UNIVERSIDADE FEDERAL DO PARANÁ

RAFAEL FERNÁNDEZ DE ALAIZA GARCÍA MADRIGAL

BIOLOGIA COMPARATIVA E CARACTERÍSTICAS ZOOTÉCNICAS DO CAMARÃO-BRANCO *LITOPENAEUS SCHMITTI* (BURKENROAD, 1936) (CRUSTACEA: DENDROBRANCHIATA: PENAEIDAE)

CURITIBA

2018

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Orientador: Prof. Dr. Eduardo Luis Cupertino Ballester

Coorientador: Prof. Dr. Ubiratã de Assis Teixeira da Silva

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Os membros da Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em ZOOLOGIA da Universidade Federal do Paraná foram convocados para realizar a arguição da tese de Doutorado de **RAFAEL FERNANDEZ DE ALAIZA GARCIA MADRIGAL** intitulada: **Biologia comparativa e características zootécnicas do camarão-branco *Litopenaeus schmitti* (Burkenroad, 1936) (Crustacea: Dendrobranchiata: Penaeidae)**, após terem inquirido o aluno e realizado a avaliação do trabalho, são de parecer pela sua Aprovação no rito de defesa.

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Curitiba, 30 de Julho de 2018.

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RESUMO

O objetivo deste trabalho foi gerar informações sobre características morfológicas e zootécnicas de *L. schmitti* na costa Atlântica da América Central e do Sul, visando sua conservação e potencial de cultivo. No Capítulo 1, fizemos uma revisão sistemática das publicações sobre a carcinicultura tanto para discutir informações atualizadas sobre a introdução de espécies não-nativas quanto para avaliar os indicadores de eficiência de espécies não-nativas em comparação com espécies nativas, com o uso de ferramentas de meta-análise. O tamanho do efeito calculado resultou em um valor positivo, significando que, de acordo com os dados considerados, o uso de espécies não nativas resultou, em geral, em maiores valores de taxa de crescimento em relação às espécies nativas observadas. Outros aspectos, como o surgimento e a disseminação das principais doenças virais que afetam a carcinicultura global, também foram revisados. Na mesma discussão, abordamos as razões pelas quais grandes empresas, governos e associações relacionadas à produção e comércio de camarões cultivados devem financiar e apoiar o desenvolvimento do cultivo de espécies nativas. No Capítulo 2, avaliamos o potencial zootécnico de *L. schmitti*, através da análise de variáveis biológicas selecionadas em seis populações geograficamente isoladas, dispersas ao longo da costa brasileira, e uma da costa cubana. As variáveis mais influentes de acordo com a Análise dos Componentes Principais foram: Comprimento do Abdômen, Peso Total, Comprimento Total Parcial e Peso do Abdômen com o Exoesqueleto. O peso da cauda foi estimado usando o comprimento e profundidade do sexto segmento abdominal. O estudo demonstrou diferenças morfológicas significativas entre todas as populações naturais testadas ($p < 0{,}001$). A equação de regressão indicou um crescimento alométrico positivo para *L. schmitti.* Também foram encontradas diferenças de cor, com a presença de manchas brancas ventrais no esternito XIV da fêmea de algumas populações brasileiras, não relatadas anteriormente na literatura. A revisão da literatura indicou que o maior comprimento total relatado para o gênero *Litopenaeus* no ambiente natural correspondeu a um espécime de *L. schmitti*. No Capítulo 3, comparamos o desempenho zootécnico do camarão nativo *L. schmitti* e do camarão exótico *L. vannamei*. Juvenis de tamanho e peso semelhantes foram cultivados sob condições controladas, separadamente, em duas densidades diferentes: 30 e 50 camarões / m². Além disso, em outros dois tratamentos, as duas espécies também foram cultivadas juntas (mistas), com e sem alimentação. Após 60 dias, para ambas densidades de estocagem dos tratamentos monocultivos, a taxa média de crescimento observada para *L. vannamei* foi de 1,0 g / semana, enquanto que *L. schmitti* alcançou apenas 0,1 g / semana. O peso final médio foi de 10,4 ± 2,0g; 10,7 ± 2,1g para *L. vannamei* e 2,8 ± 0,3g; 3,2 ± 0,3g para *L. schmitti*, para respectivas densidades de 50 e 30 camarões / m^2. Sob condições estritas de jejum, ambas as espécies praticaram predação / canibalismo entre si de maneira semelhante. Os resultados refletiram as vantagens zootécnicas esperadas de uma espécie tão intensivamente melhorada como *L. vannamei*, mas também corroboraram o efeito negativo que altas densidades e falta de alimento natural no cultivo podem exercer sobre as espécies nativas. O potencial para o cultivo de *L. schmitti* em baixas densidades e o possível impacto do escape de *L. vannamei* ao ambiente natural foram analisados. A novidade científica desta pesquisa é que, pela primeira vez, as populações de camarão branco de Cuba e do Brasil foram comparadas do ponto de vista biológico. A importância dos estudos de espécies nativas, como *L. schmitti* e seus benefícios sociais e para a conservação da biodiversidade, também foram discutidos.

Palavras chave: Zoologia Aplicada; carcinicultura; espécies nativas; espécies exóticas; populações naturais

ABSTRACT

The objective of this study was to generate information about morphological and zootechnical characteristics of *L. schmitti* in the Atlantic coast of Central and South America, aiming its conservation and potential cultivation. In Chapter 1, we made a systematic revision of the publications about shrimp farming both to discuss updated information about the introduction of non-native species and to evaluate the efficiency indicators of non-native species in comparison to native ones, with the use of meta-analysis tools. The calculated effect size resulted in a positive score, meaning that, according to the considered data, the use of non-native species resulted generally in higher values of growth rate in relation with the native species observed. Other aspects like the emergence and dissemination of the main viral diseases affecting global shrimp farming were also revised. In the same discussion, we address the reasons why big companies, governments and associations related to the production and commerce of farmed shrimp, should finance and support the development of native species farming. In Chapter 2, we evaluate the zootechnical potential of *L. schmitti*, though the analysis of selected biological variables in six geographically isolated populations, dispersed along the Brazilian coast, and one from Cuban coast. The most influent variables according with the Principal Component Analysis were: Abdomen Length, Total Weight, Partial Total Length and Abdomen Weight with Exoskeleton. Tail weight was estimated using length and depth of 6th abdominal segment. The study demonstrated significant morphological differences among all natural populations tested ($p < 0,001$). Regression equation indicated a positive allometric growth for *L. schmitti*. Color differences were also found, with the presence of white ventral spots in the female's sternite XIV of some of Brazil's populations, not previously reported in literature. The literature review indicated that largest total length reported for genus *Litopenaeus* in the natural environment corresponded to an *L. schmitti* specimen. In Chapter 3 we order compared the zootechnical performance of the brazilian native shrimp *L. schmitti* and the exotic shrimp *L. vannamei*. Juveniles of similar size and weight were grown under controlled conditions, separately, at two different densities: 30 and 50 shrimp/m². In addition, in other two treatments, both species were also cultivated together (mixed), with and without feeding. After 60 days, for both stocking densities of monoculture treatments, the mean growth rate observed for *L. vannamei* was 1.0 g/week while *L. schmitti* achieved only 0.1 g/week. The mean final weight was 10.4±2.0g; 10.7±2.1g for *L. vannamei* and 2.8±0.3g; 3.2±0.3g for *L. schmitti*, for respective densities of 50 and 30 shrimp/m^2. Under strict fasting conditions, both species practiced predation/cannibalism among themselves in a similar fashion. The results reflected the zoothechnical advantages expected of from a species so intensively engineered such as *L. vannamei*, but also corroborated the negative effect that high densities and lack of natural food in the cultivation can exert over native species. The potential for *L. schmitti* cultivation in lower densities and the possible impact of the escape of *L. vannamei* into the natural environment were analyzed. The scientific novelty of this research is that, for the first time, the white shrimp populations of Cuba and Brazil were compared from the biological point of view. The importance of studies of native species such as *L. schmitti* and its social benefits and for the conservation of biodiversity, were also discussed.

Keywords: Applied Zoology; shrimp farming; native species; exotic species; natural populations

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1. INTRODUÇÃO GERAL

Os crustáceos pertencem ao maior filo do reino animal, o Artrópode, caracterizado por apêndices articulados e um exoesqueleto ou cutícula que é trocado periodicamente, mediante o processo de ecdise. Embora a maior parte das espécies deste filo sejam terrestres, o subfilo Crustácea é predominantemente aquático (Fast e Lester, 1992). Mais de 67.000 espécies vivas de crustáceos já foram descritas e, o número de espécies que ainda não foi descoberto pode ser possivelmente dez vezes maior (Brusca e Brusca, 2003). A diversidade morfológica é mais alta no subfilo Crustácea que em qualquer outro táxon no planeta Terra (Martin e Davis, 2001).

Os crustáceos decápodes de maior interesse comercial, em ordem de importância são: camarões marinhos e de água salobra, camarões de água doce, lagostins de água doce, lagostas americanas, lagostas espinhosas, caranguejos e siris (Wickins e Lee, 2008). Várias destas espécies têm um alto valor econômico devido à sua ampla aceitação como alimento no mundo inteiro, e altos preços, em comparação com outros produtos do mar. Das 343 espécies de camarão de interesse comercial reportadas pela FAO, 110 correspondem aos camarões peneídeos e representam aproximadamente 80% da pescaria mundial de camarões (Dore e Frimodt, 1987; Fast e Lester, 1992). Esta pescaria popularizou-se em todo mundo a partir dos anos 50 (García e Le Reste, 1987).

O cultivo e o aproveitamento de várias espécies de camarões marinhos e de água doce, e de siris, na região do Indo-pacífico, remonta a centenas de anos, dado que os viveiros de cultivo extensivo de peixes, ao serem cheios com a maré, também eram povoados por estes crustáceos, que formavam parte da despesca do viveiro (Wickins e Lee, 2008). Entretanto, a produção e o consumo destes animais eram limitados fundamentalmente pela falta de sementes (formas jovens) para a estocagem dos viveiros. Mas, a produção destes crustáceos de forma regular só foi estabelecida após o desenvolvimento de técnicas modernas de reprodução e larvicultura. No caso dos camarões marinhos, são clássicos os trabalhos do Hudinaga (1969) no Japão, que conseguiu o cultivo comercial do *Penaeus japonicus* em 1967 depois de 34 anos de investigações.

Zootecnia é definida como "A ciência aplicada que estuda e aperfeiçoa os meios de promover a adaptação econômica do animal ao ambiente criatório, e deste àquele" (Ferreira *et al.*, 2006). Em geral, esta ciência pretende maximizar a produção e o lucro, minimizar o tempo necessário e ter sempre em conta o bem-estar animal.

A aquicultura é um dos ramos da zootecnia que mais cresce a nível mundial. No ano de 2013, foram produzidas 70,2 milhões de toneladas, crescendo 5,6% em relação à produção do ano anterior (F.A.O., 2015). O significado da palavra aquicultura foi definido como "A arte de multiplicar e criar animais e plantas aquáticas". O cultivo de crustáceos constitui, junto ao das algas, moluscos e peixes, as quatro áreas principais da produção aquícola a nível mundial (Barnabe, 1994). Entretanto, em relação ao valor comercial (em dólares/kg), os crustáceos ultrapassam a outros itens como os peixes, moluscos e outros animais aquáticos (o que engloba anfíbios, répteis, pepinos e ouriços do mar). As 6,7 milhões de toneladas de crustáceos colhidas no ano de 2013 representaram 9,5% da produção aquícola mundial (excluindo as algas) com um valor estimado de mais de 31 bilhões de dólares, o que equivale a 21,2% do valor total da produção (F.A.O., 2015).

