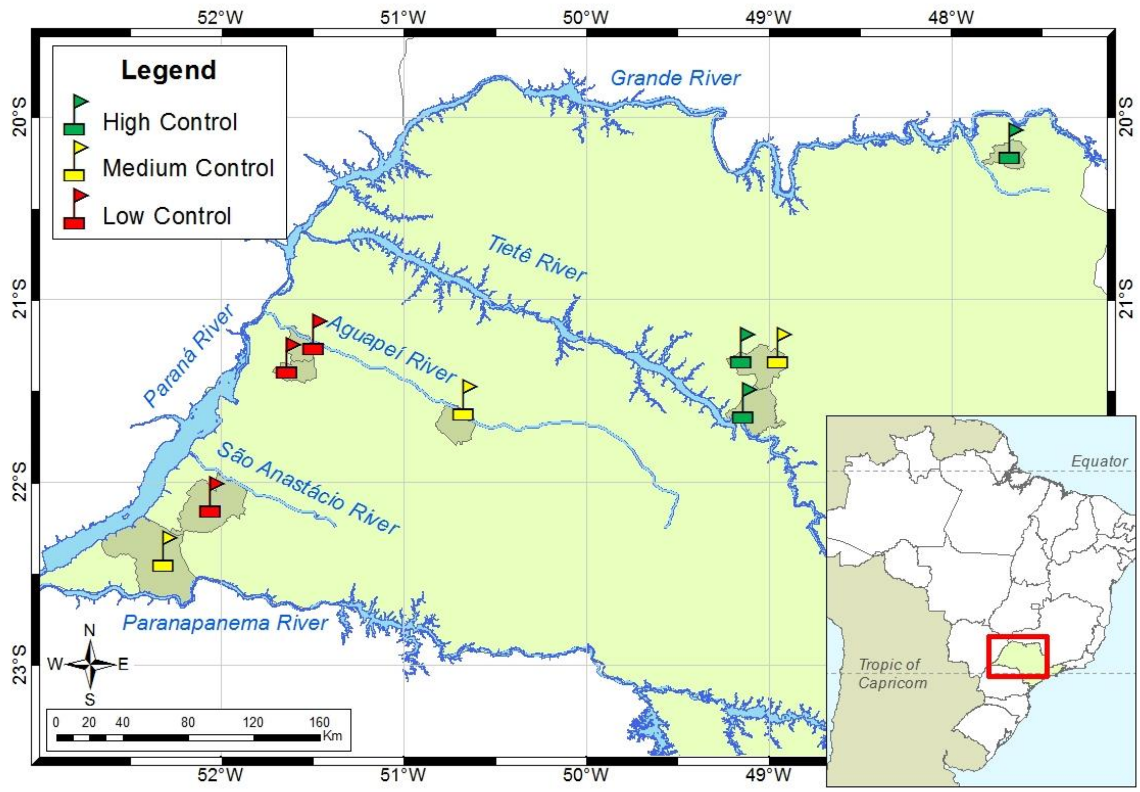


Figure 1 – Location and classification of the selected farms in Sao Paulo State.

2.2. EXPERIMENTAL DESIGN

We have analyzed the factor production system, with three levels (husbandry types) and three replicates for each level (each farm). We interviewed nine farmers to obtain the necessary data to calculate the indicators and determine the social sustainability of the lambari production systems using semi-structured questionnaires. These are true replicates because we obtained from different farmers.

2.3. GOVERNANCE INDICATORS

We defined the governance indicators according to their relevance for the lambari production business in Sao Paulo State. A participatory approach was used during the interviews to register the actor's perceptions and knowledge in the territory through progressive score according to its benefits, starting from zero for the worst considered condition. Similar approach has been used by Lazard *et* *al*. (2011). The indicators were grouped in three types of governance: hierarchical, market and participatory.

2.3.1. Hierarchical governance

Infrastructure (I): The development of the activity depends directly on the infrastructure conditions existing in the territory provided by the government. How are the conditions in the territory in relation to: access roads to the project, connection between territories, telephone, electricity, internet, health posts, input industries, processing industries, ports, airports, railroad? We analyzed the set of infrastructure (great=4, good=3, medium=2, bad=1, terrible=0) and in the sum of the infrastructures available.

Presence of Extension and Technical Assistance (PTA): The development of the activity goes directly by the presence in the territory of agents of public aquaculture extension and agents of the technical assistance of the private initiative (Specific public or private=2, Private or non-specific=1, Not existent=0).

Presence of the State Assistance (PSA): The government represented in its various structures at the municipal, state and federal level effectively acting on the stimulus, regulation and supervision can determine the degree of development of the activity. The existence of sectoral and thematic chambers integrated by fish farmers, government agents and other representatives of the production chain in the territory contribute to the development of the activity. As well as the existence of development plans in the territory (Present=2, Partially present=1, Not present=0).

Existence of Certification and Traceability (ECT): Does local government provides easy-to-access and low-cost certification and traceability programs? The certification and traceability indicators can be analyzed separately (Existent=2; In transition=1; Absent =0).

Official Supervision (OS): The presence of the state as regulating and disciplinary body of the activity development in the exclusive functions of sanitary surveillance and inspection (Existent = 2; Partially existent = 1; Absent = 0).

Credit Lines for loans (CL): The development of the activity needs easy access to loan, compatible with the business and with easy access. In the territory where the activity develops there are credit lines? (Total with easy access=2, Total with difficult access=1, Partial with easy access=1, Does not exist = 0).

2.3.2. Market governance

Fingerling origin and source (FS): Considering the origin (local=3, regional=2, national=1 or international=0) and source (capture in the natural environment=0, use of natural environment reproducers=1, use of breeding stock=2).

External Input Dependency (EID): Are the inputs used by aquaculture (food, fertilizer, equipment, labor, medicines, technologies, etc.) available in the territory or are they imported? (Local = 3; Regional = 2; National = 1; International = 0).

Multiple Use (MU): we quantified the number of uses of the farm. More efficient and sustainable production systems should promote multiple uses of resources. In the case of aquaculture other than the cultivation of fish, other uses may be associated with: water reserve, irrigation, leisure, landscape, tourism, education, animal watering, transportation, etc. The more uses, the more sustainable the activity. (number of uses = n)

The Production Systems (PS) practiced in the territory can define how much the business is sustainable for the region. Diversified systems and that favor the efficient use of the trophic chain of nurseries tend to be more sustainable. (Polyculture=3, Monoculture with herbivorous fish=2, Monoculture with carnivorous fish=1)

Crisis Response Readiness (CRR): Is the productive sector and other segments (public, private, third sector) of the aquaculture production chain present in the territory capable of responding to crises (economic, social, environmental and governance)? (High = 3; Average = 2; Low = 1; Does not have = 0)

Risks (R): The activity developed in the territory that suffers with droughts and floods, besides the economic losses can compromise its sustainability. (Frequent droughts and / or floods = 0; Droughts and / or sporadic floods = 1; No droughts and / or floods = 2)

2.3.3. Participatory governance

Community Perception and Participation (CPP): What does the society think about the various aspects involving the activity in the territory? How important is it to the region, its environmental impact and the generation of jobs and income? Does society participate in the actions and decisions involving the activity? Concerning the importance for the region (Important = 2; Do not know = 1; Not Important = 0) As regards pollution (Polluted = 0; Do not know = 1; Does not pollute = 2) As for the generation of employment and income (Positive = 2; Do not know = 1; Negative = 0) The participation of the society on decisions regarding the production (Participate actively = 2; Partially participate = 1; Not participating = 0)

Media Perception (MP): The media agencies present in the territory can influence in a positive or negative way the development of the activity. (Positive = 2; Indifferent = 1; Negative = 0)

Consumer Perception (CP): Since the consumer is the reason for the business, what is his perception of the activity carried out in the territory? Is the consumer aware of and willing to defend local production? (Positive = 2; Indifferent = 1; Negative = 0)

Presence of Teaching, Research and Innovation (TRI): Do the territory have public and private entities (Universities, Research Centers) that form technicians and carry out research and technological innovation involving all links of productive chain? (Has = 2; Partially has = 1; Does not have = 0) Are actions articulated involving research x extension x production? (Total = 2; Partial = 1; Does not have = 0)

Availability of Information (AI): Information is important for decision making (production statistics, available labor, infrastructure, logistics, raw materials, etc.). Is the territory where aquaculture projects are developed that has information that estimate interest for investors and is it freely available? (Complete information = 2; Partial information = 1; No information = 0)

Collaborative Network (CN): Collective actions are healthier and can contribute for better and quickly success of the business and development of aquaculture in the territory. (Single= 1; Informal group= 2; Formal group= 3; Cooperative= 4)

Future Projection (FP): What is the expectation of the future of the farmer business being evaluated by himself over the 10-year horizon? (Positive = 2; Regular = 1; Negative = 0).