O fato dos crustáceos serem um alimento muito bem aceito em todas as latitudes e que possuem um alto valor, quando comparado a outros organismos aquáticos, é um aspecto de grande importância no cultivo. Geralmente, o objetivo deste cultivo é mais comercial do que enfocado à produção de alimentos como tal.

Os camarões marinhos, e em específico os da Família Penaeidae, entre todos os crustáceos, são os mais cultivados. No ano de 2013 a produção mundial de camarão de cultivo foi de 4,3 milhões de toneladas gerando mais de 22 bilhões de dólares americanos (F.A.O., 2016a). Isto faz com que as principais espécies de camarões sejam muito estudadas (Fast e Lester, 1992; Funge-Smith e Briggs, 2003; Benzie, 2009; Ballester *et al.*, 2010; Chavanich *et al.*, 2016; Galal-Khallaf *et al.*, 2016; Srinivas *et al.*, 2016), o qual também beneficia indiretamente ao cultivo de outros crustáceos Decapoda, contribuindo com conhecimentos úteis nas distintas áreas da biologia. Além disso, os camarões peneídeos despertam um grande interesse ambiental e ecológico devido à sua ampla distribuição geográfica, abundância e posição na pirâmide trófica. Deve-se também mencionar que, enganos cometidos no passado ao utilizar áreas de mangues para a construção de viveiros de produção, provocaram danos ambientais e conflitos sociais, que essa indústria está ainda hoje procurando superar (E.J.F., 2003; Chamberlain, 2010).

A seleção das espécies para à aquicultura é um tema muito estudado, já que o conhecimento da biologia das diferentes espécies facilita a seleção das mais apropriadas para o cultivo. Entre os aspectos a se levar em conta para a seleção de espécies, devem ser considerados os objetivos do cultivo, condições geográficas e climáticas, condições para a cultura dos organismos, a aceitação do consumidor e do mercado, custo de produção, consumo doméstico vs. exportação, etc., tudo tendo em vista as características biológicas das espécies candidatas (F.A.O., 1978) (Tabela 1). Também são importantes os aspectos relacionados com a genética. Estes últimos podem ser, no caso dos crustáceos, relacionados à adaptabilidade às condições ambientais de cultivo (que por sua vez precisam simular o ambiente natural), ter um alto potencial evolutivo (considerando o número de espécies no gênero e o número de populações geográficas da espécie) e a herdabilidade de suas principais características (Nelson, 1977).

Tabela 1. Características biológicas e de interesse zootécnico a serem considerados na seleção de espécies para a aquicultura (adaptado da F.A.O. (1978)).

Aspecto a considerar	Características biológicas desejáveis	Interesse zootécnico no cultivo da espécie
Alimentação:	- Posição baixa na cadeia trófica (Detritívoro, herbívoro, omnívoro, etc.); - Conversão eficiente de alimentos; - Voracidade; - Aceitação de rações comerciais.	- Baixa porcentagem de proteína na ração; - Aceitação de alimentos naturais; - Baixa quantidade de alimentos/kg de biomassa na despesca (FCA); - Baixo custo de produção.
Crescimento:	- Crescimento rápido e contínuo até adulto; - Mudas frequentes (nos crustáceos); - Taxa metabólica alta; - Animal robusto, alto coeficiente na relação comprimento-peso; - Tolerância a altas densidades de estocagem e no cultivo.	- Obtenção de animais grandes e de alta biomassa na despesca; - Ciclo de engorda curto; - Maior proporção de carne/kg de biomassa na despesca; - Baixo custo de energia, mão de obra, etc. durante o ciclo de produção.
Reprodução:	- Facilidade de reprodução em cativeiro; -Maturação precoce; - Alta fecundidade; - Facilidade de obtenção e manejo dos estoques de matrizes; - Alta sobrevivência das matrizes e das larvas.	- Possibilidade de obtenção de pós-larvas o ano todo, com quantidade e qualidade; - Baixo custo para manutenção de reprodutores e produção de pós-larvas.
Rusticidade:	- Amplos limites de tolerância de salinidade, temperatura, concentração de oxigênio e outros parâmetros ambientais; - Resistência a doenças;	- Alta sobrevivência nas condições de cultivo; - Animais saudáveis, evitando perdas por mortalidade.
Ciclo de vida:	- Desenvolvimento ontogenético rápido; - Distribuição geográfica ampla.	- Facilidade no cultivo em todos os estágios.

Dada a mencionada importância dos camarões peneídeos, o debate sobre seu aproveitamento e a conservação das populações naturais tem grande atualidade (Lutz *et al.*, 2015; Fujiwara *et al.*, 2016). Especificamente, decisões sobre a introdução e o emprego de espécies exóticas e as consequências sobre as espécies nativas e o ambiente natural, são temas de grande prioridade e transcendência (Peres e Klippel, 2006; Pincinato e Asche, 2016; Occhi *et al.*, 2017). Além disso, também existem debates sobre se o processo de seleção de espécies de camarões para o cultivo já está concluído pelo fato de que agora se conta com espécies "internacionais" (Saint-Paul, 2017); e ainda se o cultivo de uma única espécie de camarão marinho a escala global é desvantajosa (E.S.P.A.E.-E.S.P.O.L., 2018) ou é um processo inexorável com data de culminação já marcada (Ramasubramanian *et al.*, 2017).

Por isso, é interessante aprofundar o estudo de algumas características biológicas de interesse zootécnico deste grupo. Para a classificação taxonômica, foi seguida a proposta de Martin e Davis (2001), a qual é amplamente aceita na literatura sobre o tema. Esta classificação só considera as famílias dos crustáceos viventes, tendo em conta tanto estudos morfológicos como moleculares. Dita classificação inclui: Subphylum Crustácea Brünnich, 1772; Classe Malacostraca Latreille, 1802; Subclasse Eumalacostraca Grobben, 1892; Superordem Eucarida Calman, 1904; Ordem Decapoda Latreille, 1802; Subordem Dendrobranchiata Bate, 1888; Superfamília Penaeoidea Rafinesque, 1815; Família Penaeidae Rafinesque, 1815; Género *Litopenaeus spp.* (camarão marinho).

Como objeto deste trabalho, decidimos selecionar o camarão branco do Caribe e do Atlântico Sul *Litopenaeus schmitti* (Syn. *Penaeus schmitti*) (Perez-Farfante e Kensley, 1997) (Decapoda: Penaeidae). Esta espécie está distribuída nas Antilhas, de Cuba até Guadeloupe, e na costa atlântica do Centro e Sul da América, de Cabo Catoche no México até Rocha, no Uruguai (Pérez-Farfante, 1969; Rojas, 1982; Zolessi e Philippi, 1995; F.A.O., 2016c). Esta extensa distribuição, de mais de 9000 km de litoral, e a constante pesca de que é objeto (Santos *et al.*, 2004), fazem o estudo desta espécie nativa interessante. Além disso, o fato de *L. schmitti* já ter sido cultivado comercialmente durante anos em vários países (Bezerra e Ribeiro-Alves, 1995; De

Paiva *et al.*, 1995; Fonseca e Fernández De Alaiza, 2003), garante o domínio de sua reprodução, e possivelmente de alguns dos elementos já mencionados para a seleção de espécies para o cultivo. O êxito obtido no Japão com a reprodução e o cultivo do *Penaeus japonicus* incentivou o cultivo de várias espécies nativas em todo mundo, no entanto, em muitos casos não foram bem sucedidos (Chamberlain, 2010). Evidentemente a domesticação é um processo gradual, que em alguns animais domésticos data de milênios.

Devido às características comerciais da atividade de carcinocultura, priorizam-se as espécies de melhor crescimento e melhores índices zootécnicos. Em praticamente toda região da costa Atlântica da América Central e do Sul, o cultivo comercial de *L. schmitti* foi abandonado e esta espécie nativa foi substituída pelo camarão branco do Pacífico, *Litopenaeus vannamei* Boone (1931) (Jory, 2017). Esta é uma tendência mundial, que chegou a crescente substituição do camarão nativo *Penaeus monodon* pelo *L. vannamei* na Ásia. O camarão cinza *L. vannamei* é a espécie de camarão que mais se cultiva no mundo (4,3 milhões de toneladas em 2013 (F.A.O., 2016b)), constituindo quase a totalidade da produção no continente americano (Fernández De Alaiza García Madrigal *et al.*, 2017). Entretanto, o uso desta e outras espécies introduzidas também é rechaçado por setores ambientalistas (Angelo e Silva, 2005; Santos, 2005; Peres e Klippel, 2006; Lima-Júnior *et al.*, 2014), o que abre uma oportunidade ao cultivo e conservação de espécies autóctones de camarão, atividade que deveria ser também apoiada pelos governos e as empresas produtoras.

Por outro lado, existem vários estudos sobre as populações naturais do *L. schmitti* usando técnicas morfométricas e genéticas, em Cuba (Espinosa *et al.*, 2002; Espinosa *et al.*, 2003; Borrell *et al.*, 2007), Colômbia (Valle *et al.*, 2015) e no Brasil (Maggioni *et al.*, 2003; Luvesuto, 2006).

Entretanto, na literatura não encontramos uma comparação das populações na extensa distribuição dessa espécie.

Considerando os elementos expostos, propusemos as seguintes hipóteses:

Hipótese: 1- Não há diferenças em aspectos biológicos das populações do camarão branco *L. schmitti* em Cuba e no Brasil.

2- *L. schmitti* apresenta características zootécnicas compatíveis com as de *L. vannamei*.

A presente tese foi redigida segundo as Normas da ABNT (Amadeu, 2017).

1.1. OBJETIVOS

1.1.1. Objetivo geral

Avaliar o potencial zootécnico de *L. schmitti*, como base para seu cultivo e conservação na costa atlântica das Américas Central e do Sul, utilizando como ferramenta o estudo de características biológicas da espécie.

1.1.2. Objetivos específicos

- ✓ Conhecer a tendência atual do uso de diferentes espécies de camarões peneídeos na carcinocultura mundial;
- ✓ Diferenciar aspectos da biologia das populações de *L. schmitti* no Brasil e em Cuba, usando medidas morfológicas e outros indicadores biológicos;
- ✓ Comparar o desempenho zootécnico de juvenis do camarão branco *L. schmitti* e do camarão cinza *L. vannamei* em condições controladas de laboratório.

CAPÍTULO I

Use of native and non-native shrimp (Penaeidae, Dendrobranchiata) in world shrimp farming*

(Formatado conforme "Instruções aos Autores" em anexo I)

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Abstract

The 2013 global farmed shrimp production totaled 4.3 million tons, whereas the production of *Litopenaeus vannamei* as non-native species represented the 64% of that amount. The risks of introducing non-native or exotic species are a growing environmental concern. Therefore, the objective of this study was to discuss updated information about the introduction of non-native species and to evaluate the efficiency indicators of non-native species in contrast to native ones. The results of a systematic revision of the publications about shrimp farming are presented, comparing the zoo-technical performance of native and non-native species, with the use of meta-analysis tools. The conducted search returned 4680 results, corresponding to the articles that included one of the criteria previously established by the present work. Seven publications, which included 22 studies, met the requirements for the meta-analysis. The effect size calculated was positive, meaning that, according to the considered data, the use of non-native species resulted generally in higher values of growth rate in relation with the native species observed. Other aspects like the emergence and dissemination of the main viral diseases affecting global shrimp farming were also revised. We conclude that, although the advantages of using non-native species, especially *L. vannamei*, over native species are clear, there are enough compelling evidences to support the viability of small-scale native species farming. We also discussed why big companies, governments and associations related to the production and commerce of farmed shrimp should finance and support the development of native species farming.

Key words: aquaculture, disease emergence, exotic species, *Litopenaeus vannamei*, meta-analysis, penaeid shrimp

1. Introduction

Generally, there are two main motivations for farming of aquatic organisms: food consumption and profit generation. Penaeid shrimp is much more cultivated for commercial purposes than to be used directly as food. That's why the selection of the shrimp species to be farmed depends much more on the financial results proportioned than any other criteria.

Many species of marine shrimp have been tested for farming, but only a few showed promising results and are presently considered the "leader" species. For this selection, the economic results, along with the zootechnical parameters, are analyzed together with variables such as disease tolerance, production costs, market prices and, increasingly more important, the legal and environmental limitations related with the species (Parker *et al.*, 1974 ; Wyban, 2007b). After the pioneering work of Hudinaga on the reproduction, larval rearing and grow out of *Marsupenaeus japonicus* (Hudinaga, 1969 ; Chamberlain, 2010), the methodology was later developed for *Penaeus monodon* and other species in Taiwan, the U.S. and other countries. Then, by 1984 the techniques for larval breeding of 24 species of the genus *Penaeus* and seven of the genus *Metapenaeus* were partially or fully established (Liao, 1985). This meant a significant advance for the emergent shrimp farming industry, which no longer depended solely on natural wild broodstocks or postlarvae.

By the end of the 20th century, 56% of the world shrimp production corresponded to the Asian tiger shrimp *P. monodon*, grown as a native species in Thailand, China, Indonesia, Philippines, Vietnam, Taiwan, Malaysia and other Asian countries (Rönnbäck, 2001). However, due to its higher productive efficiency, eventually almost every country where this type of farming is produced shifted to shrimp farming based mainly in the cultivation of non-native species. From the beginning of the 21st century, the most widely introduced species has been the Eastern Pacific white shrimp *Litopenaeus vannamei* (Escobar, 1985 ; Benzie, 2009). In 2014, 3.0 million tons of this single species have been produced, 78% of it in Asia (Saumena, 2015). This represent the biggest relocation of a single species in the history of the planet (Walker & Mohan, 2009).

In the American continent, Ecuador was one of the pioneering countries in shrimp farming, along with Panama and Peru. In these countries, the farming was first developed, since 1970's, in an extensive way (Escobar, 1985).With the growth of the activity, Ecuador has became the largest world producer. According to Rosenberry (1990), several aspects contributed to this development, from geographical (high temperatures, lands, brackish water, appropriate species for farming), to political and social (governmental support, labor, capital).

Between 1970 and 1990, there had been cultivation experiences in almost all the countries of tropical America, using both native species like *Farfantepenaeus subtilis, Litopenaeus setiferus, Farfantepenaeus brasiliensis, Farfantepenaeus duorarum, Litopenaeus occidentalis, Litopenaeus schmitti, Farfantepenaeus californiensis* as well as non-native such as *Marsupenaeus japonicus, Fenneropenaeus chinensis* and *Penaeus monodon.* However, by 1990, the use of *L. vannamei* has already grown to 92% of the shrimp farming production in the continent, with *Litopenaeus stylirostris* contributing with only 6%. Both species were based mainly on the natural stocks captured from Peru to Mexico.

Several elements are taken into account when discussing the pros and cons of non-native shrimp species introductions. In "The Shrimp List" the risks of continuing introduction of the *L. vannamei* in India are discussed, given that the culture of *Penaeus indicus* and *P. monodon* is not profitable enough (Rosenberry, 2015).

Nonetheless, there are still several reasons why it may be worth considering the cultivation of native shrimp species, especially when small-scale organic farming is been planned, as some organic certification systems only allow the cultivation of native species (Briggs *et al.*, 2004). It must be taking into consideration, that there is a tendency worldwide to prefer the consumption of native rather than non-native species and in general, both in respect of nature, but also due to a positive consumer perception. When commercialized within its specific niche, the higher price reached by this type of product may compensate their lower zootechnical qualities for cultivation. From the environmental point of view, there are also contradictory opinions.

Even though the cultivation of *L. vannamei* may be promoted because of its lower animal protein requirements, which could favor the granting of a "green" environmental certification, its introduction into Asian countries has still been rejected mainly due to the risk of introducing new virus or polluting local shrimp stocks (Funge-Smith & Briggs, 2003 ; Karunasagar & Ababouch, 2012).

On the other hand, many studies have been published about the biology, genetics and zoo-technic performance of *L. vannamei* and other leader species, mainly highlighting its zootechnical advantages over native ones (Parker *et al.*, 1974 ; Lawrence *et al.*, 1987 ; Rönnbäck, 2001 ; Briggs *et al.*, 2004 ; Benzie, 2009 ; Liao & Chien, 2011). The criteria of favouring its introduction are supported by Wyban (2007b), based on the successful cultivation of this species in Thailand. In spite of the supposed advantages of the use of non-indigenous marine shrimp species, the risks of introducing non-native or exotic species are well documented. Although specific evidences of impacts caused by marine shrimp introductions are still lacking, it is generally accepted that, at least for other aquatic species, the risk of escape and spreading in the new environment is even greater than for land species (F.A.O., 1996 ; Briggs *et al.*, 2004).

Therefore, the objectives of this study intend to answer the following questions:

1. What is the current rate of the use of non-native species in world shrimp farming?

2. To what extent are cultivation efficiency indicators of non-native species better than native ones?

3. What have been the consequences of introducing penaeid shrimp for farming purposes on wild populations of native species?

2. Methods

2.1. Revision and selection criteria

Initially, a systematic revision of publications about shrimp farming and production systems in different countries was conducted to identify studies comparing zootechnical performance between native and non-native species. With this information, meta-analysis tools were used to establish the general differences in this performance between both groups to generate information that could be useful for decision-making.

The study focused on the differential effect exerted by the use of native and non-native penaeid shrimp on quantitative cultivation efficiency indicators, from here on considered as "response variables". The aim was to select studies where a numerical ratio of "effect size" could be obtained (Coltman & Slate, 2003).

During the search on the Wiley Online Library (http://onlinelibrary.wiley.com/), the terms: (shrimp OR native OR non-native OR vannamei) AND (pond OR culture OR comparisons OR experiments) AND (growth OR yield OR survival) were used. The search included all the studies published up till April, 2017, in the topics: Aquaculture, Fisheries & Fish Science. Searches were also carried out in the Thompson Reuters platform (ISI – Web of Science, www.isiknowledge.com), and the databases: Science Direct, Springer, Web of Science and Scopus.

The articles were selected if 1. it included at least one species of penaeid shrimp introduced with farming purposes (SPECIES/INTRODUCTION); 2. it showed the results of any experiment or sampling, either in ponds or under laboratory conditions, where it is compared with a native species (COMPARISON); 3. it provided performance indicators that allow to quantify the advantages of one species over the other (INDICATORS).

During our analysis, we defined shrimp farming with native species as "control", and farming with non-native species as "treatment", following Gallardo *et al.* (2016), who quantified the effect (ecological impact) of invasive species on aquatic ecosystems.

In the begging of the search, at first we collected the following response variables: Final Weight (g); Yield (kg ha^{-1} $crop^{-1}$) (t/ha/crop); Survival (%); Weekly Growth (g $week^{-1}$) (g/week); Feed Conversion Rate (FCR); "Seed" Efficiency (harvested tons/millions PLs) and Production Efficiency (USD ha^{-1} $year^{-1}$) (USD/ha/year). Later on other response variables, useful to characterize a cultivated species, were found and added. These were: Final Biomass (g) at the end of the experiment, Weight Gain (%) (Williams *et al.*, 1996) and Length-weight Ratio Regression Coefficient (b) (Hutchins *et al.*, 1979). The former reflects the robustness of individuals for a certain size, and it was also considered interesting from the zootechnical and commercial point of view.

As the search continued, other important information, such as the country where the work was carried up , species used, the type of study (whether experimental or commercial), postlarvae origin (for native species only: cultivated or wild parents), the culture system classification, according to Fast & Lester (1992) and the conditions of ponds or tanks (indoor or outdoor), was also collected from every analyzed article or study.

The dispersed information gathered among the articles was summarized in a spreadsheet to facilitate the application of the meta-analysis technique. The obtained data were processed using the software MetaWin, version 2.1. according to the method proposed by U.C.D.H.S.C. (2006). Only studies in which the average values of the indicators to be compared were accompanied by standard deviation (SD), or the variance (S^2) values were included (Borenstein *et al.*, 2009).

To identify the current ratio of native and non-native species in world shrimp farming, the F.A.O. (2016a) statistics were used. The name of the species used in this study follows the nomenclature proposed by Perez-Farfante and Kensley (1997).

3. Results and Discussion

3.1. Use of non-native species

The distribution of the most cultivated penaeid species internationally is shown in Table 1. These are also the most introduced species with farming purposes.

The 2013 global farmed shrimp production totaled 4.3 million tons, whereas the production of *L. vannamei* as non-native species represented the 64 % of that amount (reaching 70 % in the Eastern Hemisphere) (F.A.O., 2016a). A summary of target species and producing countries in 2013 is shown in Table 2.

In the main producing countries like China, Indonesia, Thailand and India, farmed shrimp production is heavily based on *L. vannamei*, a non-native species for Asian waters. China alone produced over 1.4 million tons in 2013, while *L. vannamei* represented 84% of that. Yet, in Vietnam, of the 540 thousand tons produced, 51% still corresponds to native species (mainly *P. monodon*), while *L. vannamei* already represents 47% of the annual harvest.

Table 1. Geographical distribution of penaeid shrimp species, which are (or were) most cultivated worldwide.

Specie	Common Name (F.A.O., 2016b)	Author	Geographical distribution (F.A.O., 2016b)
Litopenaeus vannamei	Whiteleg shrimp,	Boone (1931)	Native to the Eastern Pacific coast from Sonora, Mexico in the North, through Central and South America as far South as Tumbes in Peru.
Penaeus monodon	Giant tiger prawn	Fabricius (1798)	Inhabits the coasts of Australia, South East Asia, South Asia and East Africa.
Fenneropenaeus indicus	Indian white prawn	Milne Edwards (1837)	Inhabits the coasts of East Africa, South Africa, Madagascar, the Gulf, Pakistan, the Southwest and East coast of India, Bangladesh, Thailand, Malaysia, Philippines, Indonesia, Southern China and the Northern coast of Australia.
Fenneropenaeus merguiensis	Banana prawn	de Man (1888)	Indo-West Pacific: from the Persian Gulf to Thailand, Hong Kong, and the Philippines. Indonesia, New Guinea, New Caledonia and N. Australia (north of 29°S).
Litopenaeus stylirostris	Blue shrimp	Stimpson (1874)	Eastern Pacific: from Baja California (Mexico) to Peru.
Litopenaeus setiferus	Northern white shrimp	Linnaeus (1767)	Western Atlantic: East coast of U.S.A. from New Jersey to Texas; east coast of Mexico from Tamaulipas to Campeche; especially abundant in the Gulf of Mexico.
Marsupenaeus japonicus	Kuruma prawn	Bate (1888)	Indo-West Pacific: from the Red Sea, E. and S.E. Africa to Korea, Japan and the Malay Archipelago, also reported from Fiji. Eastern Atlantic: the species entered the eastern Mediterranean through the Suez Canal and has reached the south coast of Turkey.
Fenneropenaeus chinensis	Fleshy prawn	Osbeck (1765)	Indo-West Pacific: Korea; China; Hong Kong. Records from outside this area are doubtful and may pertain to one of the other *Fenneropenaeus* species.