Business Management (BM): Do the farmers participate directly in the management of the business? (Participate actively = 2; Delegates to third parties = 1; Not participating = 0)

2.4. DATA ANALYSIS

Each indicator was converted into a performance scale (Bellen, 2008), with scores ranging from 0 to 1 and expressed in multidimensional diagrams. The treatment with the best indicator value (more sustainable when compared to the others) was arbitrarily scored as 1, and the others were determined by proportion. Thus, the indicators were grouped into three categories: (a) Hierarchical governance; (b) Market governance; (c) Participatory governance. A governance sub-index was computed for each category by the average of their respective indicators. The Governance Index was determined by the average of the three sub-indexes for each system. The governance indicators of the lambari production systems were classified by how sustainable they are according to the range of the performance scale (Valenti, 2008) as shown in Table 2. In addition, a global analysis about the aquaculture sector based on the theoretical model of public policy and development analysis used by Silva *et al*. (2007) were performed to join with the local approach given by the indicators.

Table 2 – Performance scale used in the classification of sustainability for the lambari production systems of Sao Paulo State.

Range	**Classification**
0.000 - 0.200	Not sustainable
0.201 - 0.400	Low sustainability
0.401 - 0.600	Medium sustainability
0.601 - 0.800	Potentially sustainable
0.801 - 1.000	Sustainable

Adapted from Valenti (2008)

The obtained variables were compared between systems by multivariate exploratory data analysis. Data was standardized to perform Cluster (using Euclidian distance and UPGMA - Unweighted Pair Group Method using Arithmetic averages) and Principal Components Analysis (PCA).

3. RESULTS

The governance indicators describe the perceptions of the farmers in a qualitative approach divided by hierarchical, market and participatory governance (Table3).

Table 3 - Governance indicators of different production systems of lambari *Astyanax lacustris*

Governance indicators	**LCS**	**MCS**	**HCS**
Hierarchical governance			
Infrastructure	Medium	Medium	Good
Presence of technical assistance	Non-specific	Non-specific	Non-specific
Presence of the State assistance	Not present	Partially present	Partially present
Certification and traceability	Absent	Absent	Absent
Official supervision	Partially existent	Absent	Existent
Credit lines for loans	Difficult access	Difficult access	Difficult access
Market governance			
Fingerlings source	Local, breeding stocks	Local, breeding stocks	Local, breeding stocks
External input dependence	Regional	Regional	Regional
Multiple use	2±1	0±1	1±1
Production systems	Herbivorous monoculture	Herbivorous monoculture	Herbivorous monoculture
Crisis response readiness	Average	High	Average
Risks	Droughts, floods	Droughts, floods	Droughts, floods
Participatory governance			
Community perception and participation:			
- Importance for the region	Important	Do not know	Important
- As regards pollution	Do not know	Does not pollute	Do not know
- Generation of employment	Positive	Positive	Positive
- Decisions about the production	Not participating	Not participating	Not participating
Media perception	Indifferent	Positive	Positive
Consumer perception	Positive	Positive	Positive
Teaching, research and innovation:			
- As for existence	Partially has	Do not have	Do not have
- Concerning articulation	Partial	Do not have	Partial
Availability of Information	Partial	Partial	Complete
Collaborative network	Individual	Individual	Individual
Future projection	Regular	Regular	Positive
Business management	Participate actively	Participate actively	Participate actively

The data were transformed in performance scale (Table 4) to perform the exploratory data analysis (Figure 2 and 3) and the multidimensional graphics (Figure 4) for the quantitative approach.

Table 4 – Governance indicators of different production systems of lambari *Astyanax lacustris* expressed in performance scale.

Governance indicators	**LCS**	**MCS**	**HCS**
Hierarchical governance			
Infrastructure	0.583±0.144	0.500±0.250	0.667±0.144
Presence of technical assistance	0.500±0.000	0.333±0.289	0.500±0.000
Presence of the State assistance	0.167±0.289	0.333±0.577	0.500±0.500
Certification and traceability	0.000±0.000	0.000±0.000	0.167±0.289
Official supervision	0.333±0.289	0.167±0.289	0.833±0.289
Credit lines for loans	0.667±0.289	0.500±0.000	0.500±0.000
Market governance			
Fingerlings source	1.000±0.000	1.000±0.000	1.000±0.000
External input dependence	0.667±0.000	0.667±0.000	0.667±0.000
Multiple use	0.556±0.385	0.111±0.192	0.222±0.192
Production systems	0.778±0.192	0.667±0.000	0.778±0.192
Crisis response readiness	0.556±0.385	0.889±0.192	0.778±0.192
Risks	0.500±0.000	0.500±0.500	0.333±0.289
Participatory governance			
Community perception and participation	0.583±0.217	0.625±0.217	0.625±0.144
Media perception	0.500±0.000	1.000±0.000	1.000±0.000
Consumer perception	1.000±0.000	1.000±0.000	1.000±0.000
Teaching, research and innovation	0.417±0.000	0.000±0.289	0.333±0.000
Availability of Information	0.333±0.289	0.500±0.000	1.000±0.000
Collaborative network	0.250±0.000	0.250±0.000	0.333±0.144
Future projection	0.333±0.577	0.667±0.289	0.833±0.289
Business management	1.000±0.000	1.000±0.000	1.000±0.000

The cluster analysis did not recovered the groups defined a priori for the production systems due a larger variability of the economic indicators (Figure 2). However, partial grouping can be idenfied to LCS and HCS.

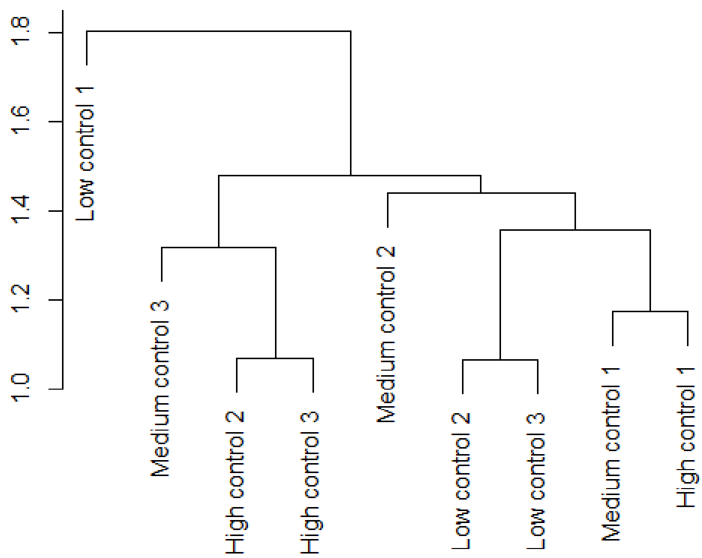


Figure 2 - Dendrogram of dissimilarity of environmental sustainability indicators of lambari production systems (Euclidean distance)

The governance indicators submitted to the Principal Components Analysis (PCA) are not able to show which components could generate patterns for clustering of cohesive groups (Figure 3).

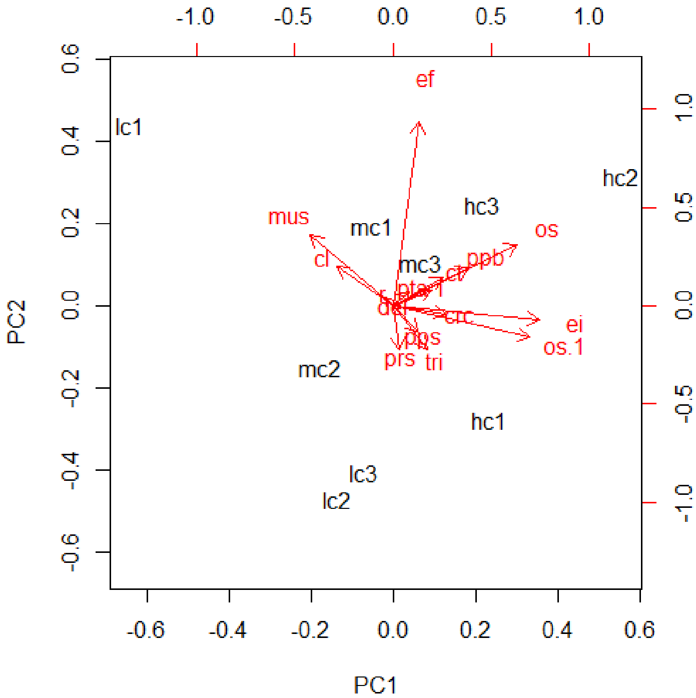
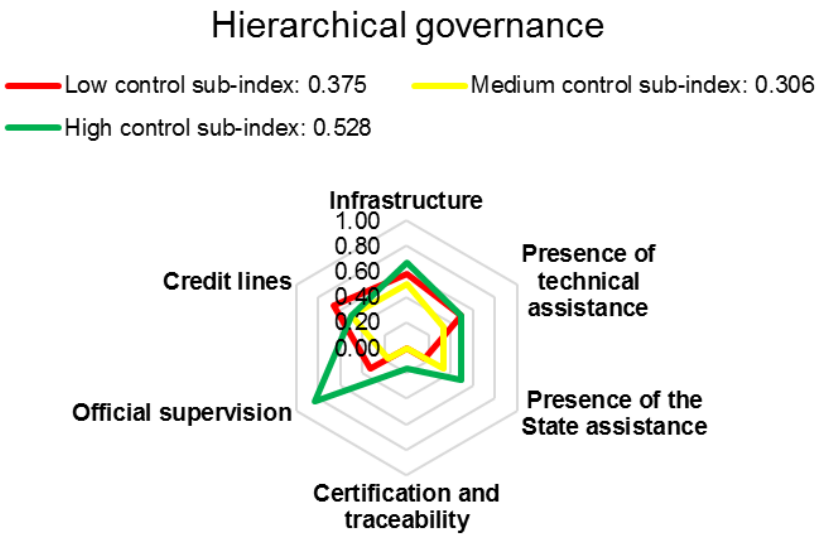


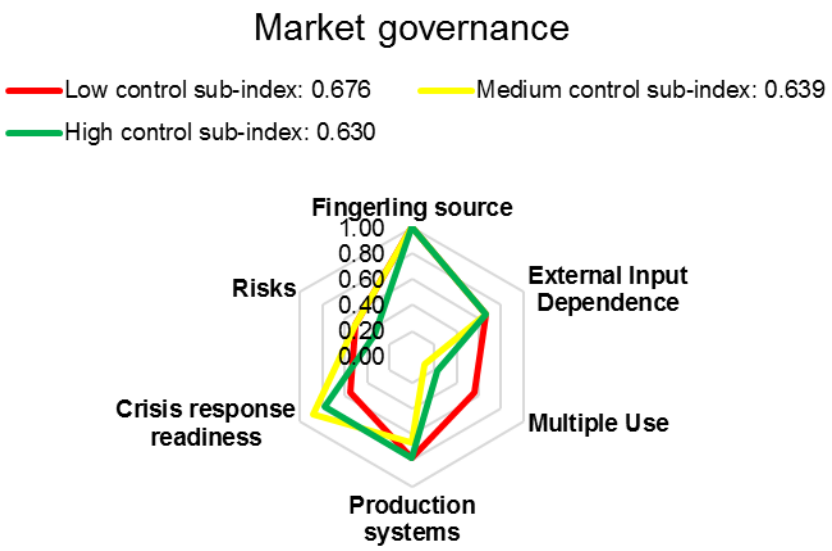
Figure 3. Principal components Analysis (PCA) for governance indicators of lambari production systems in São Paulo State. fingerlings source=fs; multiple use=mus; infrastructure=i; production systems=ps; presence of technical assistance=pta; presence of the state assistance=psa; certification and traceability=ct; official supervision=os; credit lines=cl; external input dependence=eid; community perception and participation=cpp; media perception=mp; teaching, research and innovation=tri; consumer perception=cp; availability of information=ai; collaborative network=cn; future projection=fp; business management=bm; crisis response readiness=crr; risks=rk

The LCS had a better score in the category market governance (Figure 4b). However, the HCS had a better performance in two of three categories of governance indicators, represented by Figure 4a-4c for hierarchical and participatory governance, respectively. This is reflected at the score in the governace index (Figure 4d).

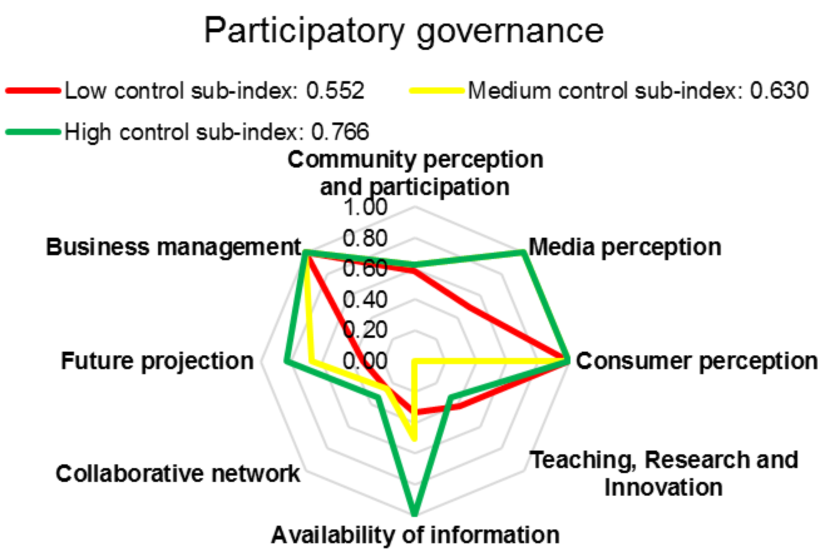
a)


Hierarchical governance
Low control sub-index: 0.375
Medium control sub-index: 0.306
High control sub-index: 0.528
Infrastructure
1.00
0.80
0.60
0.40
0.20
0.00
Presence of technical assistance
Presence of the State assistance
Certification and traceability
Official supervision
Credit lines

b)


Market governance
Low control sub-index: 0.676
Medium control sub-index: 0.639
High control sub-index: 0.630
Fingerling source
1.00
0.80
0.60
0.40
0.20
0.00
External Input Dependence
Multiple Use
Production systems
Crisis response readiness
Risks

c)


Participatory governance
Low control sub-index: 0.552
Medium control sub-index: 0.630
High control sub-index: 0.766
Community perception and participation
1.00
0.80
0.60
0.40
0.20
0.00
Media perception
Consumer perception
Teaching, Research and Innovation
Availability of information
Collaborative network
Future projection
Business management

d)

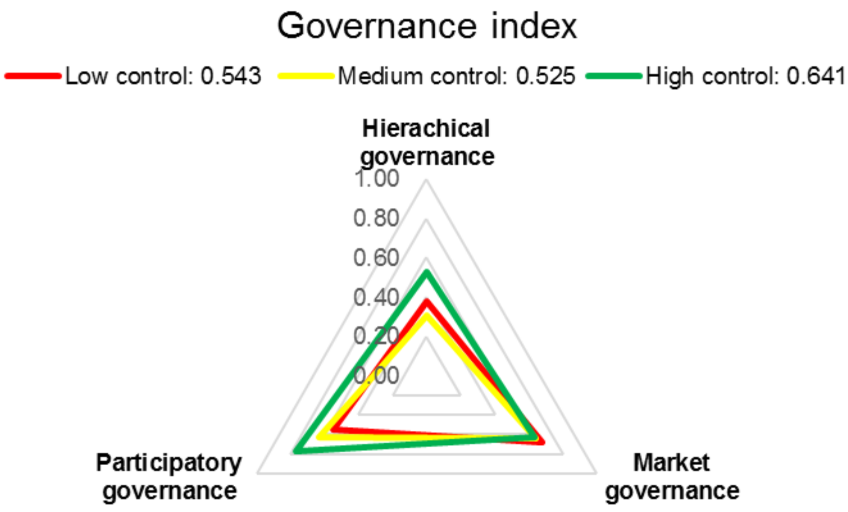


Figure 4 – Governance indicators of lambari production systems in São Paulo State, obtained for each category: (a) Hierarchical governance; (b) Market governance; (c) Participatory governance; and the general index (d) Governance index, with their respective sub-index for each treatment.