In American continent, nowadays, practically the whole production is based on *L. vannamei*. As this species is found naturally in the coastal areas of certain American regions, of the 586 055 tons harvested in 2013, 81% of *L. vannamei* was produced in the "native" areas for this species and only 19% of the cultivations (110 321 tons) occurred in countries or regions where it is considered a non-native species.

Table 2. Farmed shrimp production by country in 2013, using native and non-native species (F.A.O., 2015).

	NATIVE								NON-NATIVE			
COUNTRY	*L. vannamei*	*P. monodon*	*F. chinensis*	*F. merguensis*	*F. indicus*	*M. japonicus*	*Penaeus spp.*	*Metapenaeus spp.*	*L. vannamei*	*L. stylirostris*	*M. japonicus*	TOTAL
China	-	72,008	41,931	-	-	45,949	108,836	-	1,429,929	-	-	**1,698,653**
Indonesia	-	175,318	-	17,561	-	-	-	54.274	376,189	-	-	**605,781**
Vietnam	-	276,309	-	-	-	-	-	8.129	256,197	-	-	**540,635**
Thailand	-	16,193	-	379	-	-	259	325	311,879	-	-	**329,035**
India	-	78,500	-	-	700	-	-	-	211,200	-	-	**290,400**
Bangladesh	-	68,948	-	-	2,699	-	10,925	-		-	-	**82,572**
Filipinas	-	49,467	-	1,871	-	-	-	757	7,597	-	-	**59,692**
Myanmar	-	52,000	-	-	-	-	-	-		-	-	**52,000**
Malaysia	-	4,483	-	-	-	-	-	-	45,474	-	-	**49,957**
Saudi Arabia	-	-	-	-	19,544	-	-	-	-	-	-	**19,544**
Taiwan	-	425	-	-	-	60	-	-	13,207	-	-	**13,693**
Iran	-	-	-	-	-	-	-	-	12,698	-	-	**12,698**
Egypt	-	-	-	-	-	-	5,853	-	-	-	-	**5,853**
Madagascar	-	5,362	-	-	-	-	-	-	-	-	-	**5,362**
Sri Lanka	-	4,430	-	-	-	-	-	-	-	-	-	**4,430**
South Korea	-	-	42	-	-	-	-	-	3,785	-	-	**3.827**
Australia	-	-	-	-	-	-	3,742	-	-	-	-	**3,742**
Japan	-	-	-	-	-	1,596	-	-	-		-	**1,596**
New Caledonia	-	-	-	-	-	-	-	-	-	1,573	-	**1,573**
Brunei Darussalam	-	-	-	-	-	-	-	-	-	500	-	**500**
Oman	-	-	-	-	350	-	-	-	-	-	-	**350**
Tanzania	-	285	-	-	-	-	-	-	-	-	-	**285**
United Arab Emirates	-	-	-	-	280	-	-	-	-	-	-	**280**

Cambodia	-	-	-	-	-	-	120	-	-	-	-	**120**
Pakistan	-	-	-	-	-	-	112	-	-	-	-	**112**
French Polynesia	-	-	-	-	-	-	-	-	-	79	-	**79**
Singapore	-	-	-	-	-	-	58	-	-	-	-	**58**
Others	-	54	-	-	-	-	1	-	1	12	-	**68**
Subtotal Eastern Hemisphere	**0**	**803,783**	**41,973**	**2,250**	**23,573**	**47,605**	**129,906**	**63,485**	**2,668,156**	**2,164**	**0**	**3,782,894**
Ecuador	304,000	-	-	-	-	-	-	-	-	-	-	**304,000**
Brazil	-	-	-	-	-	-	-	-	64,669	-	-	**64,669**
Mexico (†)	56,336	-	-	-	-	-	-	-	3,956	-	-	**60,292**
Honduras	49,427	-	-	-	-	-	-	-	-	-	-	**49,427**
Nicaragua	26,368	-	-	-	-	-	-	-	-	-	-	**26,368**
Peru	17,883	-	-	-	-	-	-	-	-	-	-	**17,883**
Guatemala	11,049	-	-	-	-	-	-	-	-	-	-	**11,049**
Belize	-	-	-	-	-	-	-	-	7,080	-	-	**7,080**
Panama	6,954	-	-	-	-	-	-	-	-	-	-	**6,954**
United States	-	-	-	-	-	-	-	-	5,643	-	-	**5,643**
Colombia (†)	-	-	-	-	-	-	-	-	4,545	-	-	**4,545**
Cuba	-	-	-	-	-	-	-	-	4,116	-	-	**4,116**
Costa Rica	2,890	-	-	-	-	-	-	-	-	-	-	**2,890**
El Salvador	771	-	-	-	-	-	-	-	-	-	-	**771**
Surinam	-	-	-	-	-	-	-	-	177	-	-	**177**
Others	-	-	-	-	-	-	9	-	135	-	47	**191**
Subtotal Western Hemisphere	**475,678**	**0**	**0**	**0**	**0**	**0**	**9**	**0**	**110,321**	**0**	**47**	**586,055**
TOTAL	**475,678**	**803,783**	**41,973**	**2,250**	**23,573**	**47,605**	**129,915**	**63,485**	**2,778,477**	**2,164**	**47**	**4,368,949**

Figure 1. Countries that reported, in 2013, penaeid shrimp commercial crops, according to the native and non-native species farming ratio. Source: F.A.O. (2016a) database.

This situation can be appreciated from a global perspective in Figure 1. Note that countries with seacoasts in both oceans (Pacific and Atlantic), like Colombia and Mexico, *L. vannamei* species can be considered native, when it is cultivated in the shrimp farms of the Pacific coast, and non-native, when it is cultivated in the Caribbean Sea and the Gulf of Mexico coasts.

In almost all Asia (where 87% of global farmed shrimp is produced), *L. vannamei* farming has been introduced or is predominant.

Presently, only in Africa and the Middle East, due to an incipient development of shrimp farming, cultivation is still mainly focused on native species. In that region, the main cultivated species in 2013 were *Fenneropenaeus indicus* (Saudi Arabia, 19 544 tons), *P. monodon* (Madagascar, 5362 tons) and *Penaeus spp.* (Egypt, 5853 tons). However, even in this region there are exceptions. After introducing *L. vannamei* species, Iran managed to produce over 12 000 tons in 2013 (F.A.O., 2016a).

The remarkable importance of *L. vannamei* for word marine shrimp production in the present day may be seen in Figure 2, especially when compared to other farmed species. This fact can be explained, in part, by the purely commercial purpose of this activity.

3.2. Meta-analysis – effect size

The conducted searches returned 4680 results, corresponding to the studies that included one of the established selection criteria. Of them, 321 results containing the term "penaeid shrimp species native non-native world shrimp farming" were preselected. During further analysis, however, the majority of the articles failed to contain the minimum statistical information needed for conducting the meta-analysis.

Some of these studies hold a historical importance as their results clearly demonstrated the advantages of certain non-native species and, at that time, were used to recommend their introduction. Unfortunately, many of these works could not be included in the selection process because they failed to meet Borenstein *et al.* (2009) criteria.

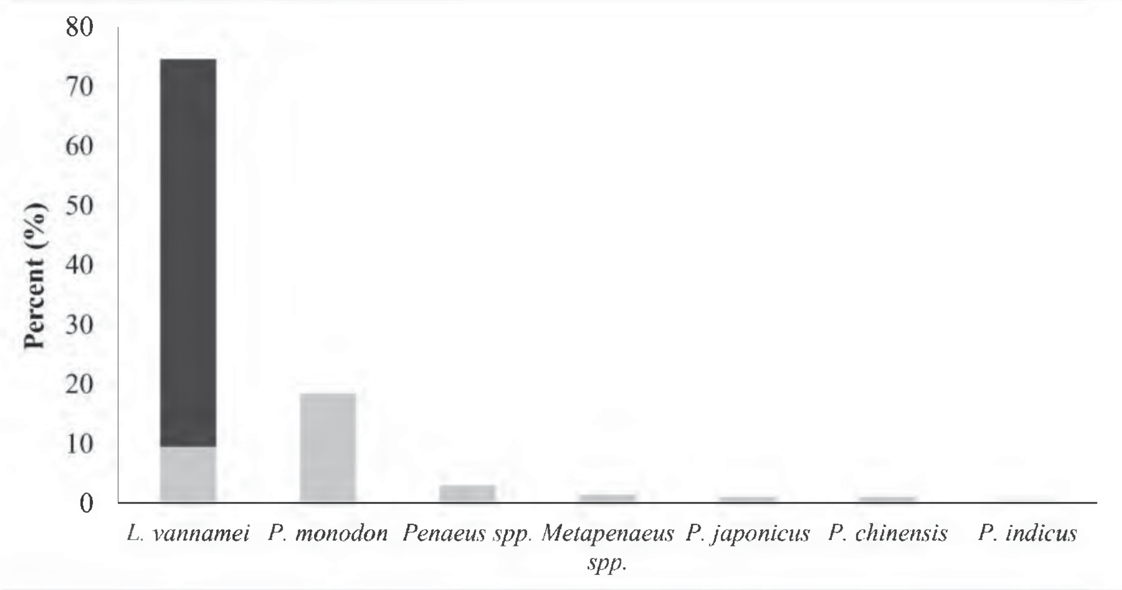

Figure 2. Ratio (in %) of the main native and non-native species, in global production of farmed penaeid shrimp in 2013. Source: F.A.O. (2016a) database.

Only seven of the selected papers contained all the needed information. The calculated effect size corresponds to comparison data of the performance of non-native species, in relation to native ones, in the U.S. (Hutchins *et al.*, 1979 ; Sandifer *et al.*, 1993 ; Williams *et al.*, 1996); Thailand and Vietnam (Limhang *et al.*, 2005 ; Boyd *et al.*, 2017); Mexico (Rosas *et al.*, 2001) and Brazil (Peixoto *et al.*, 2003) (Table 3). As it may be seen, of the 22 studies analyzed, 19 of them showed a positive effect of the use of non-native over native species and only in three of them (studies 2, 3 and 4), the observed effect was the opposite. This one corresponded to the results of pond farming in Texas, during 1972-1979, when the native species *F. duorarum* had a robustness indicator ***b*** in the length-weight ratio (L-W) larger than *L. occidentalis, L. stylirostris* and *L. vannamei*.

Table 3. Shrimp species, productive indicators and Meta-analyses results for each study.