The HCS presented the best score for the institutional sustainability. The final governance index classified it as potentially sustainable for this dimension. However, MCS and LCS are classified as medium sustainability according to the performance scale (Figure 4d, Table 5).

Table 5 – Sustainability classification of the lambari production systems, according to the performance scale.

Sub-indexes	**LCS**	**MCS**	**HCS**
Hierarchical governance	Low sustainability	Low sustainability	Medium sustainability
Market governance	Potentially sustainable	Potentially sustainable	Potentially sustainable
Participatory governance	Medium sustainability	Potentially sustainable	Potentially sustainable
Final Score	Medium sustainability	Medium sustainability	Potentially sustainable

4. DISCUSSION

Usually, the institutional dimension deals with governance issues in a global viewpoint (Lazard *et al*., 2011; Gisselquist, 2014). That means that the comparisons of governance indicators occur between nations and countries data for global demands. Therefore, it lacks of studies about governance indicators applied for aquaculture to compare results with local production systems. The current proposal is to start a local point of view to assess the interactions between local stakeholders with their territory. The integration of these two approaches may picture an ideal description of the institutional dimension as the fourth pillar of sustainable development for aquaculture. Thus, we organized the discussion of the present study under these considerations.

4.1. Local approach of the institutional dimension

Although the scores of each sub-index are close comparing the production systems, the hierarchical governance is classified as medium sustainably for HCS and low sustainability for LCS and MCS. The HCS presented better satisfaction with the conditions of the infrastructure of their territory. They are located closer to regional important cities that offers better services and roads. The LCS and MCS has farmers located in rural settlements with difficult accesses. That reflects the lack of State assistance for the LCS. However, official supervision partially occurs in their territory but just for cattle. There is no supervision for lambari, specially because they are sold live. All the production systems share the same problems of the lack of specific technical assistance that is mostly focused on cattle or sugarcane production. Also, there is no stimulation for the creation of certification and traceability of the aquaculture products. The inclusion of traceability mobilizes all the dimensions of sustainable development, providing transparency of the environmental and socioeconomic conditions of the production for consumers. However, one HCS farmer is working on the production of a different triploid lambari, that may give him market advantages. In addition, specific government credit line to provide loans are important tools for develop Brazilian agroindustry but especially family farming. It opens opportunities to turn feasible for farmers to invest in inputs or equipment that may improve their productivity (CAISAN, 2017). All the farmers considered that loans exist, but difficult to have access due the bureaucracy and non-inclusive regulations that benefits the wealthier farmers from other sector like sugarcane and cattle.

The market governance shows stronger influence to guide the industry. The set of indicators used for this category presented similarities in terms of management of monoculture of herbivorous species, local fingerling source, regional dependence to external inputs, risks to droughts and floods. Little variations for these items can be identified with the performance scale. However, there are some indicators that contributes for differentiation between productions systems. The LCS uses the pond for other proposes like water for irrigation, for cattle watering and also to swim for leisure. The LCS offer other products, like milk, cattle, fruits and vegetables to diversify the income of the families. Even with the multiple use with water reservation, the farmers have the perception that they have lower capacity to react to financial or environmental crisis. The MCS presented limited exploitation of the water and the land of its farms, focused on the lambari production. Also, MCS presented a better perception for crisis response readiness. The HCS offers extra services, like restaurants, bait shops and sport fishing parks. These services provide income and make the farmers confident to react to crises but vulnerable to risks, especially with droughts. Although the LCS presented better performance for market governance, the other systems closely followed the scores in this category and they are all classified as potential sustainability.

For all the farmers, the society perceptions of its production are positive and there are no conflicts about it. However, MCS and HCS has more proximity, accesses and better perception of the media than the LCS, that sees it as indifferent. One LCS farmer participated once from a research which his daughter was co-author of an economic study about lambari at his own farm. Even so, the perception of the LCS about the presence of teaching, research and innovation is limited and partially existent. However, the other production systems affirm that does not have. However, the HCS established proximity with researchers and they have more access to complete information related to lambari production. Also, HCS positively projects their future with new market opportunities for lambari while HCS and LCS just see as regular expectancy.

4.2. Global considerations of the institutional dimension of aquaculture

In order to contribute to a global viewpoint of the institutional dimension to join with the local analysis presented so far, some information about the national reality must be taken account. Government instability is one of the sources of lack of development of the aquaculture industry in Brazil. Although the country has a great potential and even plans to increase the production 104% until 2025 (FAO, 2016), the fisheries and aquaculture office, (created in 2003 and archiving a ministry status in 2009), has recently downgraded. Since then, other institutional changes have occurred. In 2015 and 2017 the office changed government structure and it is nowadays linked to the Industry, Exterior Commerce and Services Ministry. Independent of the pertinence of the reallocation, these actions impact the consolidation of public policies, technical team and procedures, reducing the predictability of regulations and being more confuse for farmers to get access to beneficial information.

The principles of governance for aquaculture are accountability, effectiveness/efficiency, equity and predictability (Hishamunda *et al.*, 2014). According to the scenario described above, the Brazilian aquaculture face challenges to reach good governance. The accountability is also impacted due the 79th position in the ranking of the Transparency International's Corruption Perceptions Index (CPI), 2016. The interpretation of this indicator is affected by the functioning of the criminal justice system and the variation in official crime statistics that negatively impact the hierarchical governance (Gisselquist, 2014). Also, the political crises and the economic recession of the country results in 14.2 million unemployed Brazilians (IBGE, 2017). The State and private sector are not offering enough job positions or acting to open opportunities to provide income to the population. Thus, the solidary economy is a reality in the world as an organizational alternative to promote income to several families. The book "Un Million de Révolutions Tranquilles: comment les citoyens changent le monde", Bénédicte Manier shows that cooperatives around the world provides 100 million job position, 20% more than multinational companies. In the United States, 30,000 cooperatives generate 2 million job positions. In Italy, 85,000 cooperatives impact with 7.5% of the gross domestic product (GDP). The government must support the strengthening of the solidarity economy. When applied to aquaculture it can reduce the impacts of small bargaining capacity on the marketing process, avoiding the paralysis of small-scale activities as a competition affect by the intensive production of agribusiness. The efficiency of large-scale production promotes prices lower than the cost of production of small-scale aquaculture. In addition, it can reinforce the social reproduction of the activity, transferring the culture to future generations.

Farmer does not have a social organization. They mostly work alone at individual business. However, one farmer from the HCS works associated to informal groups. This farmer is the biggest lambari producer in Brazil and he has partnerships with 15 smaller farms. To increase the governance, cooperatives, associations and/or informal groups could organize to improve the social solidarity economy (Kawano, 2013). When social organization of the farmers occurs, collective innovations can happen, increasing the social capital with trust and solidary relations (Singer, 2006). The geographic proximity with different actors of the productive chain affects the hierarchical governance with the participatory approach. The public opinion also helps with the business. The society has a favorable perception about the production of lambari. They consider that the industry does not impact the environment and provide job positions with social inclusion. Thus, the lambari production and also the aquaculture industry must be inserted in the territorial planning to develop specific programs and public policies to increase the sustainable production. Also, good governance is based on cooperation between social, individual and collective actors, where conflicts can be solved under a collaborative approach to build a collective project (Lazard at al., 2011). The industry should be in line with regulations and should be dynamic, able to discuss changes whenever it is necessary (Silva *et al.*, 2007).

4.3. Local and global considerations for mobilization of stakeholders

The evaluation of public policies indicates the effectiveness, impact, relevance and efficiency, considering the historical approach of government intervention and its effects, the population's trajectory and the transformations in the occupation of the territories (Silva *et al.*, 2007). The present study is part of the Sustainable Aquaculture research networking. It is the result of a governmental policy that finance the scientific production to understand and encourage the development of national aquaculture production considering sustainable production systems. This is formed by 38 researchers from 15 research institutions, distributed in the South, Southeast, Northeast and North of

Brazil. The aim of this research networking is to provide information about the sustainability of Brazilian aquaculture to be sent to the government for its dissemination and incorporation into public policies for the Brazilian Aquaculture Sector. The lambari production is under this context and the results of several sustainability studies evidence the high effectiveness of the policy because hit the goals to generate information about the industry. The impact is still low considering the effects on the productive sector. Although, there is a high relevance due the need to regulate and encourage sustainable production systems in Brazil. The costs of these studies promote a great benefit and can be considered an efficient policy that may have a greater impact with the further regulations for sustainable aquaculture development. The weakness of the policy so far is the lack of interactions with the farmers from the production sector who needs closer relationship with it other.

The ability to build a productive organization that creates and exploits local specificities of the economic and institutional environment are characteristics of Local Innovation Systems. This theoretical reference consider that the innovations are based on the interaction between four poles of competence: production, science, learning and financing. The sociotechnical network connects them and turn the Local Innovation feasible by mutual incorporation of procedures between members of each pole of competence (Silva *et al*, 2007). In the case of the lambari production, the results of the present study show that there is a lack of communication and interactions between government, research, extension and also financial support. There are some technological innovations in the scientific field available for development of lambari production (Sussel *et al.*, 2014; Gonçalves *et al.*, 2015; Valladão *et al.*, 2016). However, poor management practices are frequent and science-based studies are still insufficient to provide reliable technology to match rural farmer necessities (Fonseca *et al.*, 2017).

Some initiatives from governmental research institutes provided extension and outreach, transferring the technology of lambari reproduction with artificial induction with pituitary extract. This fact was a milestone for the industry and created the HCS farmers. However, it was successful because the farmers had conditions to go to those centers, learn and adopt the new techniques. The LCS and MCS has farms located in rural settlements. Although the intervention of the

State to create the rural settlements are important, other arrangements lacks attention of the government, impacting the hierarchical governance of these production systems. Thus, the lack of proximity and interactions with technical assistance and links of productive chain are responsible for lower development in the industry. The feedback of science to the production sector takes time to react and it urge to be more efficient to promote Local Innovation Systems.

To improve the governance, it is essential to promote communication between the groups of social actors in order to establish deals according to their needs. Extension agents and/or researchers must identify a common goal for different issues in a complex territory. The translation sociology concept used by Silva *et al.* (2007) is a theoretical reference able to archive this challenge through a person who has the profile to create proximity between farmers, researchers, extension agencies, government and financial agencies establishing a sociotechnical network. The action of different professionals can stimulate deals and governance improvement through the translation of the reality of the territory for a common comprehension. This process is collaborative and must emerge ideas for a model. Then, it works translating ideas and deals as rules and/or projects. As much it happens more sustainable and better governance it gets. An example in how a social actor with a translator profile may provide the insertion of the government in the sociotechnical network is presented in the figure 6.

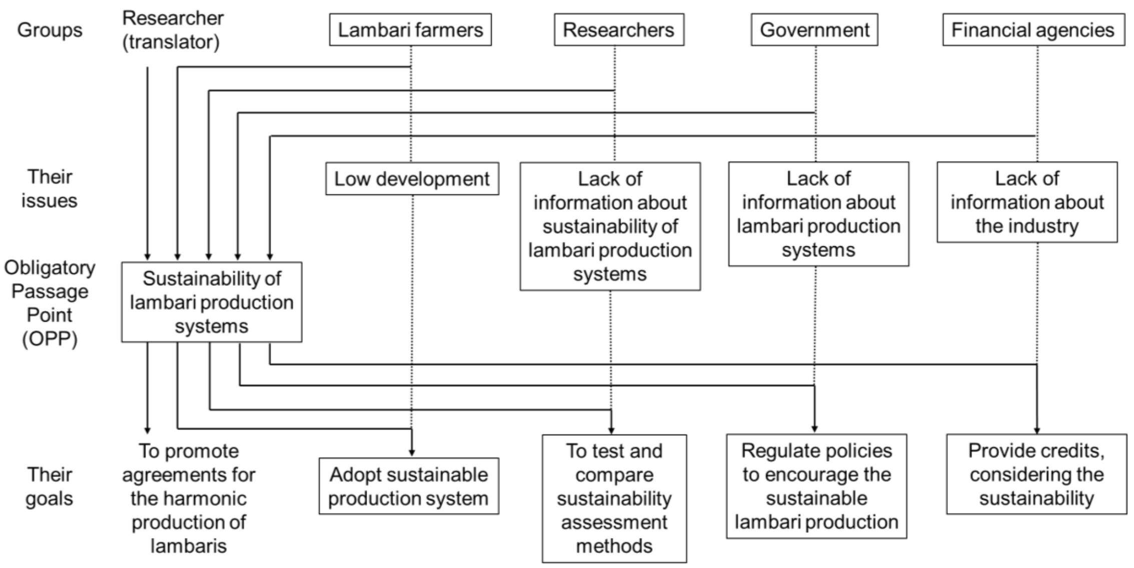


Figure 6 - Mobilization of social actors and the Obligatory Passage Point (OPP), adapted from Silva *et al*. (2007).

Isolated researches have great importance to the scientific community. However, it can be more effective for the production sector when it is followed by extension and outreach. When the government is inserted in the sociotechnical network, a wide range of opportunities can be available according to the capacity of the social actors to interact between them, to translate their issues through an obligatory passage point to share different goals. Some benefits able to improve good governance are the existence of financial support for the production sector; continuous training according to a local model of production; Research-development; increase the vigilance of the industry; taxes and environmental regulations compatible to the territory; products certification and traceability; financial support of public services and research. The sustainable development of the lambari production in the governance dimension should take into account: institutional strengthening, citizen participation in decision-making processes and the administrative autonomy of local governments and communities.

4.4. The institutional sustainability analysis for aquaculture studies

The governance indicators must be considered in aquaculture sustainability studies to compose the Institutional dimension. The set of governance indicators were adequate and effective to evaluate the institutional sustainability in lambari production systems in a local approach. This tool also presents a great applicability for institutional sustainability assessment for other aquaculture production systems. However, the choices and interpretations of sub-indexes emphasize the subjectivity in the construction of the economic index. Some governance indicators have a very close relationship with the economic, environmental and social dimensions. Also, the division of the indicators in the types of governance is not precise and may overlap their essence. However, it is important to emphasize that the current studies concerning the institutional dimension are generally evaluated on the basis of expert opinion for global approach and should therefore be the subject of further research for improving the methods. The institutional dimension, which is a governance issue, is increasingly defined as the fourth pillar of sustainable development (Lazard *et al*., 2011). Additionally, the use of a set of theoretical references may help to understand the development or non-development of the agroindustry activities.

The evaluation of public policies, the Local Innovation Systems and the translation sociology are tools that can promote interactions of research, extension services, production and financial support causing significant transformations in the aquaculture industry (Silva *et al.*, 2007). Thus, we recommend the use of the set of governance indicator as a tool for measuring the institutional sustainability to contribute to the lack of studies combining local and global approach for better comprehension.

The indicators showed great variability, partly due to the differences in their performance on hierarchical and participatory governance and also for limitations in the number of replicates used in this study. These factors may be affecting the groups during the cluster analysis. The partial clustering for LCS and HCS may be associated to the similarities of each of their relational characteristics for each of the categories of the institutional sustainability indicators. It is recommended to carry out studies that contemplate more number of farms and systems of production for better statistical analysis.