	Study	Native specie	Non-Native specie	Productive indicator	Effect size (Cohen's d) Standardized Mean Difference	Range
Limhang *et al.* (2005)	1	*P. monodon*	*L. vannamei*	Harvest weight (g)	3.14	3.14 , 3.14
Hutchins *et al.* (1979)	2	*F. duorarum*	*L. occidentalis*	Coefficient "b" Length-Weight Ratio	-4.24	-4.24 , -4.24
	3		*L. stylirostris*		-13.21	-13.20 , -13.20
	4		*L. vannamei*		-9.51	-9.51 , -9.51
	5		*L. occidentalis*		1.36	1.36 , 1.36
	6	*L. setiferus*	*L. stylirostris*		5.30	5.30 , 5.30
	7		*L. vannamei*		21.23	21.23 , 21.23
Williams *et al.* (1996)	8	*L. setiferus*	*L. vannamei*	Harvest weight (g)	4.75	4.69 , 4.81
	9				21.84	21.76 , 21.93
	10				5.33	5.32 , 5.35
	11				8.74	8.73 , 8.75
	12				11.04	11.03 , 11.05
	13				6.77	6.77 , 6.78
	14				15.44	15.44 , 15.45
Peixoto *et al.* (2003)	15	*F. paulensis*	*L. vannamei*	Yield (kg/ha/ harvest)	12.12	12.12 , 12.12
Sandifer *et al.* (1993)	16	*L. setiferus*	*L. vannamei*	Yield (kg/ha/ harvest)	7.17	7.17 , 7.17
	17	*L. setiferus*	*L. vannamei*		0.11	0.11 , 0.11
Rosas *et al.* (2001)	18	*L. setiferus*	*L. vannamei*	Harvest weight (g)	5.57	4.39 , 6.75
	19	*L. setiferus*	*L. vannamei*		3.54	2.68 , 4.39
	20	*L. setiferus*	*L. vannamei*		6.62	5.26 , 7.97
	21	*L. setiferus*	*L. vannamei*		5.56	4.38 , 6.73
Boyd *et al.* (2017)	22	*P. monodon*	*L. vannamei*	Yield (kg/ha/year)	4.29	4.25 , 4.33

The general result of the meta-analysis is shown in Figure 3. Studies 1 (Limhang *et al.*, 2005), 16 and 17 (Sandifer *et al.*, 1993) were omitted on the graph for reasons of scale, as their higher "n" value would distort the graphical representation of the remaining studies. However, the effect size values found for these three studies (3.14, 7.17 and 0.11, respectively) are valid and contribute to the overall meta-analysis result. The total value of the Hedges's *d* (also called

Cohen's *d*), is $d = 2.77$. Conventionally, is it considered that a value of '*d*' higher than 0.8 is 'large' (Cohen, 1977 ; Cohen, 1992 ; Sará, 2007). In this case, this result summarizes a positive (and large) effect size, meaning that, according to the considered data, the use of non-native species resulted generally in higher values of growth rate in relation with the native species.

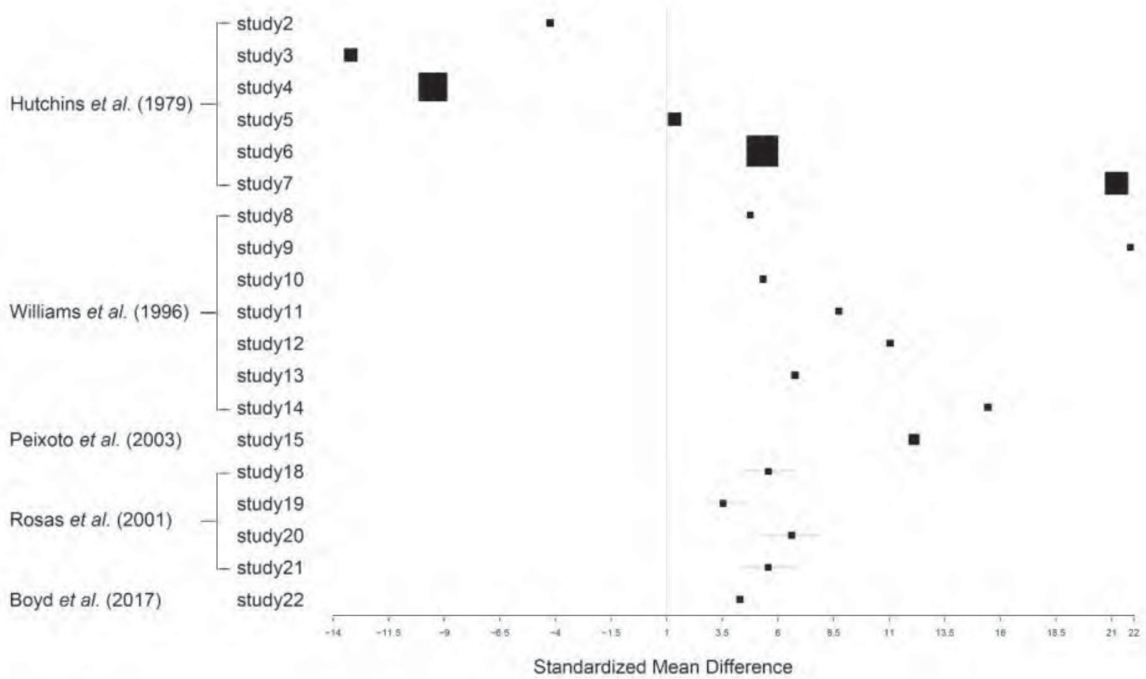

Figure 3. Effect size values calculated (Cohen's d) of the use of non-native species in relation with native ones, in 19 studies. Confidence interval: 95%. The points with positive values indicate positive effects of using non-native species, according to the productive indicators considered (see table 3). Source: Hutchins *et al.* (1979) ; Williams *et al.* (1996) ; Rosas *et al.* (2001) ; Peixoto *et al.* (2003) ; Boyd *et al.* (2017).

When considering the effect size, it is important to remember that the existence of a zootechnical advantage in the use of a non-native species it is already presumed. As it is generally a product of a deliberate introduction, it is conceivable that the non-native species will have a better performance than the native ones. And this is, to a great extent, due to a much larger "domestication" process from what the nonindigenous species have been exposed (Briggs *et al.*, 2004).

The zootechnical performance of *L. vannamei* has been compared to that of native species in several studies. In Brazil, Peixoto *et al.* (2003) demonstrated that pink shrimp *Farfantepenaeus paulensis* showed a significantly lower growth rates when compared to *L. vannamei*, in the same cultivation conditions.

Additionally, Wyban (2007a) summarized the "typical" productive and feasibility indicators between *P. monodon* and *L. vannamei* in Thailand. According to the author, because crop densities three to four times higher were possible using this species, *L. vannamei* cultivation typically yields harvest volumes three times higher than the native species (from 8 to 24 ton^{-1} ha^{-1} $crop^{-1}$ ton/ha/crop and from \$13 000 to \$36 000 ha^{-1} /ha, respectively).

Although information about production and feasibility indicators for several different species of shrimp is abundant in literature, a study comparing the dissimilarities between zootechnical performance of native and non-native penaeid species in different conditions and countries as a whole is lacking.

3.3. Consequences of species introduction

Disease dissemination

Virus like IHHNV (Infectious hypodermal and haematopoietic necrosis virus), YHV (Yellow head virus), TSV (Taura syndrome virus) and WSSV (White spot syndrome virus) are some of the aetiologies behind the most striking pandemic infirmities adversely affecting the global penaeid shrimp industry. The impact on producing countries in Asia and America has been of such scale that the OIE (Office International des Epizooties) has listed them as obligatory declaration diseases (O.I.E., 2003). These diseases are also a potential threat to wild and cultivated shellfish, and as a consequence of international commerce, the movement of infested crustaceans can readily spread the diseases throughout the world in a very short span of time (Lightner, 2003). A summary of the emergence and dissemination of the main viral diseases that have affected global shrimp farming is shown in Figure 4.

In the image, the chaotic movement of the mentioned pandemics can be seen. In addition, a notable interchange of previously unknown diseases can be observed, which appeared in shrimp farming both in Asia and America (Walker & Mohan, 2009). It is also interesting to note the importance of the role played by Hawaii in the history of dissemination of IHHNV (Tang & Lightner, 2006).

The main way for virus introduction to a distant area is through larvae pollution from infested broodstock. Cannibalism, on other hand, is the main way to spread the disease to all shrimp in a farm and bird predation is the principal form of spreading from one farm to another (Lightner & Redman, 1998).

In addition to these already classical diseases, in recent years the global shrimp farming has been affected by the pandemic generated by EMS/AHPNS (early mortality syndrome or acute hepatopancreatic necrosis syndrome), which caused estimated losses of USD 1 billion, in Asia alone (Chaichalearmmongkol & Jargon, 2013).

During the international meeting "FAO/MARD Technical Workshop on early mortality syndrome (EMS) or acute hepatopancreatic necrosis syndrome (AHPNS) of cultured shrimp" held in Vietnam (F.A.O., 2013), it was stated that 1. importing non-native species (and live shrimp in general) is contributing to disease dissemination, mainly viral. 2. The main non-native species *L. vannamei*, turned out to be more susceptible to diseases than other native ones like *P. monodon* and *Penaeus chinesis*. One of the main recommendations of the workshop was to cease live shrimp transportation from the areas or countries affected by these diseases (F.A.O., 2013). This recommendation was later decreed by several countries (N.N.N., 2013).

Live shrimp commerce can additionally complicate the matter as it has been demonstrated that genetic diversity of these viruses has been incremented due animal movement. In the case of YHV complex which affects *P. monodon* in the Asia-Pacific region, 30% were found to be recombinant (Walker & Winton, 2010).

It has been verified that these viral diseases can prevail in farming areas for 20 or 30 years after being reported for the first time. Samplings carried out in shrimp fisheries of seven Latin-American countries displayed 12 diseases, half of them caused by the following viruses: IHHNV, WSSV, IMNV, TSV, BP and LvNV (Morales-Covarrubias *et al.*, 2011 ; Silva *et al.*, 2014). It is interesting to point that the propagation of these diseases affects both countries in which *L. vannamei* is a native species (such as Mexico, Guatemala, Nicaragua and Honduras), as well as countries where the species was introduced for farming purposes (like Belize, Venezuela and Brazil).

However, verifying this effect in natural or fishery stocks is more difficult. In Asia, there is little evidence that viral diseases have contributed to the decline of wild shrimp populations. This could be caused by a combination of low population densities in the natural environment and the probable absence of the stress factors that often favour the emergence of diseases in farming systems (Rönnbäck, 2001 ; Walker & Mohan, 2009).

Furthermore, the absence of demonstrated effects on natural populations may be a misleading information. The greater sensitivity and susceptibility of early stage crustaceans to virus like WSSV, IHHNV and TSV (Flegel, 2006 ; Shields, 2012) could also explain the low prevalence in adult populations.