5. CONCLUSIONS

We conclude that the HCS presented better governance and it is classified as potentially sustainable for the institutional dimension. Also, analyzing the trajectory of lambari production development, the existence of the HCS is the result of good hierarchical and participatory governance. The HCS farmers were able to interact and establish proximity with other stakeholders of research and extension institutions. This allowed then to have access to innovative techniques that improved their production system. The market governance guides the lambari production. However, the participatory governance is able to improve the LCS and MCS governance, classified as medium sustainability. Specialized technical assistance able to provide social organization under solidary economy concept may strengthen the proximity between stakeholders. This can amplify the dialog with the government and other social actors from the productive chain to provide strategic deals to improve their productive success as well as the governance.

The combination of the set of governance indicators chosen generated an index able to detect, identify and quantify the main aspects of lambari production systems. However, it is recommended that other combinations and manipulations of the sub-indexes used to compare the differences be tested in further studies. Additionally, information about environmental, social and economic dimensions must be compared and integrated to achieve an efficient sustainability index. Thus, combining the set of indicators for local assessment with other theoretical background for global analysis provides an adequate picture of the institutional sustainability and to propose solutions.

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CAPÍTULO 6

CONSIDERAÇÕES FINAIS

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Os capítulos anteriores caracterizaram cada sistema de produção de lambari do rabo amarelo no Estado de São Paulo nas dimensões ambiental, social, econômica e institucional. De forma geral, o sistema de baixo controle se diferencia pela performance inferior aos outros sistemas de produção em todas as dimensões (Figura 1). Este sistema obteve índice geral de sustentabilidade de 0.590 e foi classificado como Sustentabilidade Média (0.401–0.600) (Tabela 1). Já os sistemas de médio e alto controle de produção apresentam melhores índices gerais de sustentabilidade, 0.686 e 0.775, respectivamente. Ambos foram classificados como Potencialmente Sustentável (0.601 – 0.800). Apesar do índice final de sustentabilidade apresentar a mesma classificação entre os sistemas de médio e alto controle, cada um deles apresentam particularidades que os diferenciam. Entretanto, o sistema de Alto Controle é o mais sustentável devido principalmente ao número de empregos que gera, maior produtividade e boas relações institucionais.

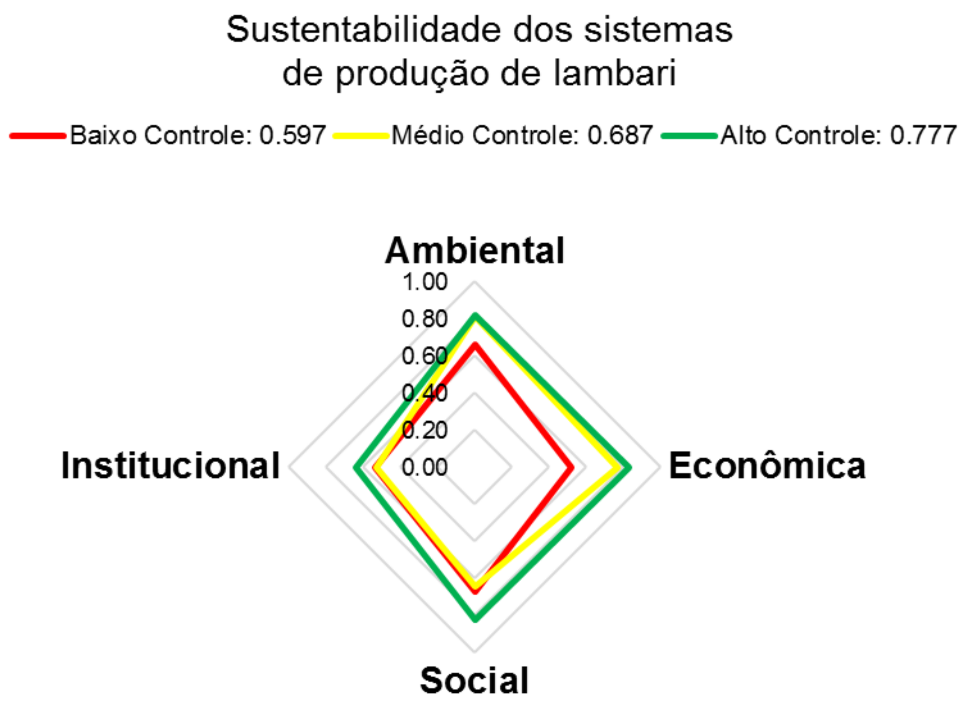

Figura 1 – Índice de sustentabilidade dos sistemas de produção de lambari.

Tabela 1 – Classificação pela escala de performance de sustentabilidade dos sistemas de produção de lambari.

Dimensão	Baixo Controle	Médio Controle	Alto Controle
Ambiental	Potencialmente sustentável	Sustentável	Sustentável
Social	Potencialmente sustentável	Potencialmente sustentável	Sustentável
Econômica	Sustentabilidade média	Potencialmente sustentável	Sustentável
Governança	Sustentabilidade média	Sustentabilidade média	Potencialmente sustentável
Índice Final	Sustentabilidade média	Potencialmente sustentável	Potencialmente sustentável

O uso de tecnologia de reprodução em laboratório amplia a produtividade do sistema de alto controle e os indicadores ambientais foram melhores em relação a emissões de poluentes. Já a falta de boas práticas na manutenção dos viveiros e controle da população de peixes foram os pontos fracos do sistema de baixo controle de produção de lambari. Estes fatores afetaram negativamente a produtividade e ocasionaram maior acúmulo de sedimentos. Dessa forma, esse sistema de produção de menor controle libera gases que podem afetar o aquecimento global. O suporte técnico é fortemente recomendado, especialmente para as fazendas que operam no sistema de controle baixo. É necessário melhorar e aplicar boas práticas de manejo (BPMs) considerando alimentação, produção e soluções simples para evitar a liberação de poluentes no ambiente durante a produção.

Os produtores que usam o sistema de baixo controle de produção de lambaris atuam há mais tempo na atividade. Esse fato aumenta resistência para a adoção de novas tecnologias e boas práticas produtivas que otimizam a produção. Essa condição se agrava pela falta de assistência técnica disponível, principalmente que acesse áreas de assentamentos como é o caso de algumas propriedades do sistema de baixo e médico controle de produção. Apesar das limitações econômicas que dificultam a contratação de funcionários, os produtores desse sistema apresentam elevado capital social em suas comunidades. As relações não são meramente mercantis. Há confiança e reciprocidade entre eles que refletem em colaboração, por exemplo a ajuda de compradores na despesca. Entretanto, o sistema de alto controle de produção apresenta maior equidade e distribuição de renda pela maior capacidade de empregar funcionários formais e informais.

Os sistemas de produção de lambari estudados apresentam viabilidade econômica com destaque ao sistema de alto controle. Todos os sistemas apresentam externalidades positivas capazes de absorver os custos dos impactos gerados pela atividade. Porém, o sistema de produção de baixo controle foi mais eficiente para absorver os custos das externalidades negativas produzidas. Isso ocorre principalmente devido à capacidade de retenção de nutrientes e pelos preços praticados pelo mercado de Carbono, Nitrogênio e Fósforo. A criação de políticas públicas específicas para a otimização dos sistemas de produção deve considerar a ideia de créditos de nutrientes por meio da quantificação das externalidades. Trata-se de uma ferramenta importante para regular sistemas de produção sustentáveis. As vantagens econômicas desse tipo de política podem encorajar agricultores e empreendedores de diferentes setores a adotar boas práticas de produção que diminua impactos considerando os serviços ambientais decorrentes da produção.

A dimensão governança é o ponto mais fraco da produção de lambari no Estado de São Paulo. Os valores obtidos prejudicam o índice final da sustentabilidade. Caso esta dimensão não fosse considerada, a classificação pelo índice final seria alterada de forma que os sistemas de baixo e médio controle estariam classificados como potencialmente sustentável enquanto o sistema de alto controle seria classificado como sustentável (Figura 2).