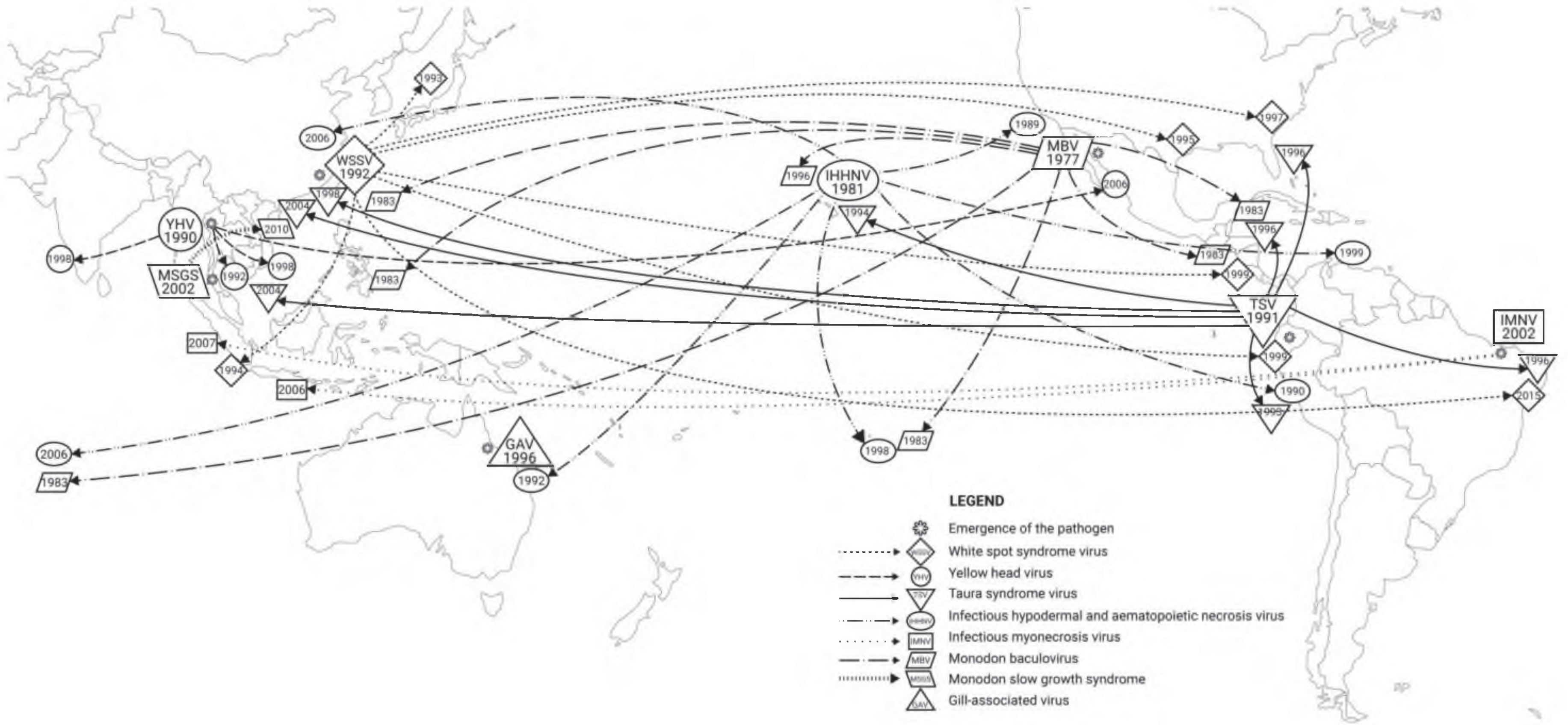

Figure 4. Historical summary of the emergence and dissemination of the main viral diseases that affect farmed shrimp. Source: Flegel (2008) ; Lightner (1996) ; Lightner (2003) ; Lightner *et al.* (2004) ; Mohan and Leaño (2011) ; Morales-Covarrubias *et al.* (1999) ; Morales-Covarrubias *et al.* (2011) ; Villegas (2016) ; Walker and Mohan (2009). Modified image of Walker and Mohan (2009).

An example of the effects on natural shrimp populations in America was the introduction of IHHNV in shrimp farms in the north-west of Mexico, those also spread to wild stocks in the Gulf of California, in the late 80s and early 90s. This aggravated the socio-economic consequences of the epidemic, causing not only significant losses in *L. stylirostris* cultivation, but also producing the collapse of this species fishery in the Gulf of California (Lightner, 2003 ; Morales-Covarrubias *et al.*, 1999).

Certain diseases can also affect other crustaceans of economic interest, such as the *Procambarus clarkii* prawn, which had its natural and farmed populations infested by WSSV since 2007 (Lightner, 1996). Even in the case in which the disease itself does not cause mortalities, natural population can act as reservoirs of the viruses, making difficult sanitary measures for controlling the situation during cultivation.

The impacts of the disease outbreaks on commercial shellfish fisheries can go beyond the mortalities alone. Other consequences can be indirect losses caused by delay in growth and the increase of predation risks (Shields, 2012). To avoid the spread of diseases from cultivation to natural shrimp populations in some occasions, it may be necessary to restrict shrimp transportation even within a same country. For instance, Owens (1990), discovered that the Strait of Torres (in the north of Australia) constitutes a zoo-geographical barrier for the populations of several shrimp species and their pathogens. Therefore, the author recommended limiting the movement of shrimp across this barrier as a way to "preserve the possible disease-free status and the genetic identity of shrimp populations". In a similar way, considering the uncertainty of the disease situation in wild shrimp populations and the existence of "risk" zones, the government of Western Australia created a "national translocation policy" for live shrimp and other aquatic species (Jones & Stephens, 2006). This document restricts the movement of specimens inside the country and demands the inclusion of risk analysis and operating measures in transfer requests.

In recent years, the combination of modern molecular technologies with traditional methods and international cooperation has permitted faster and more precise diagnoses facilitating the management of diseases in the aquatic environment (Burge *et al.*, 2016). In the future, this will provide better tools for monitoring the occurrence of disease transferring from aquaculture facilities to the surrounding environment.

In this scenario, more accurate control methods could affect the commercialization of exotic shrimp species in the future. For example, working with genetic lines in shrimp farming, of both non-native and native species, may even result in the payment of royalties for using genetic resources, which may be were originated within the country (Ramanna-Pathak, 2015).

In addition, a greater accessibility in molecular analysis methods, used in consumer service protection in Europe, allow to detect frauds in seafood markets. Thus, exotic or invasive species within the producing country can be detected by routine DNA analysis (Galal-Khallaf *et al.*, 2016). The implementation of these tools, as well as traceability techniques of the food reaching the consumer, compels the producers to higher control, including the obligation of declaring the use of exotic species in commercial crops.

Escapes to the natural environment

In the USA, invasive aquatic species are considered a growing threat. They are known to cause losses in biodiversity, to change the ecosystems, to impact economic activities, such as fishing and international commerce (Lovell *et al.*, 2006), and to cause ecological damage (Rader & Laney, 2016). Additionally, because it is very difficult to eliminate or even to control an invader species once a reproductive population is installed, it is consensual that the best measures are preventive (Ruiz & Carlton, 2003 ; Brugere *et al.*, 2017).

Even though the ecological and economic impacts of exotic species are often studied separately, they are known to be highly correlated (Vilà *et al.*, 2010). These economic impacts have been quantified, establishing the cost of some introductions and invasions. Considering the strong trophic relationships that characterize them, Gallardo *et al.* (2016) warned about the long-term consequences of biological invasions on the structure and functionality of aquatic ecosystems. Specifically concerning *L. vannamei,* it has been demonstrated that it is one of the more voracious and less selective species of marine shrimp. In a laboratory experiment, Chavanich *et al.* (2016) compared *L. vanammei* with five native shrimp species in Thailand (including *P. monodon*) and found to be significantly more aggressive in terms of food consumption. Consequently, this species could represent a serious threat if it manages to establish reproductive populations in the marine areas, where its single presence has already been reported.

The presence of *L. vannamei* and *P. monodon* in coastal areas of Brazil has been also reported (Santos & Coelho, 2002 ; Barbieri & Melo, 2006 ; Loebmann *et al.*, 2010 ; Cintra *et al.*, 2014). Even if, to date, there is no indication of established populations, the consequences of the massive translocation of this species remain uncertain (Walker & Mohan, 2009).

3.4. Cultivation of native penaeid species: a return?

Analysing the decisions made in the past about the introduction of exotic marine shrimp and its consequences (known so far) may result in less digression in the future. Ultimately, we are discussing the pros and cons of an activity that produces annually more than 4.3 million tons of a highly valuable product and earns more than $USD 22 billion, creating thousands of jobs worldwide (F.A.O., 2016a). Geographically, it also has a broad distribution, interacting with a tropical coastal strip that surrounds the planet.

The advantages of use of *L. vannamei* for cultivation should be, at this point, unquestionable. Even though, most of the studies that highlights the success achieved from its introduction, mainly in Asia (Wyban, 2007b ; Liao & Chien, 2011), do not equally balance the risks associated with it.

Our study has also demonstrated the high production potential and feasibility that can be achieved with *L. vannamei* farming. Nevertheless, it has also shown that cultivating this species in countries and environments where it is not native will always come together with the typical risks associated with the exotic species introductions: spreading diseases, escaping to the sea and possible affecting local biodiversity.

In recent years, new improving production techniques, capable to reduce these risks to an acceptable minimum, have been developed, although specially designed to *L. vannamei*. These include genetic improvement, to obtain more disease-resistant animals, closed cycle cultivation with zero water exchange, treatment and depuration barriers for waste water. For large companies that continuously invest in this industry, it is always possible to absorb the costs of these adaptations.

However, what about small producers? Since its beginning, shrimp farming has not only been practiced in intensive grow-out or by large companies. There is also the traditional farming. Hundreds of thousands of families have practiced extensive shrimp farming in the coasts of Asia for many years. There are many areas in the world where poor communities dedicate themselves to capture and maintenance of shrimp for cultivation, in earthen ponds, pens or cages, for own consumption, commercialization or live bait. How the questions of cultivation of non-native species affect these people? Walker and Mohan (2009) recognized that impact of disease in shrimp farming has been greater on the poor coastal communities than in developed ones. Could they possibly cultivate non-native species without risking economic breakdown or posing a threat to the environment if their access to this ever- increasingly technified package is denied? Should we prohibit shrimp cultivation to those who practically invented it?

Large companies and associations involved with production and commerce of farmed shrimp, along with governments and international organizations, could finance and support, through the creation of specific funds, the development of community cultivation of native species (Naylor *et al.*, 2000 ; Sultana & Thompson, 2007 ; Srinivas *et al.*, 2016 ; Ahmed & Glaser, 2016). The advance of the technology, in this case, could pursue a more resilient and holistic approach, avoiding overly introspective and unsustainable techniques.

Production of native seeds could be performed using local small larval rearing facilities based on Asian experience, rather than rely on a few large and expensive laboratories. Programmes focus of domestication enabling the use of autochthon species in community-based farms. Furthermore, these efforts could help the conservation initiatives and the advancement of the knowledge about ecological issues of the native populations, essential to programmes of repopulation of lagoons and coastal areas where small-scale fishing is practiced.

In Brazil, experiments have been carried out on the cultivation of the native species *F. paulensis*, *F. brasiliensis* and *L. schmitti* with interesting results (Peixoto *et al.*, 2003 ; Lopes *et al.*, 2009 ; Preto *et al.*, 2009 ; Marquez *et al.*, 2012 ; Peixoto *et al.*, 2013). Briggs *et al.* (2004) also recommended that there should be more investment on *P. monodon* domestication programmes, to support and encourage farmers to use indigenous species.

In this way, they would be giving opportunities to the people who live in shrimp areas in Asia, America and Africa, and promoting a friendlier relation with the environment. This could help settling the old debt of this burgeoning industry with its origins.

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CAPÍTULO II

Morphological variations of Southern white shrimp *Litopenaeus schmitti* (Burkenroad 1936) (Crustacea: Dendrobranchiata: Penaeidae) in natural populations of Cuba and Brazil*

(Formatado conforme "Instruções aos Autores" em anexo II)

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Abstract

The objective of this study was to evaluate the zootechnical potential of *Litopenaeus schmitti* (Burkenroad 1936) to contribute to its cultivation and conservation. In order to compare geographically isolated populations, between 2014 and 2016 selected biological variables were analyzed in six populations dispersed along the Brazilian coast, and one from Cuban coast. Specimens with 8 upper rostral teeth predominated. The most influent variables according with the Principal Component Analysis were: Abdomen length, Total weight, Partial total length and Abdomen weight with exoskeleton. Tail weight was estimated using length and depth of 6^{th} abdominal segment. The study demonstrated significant morphological differences among all natural populations tested ($p < 0,001$). The populations of Santa Catarina, Brazil (28°S), had proportionally the longest abdomen and the narrower cephalothorax among all the compared populations, while the animals of Manzanillo, Cuba (20°N), had proportionally shorter and heavier abdomens. Regression equation indicated a positive allometric growth for *L. schmitti*. The largest total length reported for genus *Litopenaeus* in the natural environment corresponded to an *L. schmitti* specimen. Color differences were also reported, with the presence of white ventral spots in the female’s sternite XIV of some of Brazil's populations, not previously reported in literature. Extending these studies is recommended to contribute to the future conservation and culture of this species.

Keywords: population studies; native species; morphometric; shrimp farming; applied zoology

1. Introduction

The white shrimp *Litopenaeus schmitti* (*Penaeus schmitti*) (Perez-Farfante and Kensley 1997) (Decapoda: Penaeidae) is distributed from the north coast of Cuba (23°N) to Guadeloupe (16°N) in the Caribbean Sea. On the Atlantic coast of Central and South America, this species is distributed from Cape Catoche (21°N), Mexico, to Rocha (34°S), Uruguay (F.A.O. 2016a; Pérez-Farfante 1969; Rojas 1982; Zolessi and Philippi 1995). Fishing of white shrimp *L. schmitti* is an important economic activity in several regions in the Atlantic coast (Calumby et al. 2016; García and Le Reste 1987; Henriques et al. 2014; M.P.A. 2011; Neiva et al. 1971; Santos 2007).

In Cuban waters, the species has already been subject to fishing, reaching more than 800 tons in 1983 (Sosa 2009). However, due to factors such as overfishing, reduction of freshwater flow to the sea caused by river damming and environmental deterioration, fishery in Cuban shelf has been reduced since then to minimum levels (Borrell et al. 2007; Espinosa L. et al. 2014; Paez et al. 1997; Sosa 2009). In other areas, *L. schmitti* fishing still produces relatively good catches. In the state of Rio do Janeiro, Brazil, 3,500 t of the species were captured in 1986 (Carvalho 2013). In 2003, around 6,000 t was landed in brazilian Northeastern region (Santos et al. 2005). According to data reported by the FAO, from 2011 to 2014, 4,000 to 4,400 t of the species were fished annually in Brazil, reported under the common name of "Southern white shrimp" (F.A.O. 2016a; F.A.O. 2016b). Although the difficulty of having more accurate fishing statistics has already been pointed out (Prado and Neves 2015), the literature offers information on the catches of this species in many different places, which reflect a greater fishing activity of this resource. For example, around 8,800 t were captured by artisanal fishermen at Lake Maracaibo, Venezuela in 2007 (Alió et al. 2009; Andrade et al. 2009).

Commercial aquaculture of *L. schmitti* has been practiced in several countries between 1980 and 2000. In Cuba, more than 2,000 t / year were produced by 2003 (F.A.O. 2016a; Fonseca and Fernández de Alaiza 2003). In the initial development of shrimp farming in Brazil, *L. schmitti* was considered one of the species with the highest potential for cultivation (Bezerra and Ribeiro-Alves 1995; de Paiva et al. 1995; Nascimento et al. 1991). Until the year 2000, the Pacific white-leg shrimp *Litopenaeus vannamei* was only one of many species of shrimp been cultured around the world (F.A.O. 2016b). Since then, this species has increasingly gained the preference by culturists due to its zootechnical excellence (Ostrensky et al. 1998; Peixoto et al. 2003; Rönnbäck 2001). *Litopenaeus vannamei* has also a greater resistance to certain diseases such as IHHNV, which plagued the industry in the 90`s (Chamberlain 2010; Lightner 2003). For that reason, in most countries of the Atlantic coast of Central and South America, the commercial cultivation of *L. schmitti* and other native species has been completely abandoned and replaced by *L. vannamei* cultivation (Escobar 1985; Rosenberry 1990). This trend was observed not only in the Americas but also in Asia and the Pacific (Briggs et al. 2004). Today, around 70% of the world's current shrimp farming is based on the cultivation of *L. vannamei* (Fernández de Alaiza García Madrigal et al. 2017; Jory 2017). It has been predicted that in less than 20 years, it may become the only species of cultivated shrimp (Ramasubramanian et al. 2017).

However, by many different standards, the excessive dependence of the aquaculture industry on *L. vannamei* monoculture is not desirable (E.S.P.A.E.-E.S.P.O.L. 2018). The use of native species in certain specific situations can contribute to the resilience of the activity (Henriques et al. 2014). Even if in a direct zootechnical comparison, *L. schmitti* is easily outperformed by *L. vannamei*, in more recent studies, results have confirmed the potential of cultivation of *L. schmitti* (Marquez et al. 2012), especially if certain conditions are considered.

Furthermore, there is a growing concern among environmentalists and environment authorities about the use of exotic species in aquaculture. Leaks to the natural environment are virtually impossible to avoid (Rosenfield and Mann 1992), with probable, unpredictable, and often irreversible, environmental and socioeconomic impacts (Peres and Klippel 2006) such as biodiversity loss and impairment of ecosystem function (M.E.A. 2005). In many occasions throughout the history, the emergence of viral diseases have produced huge economic and social losses (Briggs et al. 2004; Chaichalearmmongkol and Jargon 2013; F.A.O. 2013; Fernández de Alaiza García Madrigal et al. 2017; Lightner 2003; O.I.E. 2003; Walker and Mohan 2009).

Sandifer et al. (1993) demonstrated that, even without being subject to genetic improvement or "domestication", native species such as *Litopenaeus setiferus* have proven to be viable alternatives to the cultivation of the exotic species *L. vannamei*. In certain niche markets, mainly those that value organic forms of production, native species may attain better prices, thus compensating a less-than-ideal zootechnical performance. As a matter of fact, the cultivation of *L. schmitti* and pink shrimp *Farfantepenaeus subtilis* still has been extensively developed in Guyana, utilizing wild cached post-larvae (F.A.O. 1997; Fernández de Alaiza et al. 2012). The resistance to some diseases could be another advantage of native species. Laboratory tests have shown that *L. vannamei* susceptibility to white spot virus (WSSV) is significantly higher than that of *L. schmitti* (Unzueta-Bustamante et al. 2004). In certain locations, many farms have completely ceased their activities due to the continuous outbreaks of WSSV. In these regions, the use of a tolerant species could easily compensate its lower performance. In addition, the development of all aspects of native species cultivation is a current debate. It is tough that the "regionalization" of the aquaculture can help to preserve natural biodiversity on each region (Lima-Júnior et al. 2014; Occhi et al. 2017). It also permits to change the general idea that shrimp farming is a “high capital” business. Wasielesky and Poersch (2016) demonstrated the viability of the cultivation of the native species *Farfantepenaeus paulensis* and *F. brasiliensis* in cages and pen enclosures in the South of Brazil. The cultivation of *L. schmitti* could even help declining fishing stocks (I.N.S.O.P.E.S.C.A. 2013; Rosenberry 2009).

Specifically on the cultivation of *L. vannamei* in Brazil, although local legislation demand that the risk of escapes to be minimized during the construction of the shrimp ponds, (C.O.N.A.M.A. 2002), many episodes of escapes of *L. vannamei* to the wild have been registered in several locations in the Northeastern region. Additionally there are reports about the completion of their life cycle into natural environment (Santos and Coelho 2002). These instances of escape are one of the reasons why *L. vannamei* cultivation in open environments in the country, or for commercialization of juveniles of exotic shrimp species as live bait, is almost impossible to be obtained. This practice is also prohibited by law in most Southern coastal states of USA (Wilkenfeld et al. 2010). Taking this into account, the potential for cultivating *L. schmitti* in areas of the Atlantic coast of the Americas where this species is considered native brings some important advantages in comparison to *L. vannamei*. First of all, it could contribute to the sustainability of shrimp farms (Henriques et al. 2014) especially those located at or near environmental sensitive areas, such as Conservation Units. Another direct advantage is that the cultivation in open environments or for commercialization of juveniles as live bait, forbidden for exotic species, could be licensed. The use as live bait for sport fishing in the Southeastern region of the country is considered a good business opportunity for small producers (A.E.N. 2011; de Barros et al. 2014; Henriques et al. 2014).

But in order to fulfill the potential for *L. schmitti* cultivation, much research has yet to be done. Breeding programs in shrimp farming seek the construction of lineages of high zootechnical performance. These projects need to establish the genetic diversity found among natural populations to plan crosses between these lineages (Silva 2007). Domestication and breeding of *L. schmitti* has already been the subject of research in the past (Bécquer and Espinosa 2002; Bécquer et al. 2004; Pérez-Jar et al. 2007; Pérez-Jar et al. 2010; Wilkenfeld et al. 2010). A future breeding selection program will have to rely on previous studies of morphological differentiation of populations of native species. These studies have been carried out in several countries. Due to the great importance that cultivation of *L. schmitti* had in Cuba, studies on the genetic variability of natural populations of the species were carried out with morphological techniques, allozymes and microsatellites, aiming the improvement of the broodstocks (Borrell et al. 2003; Borrell 2004; Borrell et al. 2007; Espinosa et al. 2001; Espinosa et al. 2002). In Venezuela, García-Pinto (1970) studied morphometric characters of juveniles and adults of this species captured in Lake Maracaibo and Gulf of Venezuela. By relating these characters to the length of the cephalothorax, this author found a high allometric growth. Later, Andrade and Pérez (2004) studying the growth of *L. schmitti* specimens from these same zones, proved it was significantly different between the sexes. In a study comparing different species of the genus *Litopenaeus*, Arena et al. (1997) determined that out of the 24 morphometric characters studied in the *L. schmitti, L. vannamei* and *L. setiferus*, the length of the carapace, the abdomen and the first abdominal segment were the most important variables, because they significantly differed between populations, species and sexes. Many studies have been carried out on the Northeastern coast of Brazil (Carvalho 2013; Luvesuto 2006; Santos et al. 2004; Silva et al. 2018), aiming different aspects of the issue such as growth, morphometric characterization and mortality of *L. schmitti* in a natural environment and analysis of the population structure.