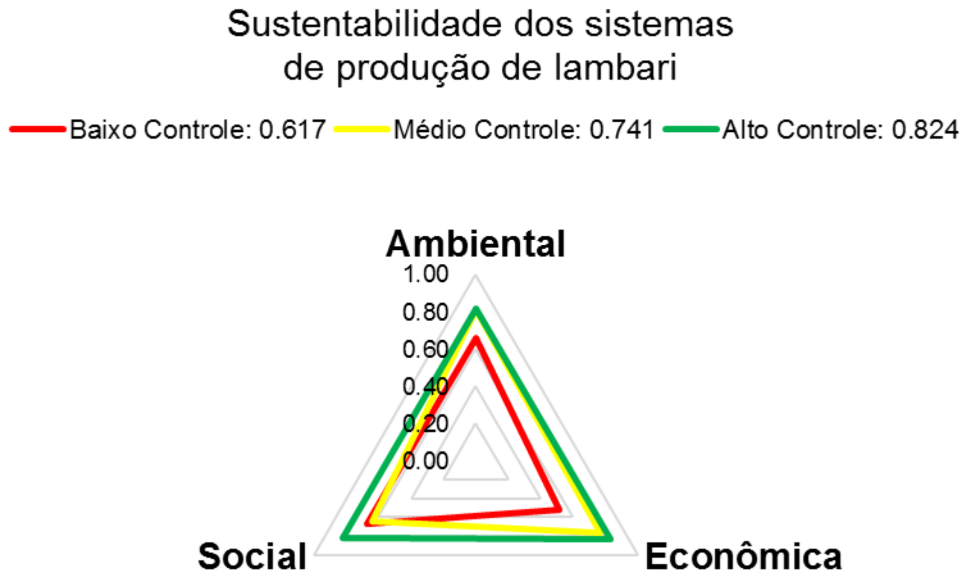

Figura 2 – Índice de sustentabilidade dos sistemas de produção de lambari, sem a dimensão institucional.

Entretanto, a constatação de que a governança é um ponto fraco da sustentabilidade da produção de lambari no Estado de São Paulo reafirma sobre a importância da aplicação dos indicadores de sustentabilidade institucional propostos. Assim, combinar o conjunto de indicadores para avaliação local com outros conhecimentos teóricos para análise global retrata de forma adequada a sustentabilidade institucional e capaz de propor soluções para os sistemas de produção aquícolas. Vale ressaltar que este é o primeiro trabalho desenvolvido pelo grupo coordenado pelo projeto Rede de Pesquisa da Sustentabilidade da Aquicultura que considera a governança como uma de suas dimensões. Dada a relevância dos impactos causados pela boa ou má governança nos sistemas de produção é extremamente necessário que a metodologia de avaliação da dimensão institucional seja considerada inclusive para a formulação de políticas públicas.

A existência do sistema de alto controle de produção de lambaris é fruto de boa governança que viabilizou a adoção de inovações tecnológicas. Houve proximidade e interação de atores sociais entre pesquisa, extensão, junto ao setor produtivo que promoveram importantes avanços para o controle da reprodução em laboratório. A governança do mercado orienta a produção de lambari. No entanto, a governança participativa é capaz de melhorar a sustentabilidade dos sistemas de produção de lambaris por meio de assistência técnica especializada capaz de fornecer organização social sob o conceito de economia solidária pode fortalecer a proximidade entre as partes interessadas. Isso pode ampliar o diálogo com o governo e outros atores sociais da cadeia produtiva para oferecer acordos estratégicos para melhorar a governança e consequentemente o sucesso produtivo. Esforços para a viabilização de equipamentos específicos para o beneficiamento do lambari para o consumo de petiscos estão em curso.

Quando ocorre organização social dos agricultores em forma de associação, cooperativa ou mesmo grupos informais, as inovações coletivas podem acontecer, aumentando o capital social baseado em relações de confiança e solidariedade. A organização social dos produtores de lambari é fundamentada no individualismo. Porém, um produtor do sistema de alto controle trabalha com grupos informais em parceria com outras 15 propriedades.

Coincidentemente, ele é conhecido como o maior produtor de lambari no Brasil. A governança da produção de lambari deve levar em conta o fortalecimento institucional, a participação do cidadão nos processos de tomada de decisão e a autonomia administrativa dos governos e comunidades locais. Porém, a realidade observada é diferente. A deficiência de assistência técnica e baixa integração de agentes da cadeia produtiva com o setor científico, extensão e produtivo trazem dificuldades ao desenvolvimento da produção de lambaris. O fato se agrava pela falta de estímulo à organização social que pode promover competitividade produtiva. Baseados nessas considerações, a tabela 2 sumariza os principais pontos forte e fracos de cada sistema de produção de lambari.

Tabela 2 – Pontos fortes e fracos identificados em cada sistema de produção de lambari *Astyanax lacustris*.

Sistema de produção	Pontos fortes	Pontos fracos
Baixo Controle	Fácil e barato; Oportunidade para geração de renda por auto emprego; Áreas reduzidas; Externalidades positivas;	Produtividade; Reprodução; Manejo; Emissão de poluentes; Poder de compra; Articulação com a cadeia produtiva; Interlocução com a pesquisa e extensão; Ração não apropriada; Baixa empregabilidade;
Médio Controle	Investimento baixo; Geração de empregos informais; Produtividade; Eficiência econômica;	Manejo e ração deficitários; Baixa geração de empregos formais;
Alto Controle	Geração de empregos formais; Eficiência e previsibilidade produtiva; Reprodução controlada; Proximidade com poder público e extensão; Acesso à mercados diversificados; Profissionalismo;	Investimentos altos; Rações mais caras; Exigência de maior conhecimento técnico;

Os resultados obtidos revelam pontos fortes e fracos da produção de lambari. As principais oportunidades apresentadas na análise SWOT (Figura 2) estão mais relacionadas à dimensão social. Produzir lambari promove redução da pobreza a produtores que adotam um dos sistemas de produção em pequenas propriedades e assentamentos rurais. Além da geração de renda que permite a aquisição de alimentos, o consumo do lambari pode também garantir a segurança alimentar por fornecer rica variedade de micronutrientes. O fato de ser consumido inteiro devido seu reduzido tamanho também garante a ingestão de cálcio oriundo dos ossos do lambari. Dentre as principais ameaças aos produtores é a falta de profissionalização causadas pela escassez de assistência técnica especializada. O sistema de baixo controle de produção pode futuramente limitar ou até mesmo excluir o acesso a alguns nichos de mercado pelos produtores. Devido ao mercado consumidor cada vez mais exigente e às dinâmicas de reorganização da cadeia produtiva em função da oscilação de preços é de fundamental importância que soluções simples, baratas e eficientes sejam propostas. Apesar dos produtores estabelecerem relações de confiança com seus clientes, a adoção de técnicas que aumente a produtividade garantirá a viabilidade econômica de forma perene para mitigar as ameaças listadas na figura 2.

Figura 2 – Análise SWOT da produção de lambari no Estado de São Paulo.

A combinação do conjunto de indicadores e a utilização da escala de performance gerou índices capazes de detectar, identificar e quantificar os principais aspectos dos sistemas de produção lambari. Estas são ferramentas adequadas e eficazes para avaliar a sustentabilidade na aquicultura de forma descritiva. No entanto, as escolhas e interpretações de indicadores que compõe sub índices enfatizam a subjetividade na construção do índice geral de sustentabilidade. Este fato também é observado na atribuição de valor máximo de referência paras as combinações lineares atribuídas ao melhor resultado. Para o aperfeiçoamento metodológico, recomenda-se a realização de outras combinações de indicadores para definição dos sub índices para comparar as diferenças em outros estudos. Além disso, é necessário a definição de valores de sustentabilidade de referência para os indicadores diferenciados por espécie para basear a determinação dos níveis de sustentabilidade de forma geral e para cada dimensão. A partir do momento que houver tais valores de referência, os resultados apresentados poderão sofrer alterações. O cálculo da escala de performance passará a ser de forma comparativa entre valores de referência globais e não mais em relação ao sistema de produção com melhor desempenho como foi apresentado. Já as análises estatísticas não foram capazes de identificar diferenças entre os sistemas de produção descritos de forma coesa. Os indicadores de sustentabilidade mostraram grande variabilidade. A ocorrência de grupamentos parciais entre o fator testado (sistemas de produção) se justifica pelas similaridades entre fazendas para cada dimensão avaliada. As principais diferenças observadas foram o tipo de manejo adotado pelos sistemas de produção de lambari, variação no tamanho das fazendas, número de empregos gerados por fazenda e relações comunitárias e governamentais. Recomenda-se a realização de estudos que contemplem maior número de fazendas e sistemas de produção de forma a ampliar o número de réplicas e aprimorar a avaliação dos dados com o uso de análises estatísticas.

A limitação econômica durante a condução do presente estudo inviabilizou realizar amostragem de um maior número de fazendas e sistemas de produção de lambari. Entretanto, as fazendas amostradas representam os sistemas de produção mais comuns do país em operação, que considera desde os menores assentamentos rurais até as maiores produções em larga escala. A produção de *Astyanax lacustres* para as nove fazendas paulistas estudadas é de 895.148 kg/ano. Ao comparar com a produção nacional observa-se que os dados oficiais publicados pelo IBGE em 2016 são subestimados, sendo 3,8 vezes menor do que as observações realizadas somente no Estado de São Paulo. Dados oficiais de produção aquícola são necessários para dar visibilidade à atividade econômica e auxiliar na elaboração de políticas públicas específicas para o setor. Entretanto, a imprecisão dos valores apresentados nas publicações oficiais nas edições de 2014, 2015 e 2016, podem comprometer a prioridade do poder público em elaborar programas de desenvolvimento para a produção de lambari.

O futuro da lambaricultura está centrado na profissionalização dos produtores em atender o mercado aquecido de iscas vivas para pesca esportiva que ainda apresenta procura maior que oferta. Com a perspectiva de aumento do número de produtores, essa relação pode mudar e a competitividade pode ser determinante na permanência de produtores menos especializados na atividade. Outros mercados emergem, como o de petiscos e de isca viva em ambientes marinhos para a pesca esportiva ou até mesmo a pesca industrial de atum. Para que as oportunidades geradas pela diversificação do mercado de lambaris sejam inclusivas para todos os produtores, serão necessárias assistência técnica, investimento e boas práticas para garantir boa performance nas quatro dimensões da sustentabilidade. Entretanto, produtores menos capitalizados para investir em equipamentos de evisceração ou em logística de entrega de grandes volumes de lambaris necessitam do apoio do poder público para ter acesso à credito e assistência técnica para acessarem tais oportunidades de mercado. Há ainda opções como a utilização de sistemas multiespaciais e multitróficos que melhoraram o aproveitamento de nutrientes e de espaço, além de diversificar a produção. A utilização dessa técnica já vem sendo adotada por produtores de menor escala, que acessam diferentes mercados sob diferentes modalidades. Entretanto, há carência de apoio técnico específico em muitas regiões que auxiliem no acesso às políticas de compras públicas da produção oriunda da agricultura familiar, por exemplo.

Para cada sistema de produção de lambari estudado é possível propor uma propriedade ideal, baseado em uma taxa de atratividade que viabilize economicamente. Assim, uma propriedade ideal adotaria o sistema de alto controle de produção, considerado o mais sustentável. Esse sistema de produção necessita de investimentos em construção de laboratório, viveiros, tela anti-pássaro, veículo para entrega, além de custos com mão de obra fixa, rações de boa qualidade, combustíveis, taxas, impostos e custo de oportunidades. Considerando um projeto de implantação de uma lambaricultura em área de 1 ha de lâmina d'agua, é possível produzir 5.100 kg/ciclo ou 340.000 unidades/ciclo com taxa de sobrevivência de 85%. Nessas condições é possível obter uma TIR de 11.69% ao preço de venda de R$ 0.25 a unidade ou R$ 16,70/kg, assumindo um Custo-Patrão de R$ 5.000,00/mês e manutenção de dois funcionários fixos ao custo de R$ 2.2250/mês cada. Essa propriedade conceito deve considerar outros fatores. A utilização de uma ração com boa digestibilidade e aproveitamento dos nutrientes associado ao manejo adequado dos viveiros garante melhora no desempenho ambiental. Além disso a propriedade conceito deve localizar-se em território onde há assistência técnica especializada e proximidade com o mercado para uma boa governança. Para considerada sustentável não apenas sob a ótica econômica, é ainda recomendável o associativismo. Dessa forma é possível ampliar oportunidades de aquisição de insumos por meio de grupos de compras que possam barganhar custos menores. Além disso, é possível garantir uma distribuição de renda mais igualitária ao evitar o custo patrão sob os aspectos da economia solidária.

NOMENCLATURA INTERNACIONAL

Durante o desenvolvimento da tese, percebemos que o gênero *Astyanax* possui diversas espécies de lambaris e muitas nomenclaturas regionais, como tambiú, piaba, além das variações de espécies como lambari do rabo amarelo, lambari do rabo vermelho (*Astyanax fasciatus*). Há ainda espécies potenciais para aquarismo como o lambari listrado ou bembeca (*Hollandichthys multifasciatus*). A espécie *Astyanax altiparanae* (Garutti e Britski, 2000), reclassificada para *Axtyanax lacustris* (Lucena *et al.*, 2016) é a espécie de lambari mais estudada no Brasil. Para a literatura internacional ainda não há consenso sobre nomenclatura padrão para a espécie e são utilizados termos como yellowtail tetra, yellow tailed tetra, yellowtail lambari ou apenas lambari fish. A espécie africana *Alestopetersius caudalis* também é referida como yellowtail tetra e isso pode gerar muitas confusões. Assim, há necessidade de inclusão do lambari *Astyanax lacustris* na lista de espécies e interesse da aquicultura da FAO, com definição de nome popular para promover maior clareza sobre esta espécie de grande potencial para o desenvolvimento para aquicultura brasileira.

DOCUMENTÁRIO

O documentário “Sustentabilidade dos sistemas de produção do lambari-do-rabo-amarelo” foi gravado durante a realização desse trabalho e é parte integrante da presente tese. Esse material tem como objetivo a divulgação dos resultados gerados de forma ilustrada voltado a produtores rurais, extensionistas, pesquisadores e agentes formadores de políticas públicas.

ANEXO – CERTIFICADO COMISSÃO DE ÉTICA NO USO ANIMAL - CEUA

UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Instituto de Biociências
Câmpus do Litoral Paulista

unesp IB-CLP

CERTIFICADO

Certificamos que o projeto intitulado "Sustentabilidade dos sistemas de criação de lambaris do Estado de São Paulo", Protocolo nº **02/2017-CEUA**, sobre a responsabilidade do **Prof. Dr. Wagner Cotroni Valenti e Fernando Henrique Gonçalves**, que envolve a produção, manutenção e/ou utilização de animais pertencentes ao filo Chordata, subfilo Vertebrata (exceto o homem) para fins de pesquisa científica (ou ensino) – encontra-se de acordo com os preceitos da Lei nº 11.794, de 08 de outubro de 2008, do Decreto nº 6.899, de 15 de julho de 2009, e com as normas editadas pelo Conselho Nacional de Controle da Experimentação Animal (CONCEA), e foi aprovado pela COMISSÃO DE ÉTICA NO USO DE ANIMAIS – CEUA, do Instituto de Biociências do Campus do Litoral Paulista, em reunião de 08/05/2017.

Vigência do Projeto:	01/02/2015 à 28/02/2018
Espécie/linhagem:	Lambari-do-rabo-amarelo (*Astyanax altiparanae*)
Número de animais:	180 indivíduos (20 exemplares em 9 fazendas de criação)
Peso/Idade:	10g em média/4 meses
Sexo:	10 machos e 10 fêmeas (por fazenda)
Origem:	Pisciculturas do interior do Estado de São Paulo

São Vicente, 08 de maio de 2017.

Rafael M. Duarte

Prof. Dr. Rafael Mendonça Duarte
Presidente – CEUA

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