Therefore, the objective of this study was to evaluate the zootechnical potential of *L. schmitti*, as a base for the cultivation and conservation of this native species on the Atlantic coast of Central and South America comparing selected morphological measurements in populations occurring at the extremes of their natural distribution. In addition, morphological differences between both sides of physical barriers to *L. schmitti* distribution, interposed by the Amazon River or the resurgence of Cabo Frio, RJ (Maggioni et al. 2003; Pinheiro 2008), will be analyzed.

2. Material and methods

From 2014 to 2016, samples of shrimp of the coastal areas of Cuba and Brazil were obtained by trawling or by directly purchasing at commercial fish landing points. Shrimp sampling was carried out in Manzanillo (Cuba), and six different points of Brazilian coast: Touros (RN), Aracaju (SE), Vitória (ES), Cabo Frio (RJ), Pontal do Paraná (PR) and Laguna (SC) (Fig. 1). A total of 221 specimens were collected and processed. In addition, samples and photographs of shrimps of the same species were collected for other studies in Guaratuba Bay (Paraná, Brazil) and Morrosquillo Gulf, Colombia.

Sampling areas were selected with base on prior studies about abundance of adult specimens (Andrade et al. 2004; Bochini et al. 2014; Capparelli et al. 2012; Neiva et al. 1971; Pantaleão 2013; Santos et al. 2008; Silva and Nakamura 1981; Sosa 2009), in addition to contacts made with fishermen and inhabitants of the sampling areas. All catch sites and fishing zones were georeferenced. At each location, at least 30 specimens were collected. Different fishing arts were used such as "gerival", a trawl system used for artisanal white shrimp fishing in southern Brazil (Beccato 2009); cast nets or boat trawling, in addition to purchase at landing or selling points. The fishing gears used in the samplings were similar to those used in commercial fishing. For these reason, mostly pre-adult and adult shrimp were collected, all in inter-molt stage and in similar number for females and males. The animals were kept in a styrofoam box with ice or in a refrigerator to avoid freezing or decomposition, which could affect the measurements, especially on the appendices or soft parts (Lester 1983). All the animals were fresh processed. Before being weighed, the excess moisture was removed from each specimen by wrapping it in a cloth for a few seconds. Next, the cephalothorax was removed from the abdomen manually (to obtain the weight of the abdomen with exoskeleton), then the exoskeleton was removed and the abdomen was weighed again (to obtain the weight without exoskeleton). Finally, the upper rostral teeth were counted with the help of a manual magnifying glass.

The measurements and information listed in Table 1 follows the same order of data collection, starting with the whole animal and finishing with measurement of abdominal length (Figure 2). All measurements were performed by the same observer and always following the same criteria (Barbosa-Saldaña et al. 2012).The individuals were measured using digital caliper (Digimess, model 100.176BL) and weighed using a 0.001g portable precision digital scale (Bel Engineering, model M5-m241A). In addition, meristic features such as the number of upper rostral teeth were recorded (Espinosa et al. 2002; Holden and Raitt 1975). Images of the specimens were registered for each locality, in order to document possible differences in external characteristics. The morphological measurement followed Lester (1983), with modifications proposed by Arena et al. (1997); Espinosa et al. (1989) and Espinosa et al. (2002) (Table 1). For the measurement of Partial Total Length (PTL) in this study, the rostrum and telson were not included, since these structures often appeared broken (Nikolic and Ruiz de Quevedo 1970). However, in many studies the measurement included both structures or at least one of them (Araujo et al. 2009; Barbosa-Saldaña et al. 2012; Lutz et al. 2015; Luvesuto 2006; Pérez-Farfante 1970b).

The mean coefficient of variation (CV) of all data was calculated as well as the frequency of occurrence according to the number of rostral teeth. The correlation coefficient between the height of the sixth abdominal segment (H6S) and the weight of the abdomen with exoskeleton (WAE) was calculated too. According to Lester (1983), this measurement may be useful for a precise estimation of the weight of the live shrimp tail. In addition, in order to evaluate differences in data collected from samples of different regions of Atlantic coast, Cluster (CA) Analysis, Principal Component Analysis (PCA), Multivariate Analysis of Variance (MANOVA) and Correspondence Analysis (CVA) were performed, following James and McCulloch (1990).

3. Results

3.1 Meristic variations

In both Cuban and most of Brazilian waters, this study found the number of rostral teeth to range from 6 to 10, with predominance (mode) of 8, with the exception of Sergipe and Rio de Janeiro, where animals with 9 rostral teeth prevailed. Among the samples of *L. schmitti* population collected in southeastern Cuban region of Manzanillo, a frequency of 93% of specimens with 8 teeth was found.

In Figure 3 the frequency in number of upper rostral teeth, in the 7 populations sampled in Cuba and Brazil, compared to the frequency found by Espinosa et al. (2002) is presented.

3.2 Morphological variations

When analyzing the correlation between the Sixth abdominal Segment Depth (6SD) and Weight of Abdomen with Exoskeleton (WAE), we found a coefficient (r) of only 0.76. In the other hand, when we analyzed correlation coefficient between the Sixth abdominal Segment Length (6SL) and WAE we found a significantly greater correlation ($r = 0.94$).

In Figure 4, the values of the Variation Coefficients (VC) of all the data corresponding to the populations sampled are presented. It was considered appropriate to carry out this analysis, even with a relatively small sample size (n=30), following the criteria set out by Lester (1983) and Espinosa et al. (2002). Data from Cuba (CUB), Rio Grande do Norte (RN) and Espirito Santo (ES) shows a significantly higher variability. The results of the PCA are presented in Figure 5. It can be observed that, mainly in Principal Component 2, the greatest dispersion also corresponds to data from CUB, RN and ES, which are also the localities that presented the highest VC values. In Table 2, where the eigenvalues of the calculated Principal Components are presented, the variables of greatest influence (loadings) in Principal Component 1 (PC1) were: Abdomen length (AL), Total weight (TW), Partial total length (PTL) and Abdomen weight with exoskeleton (AWE). The PC1 axis represents size and has a positive correlation, meaning that larger animals show more differences between localities than smaller ones (de la Fuente 2010). The animal size average for each locality (Partial total length) is shown in Table 3. Larger specimens correspond to CUB, RN and ES, the same showing increased data variation.

The results of the MANOVA indicated significant differences among the seven populations tested ($p < 0.001$). The representation of this result through the CVA is presented in Figure 6. The differences between data from Cuba and the Brazilian state of Santa Catarina become more evident in this figure, reflecting the low similarity between the two data sets. Considering the significant differences found among the populations, we also compared the main measures of length and weight: AL / PTL; AW / TW and CW / PCL. The mean values calculated for these proportions are presented in Table 4.

The shrimp samples collected in southern Brazilian region of Laguna, located almost at the end of the species distribution, presented proportionately the longest (71.3%) and heavier tail

(68.5%) among all populations compared. Conversely, the animals sampled in Manzanillo, Cuba, at the northern border of the distribution, showed narrower mean carapace proportions (53.0%) and shorter abdomen (68.2%). Shrimp populations from Espirito Santo and Rio de Janeiro presented the largest carapace width (57.0%). The shrimp from these last two locations did not present significant morphological differences between them, perhaps reflecting geographic similarities. The different proportions observed between shrimps of Manzanillo (CUB) and Santa Catarina (south of Brazil) showed in table 4 confirm the results obtained by CVA.

The total length-weight ratio, considering the data of all locations (n = 221), is shown in Figure 7. The calculated regression equation: PT = 0.00001 * CT 3.1682, indicates a positive allometric growth, with $R^2 = 0.9816$.

3.3 Size variations

The maximum sizes of the shrimp collected in this work were observed in specimens collected in Manzanillo (CUB) and Touros (RN), with a total length/weight of 142 mm/62.0 g and 149 mm/70.4 g, respectively. Nikolic and Ruiz de Quevedo (1970), working at the same Cuban location, reported the collection of a specimen with 168 mm of PTL, using the same measuring method as in the present study. In the other hand, the largest reported size of a specimen of *L. schmitti* in Brazil (186 - 202 mm) correspond to specimens collected by Santos et al. (2004) between Rio Grande do Norte and the mouth of the São Francisco River.

3.4 Color variations

An interesting finding of this study, that could corroborate the mentioned morphological differences, is the presence of two whitish symmetrical spots located in the ventral thoracic region of females of *L. schmitti* collected in several localities of Brazil (Figures 9a & 9b). These spots are located in the last thoracic sternite (sternite XIV), with shape and color that resembles the position and appearance of the spermatophore of males. These spots only appear in some of the females collected in Touros (RN), Aracajú (SE) and in Guaratuba and Pontal do Paraná (PR) (Table 4). They did not appear in the collections made in Cuba nor in photographs received from the authors of the species captured in Colombia.

4. Discussion

The main contribution of the present study was the identification of a significant number of phenotypic differences between populations of white shrimp *L. schmitti* from distant regions within the species natural distribution.

The meristic variations of number of rostral teeth found in this study corroborated Pérez-Farfante (1969) who also found a mode of 8 rostral teeth, in more than 300 specimens of *L. schmitti* analyzed during her extensive research on the Western Atlantic penaeid shrimps. But in a later moment, when studying morphological characteristics of *L. schmitti*, Pérez-Farfante (1970b) did found larger variations (5-10 teeth) in different areas.

Espinosa et al. (2002), studying *L. schmitti* in the Cuban region of Manzanillo, found of frequency of 64% of individuals with 9 teeth. The authors discuss differences in the frequency of upper rostral teeth between wild and captive animals of *L. schmitti*, pointing that, despite having a common origin, captive animals tend to show 8 rostral teeth in opposition to 9 found in natural populations. Contrarily, our study performed 12 years later in the same location could not find a single shrimp with 9 rostral teeth.

The analysis of the between the Sixth abdominal Segment Depth (6SD) and Weight of Abdomen with Exoskeleton (WAE), as suggested by Lester (1983), resulted in a coefficient significantly lower than what was reported by the author for *L. vannamei* (r = 0.95) and *L. stylirostris* (r = 0.85). In the other hand, a significantly higher correlation coefficient was found between the Sixth abdominal Segment Length (6SL) and WAE. As this measurement can be easily obtained with a digital caliper, we recommend the measurement of 6SL instead of 6SD for estimation of the WAE in living *L. schmitti* specimens.

The proportion between tail and carapace may present significant variations among same species and same population. Pérez-Farfante (1970b) reported that rate of carapace growth in relation to total length growth is slower in *L. schmitti* juveniles, but this growth rate will tend to increase when animals exceed 100-108 mm in total length. Although females of *L. schmitti* are usually larger than males, when comparing gross measurements within a species, it is important to recognize that the proportion between size of carapace and abdomen length can be distinct between sexes. Porto and Fonteles (1981), in a morphometric study carried out in northern Brazil, found male abdomen to be proportionally longer and heavier than the females. Conversely, García-Pinto (1970), working in Venezuela, found two inflection points occurring when the carapace reaches lengths of 18.1 and 24.9 mm for females and 18.0 and 23.8 mm for males. The length of the abdomen was also used by Arena et al. (1997) to express significant differences among populations of the shrimp species *Penaeus setiferus, P. vannamei* and *P. schmitti*.

The maximum absolute sizes observed in this study were similar to the results obtained by other authors at the same Cuban location. In the other hand, the result was up to 30% smaller than reported by Santos et al. (2004) in part because this author included the rostrum and the telson in the total length measurement. Although the lack of standardization in the method of measurement makes it difficult to compare data from different bibliography, revising some of the available literature, it is possible to infer over the maximum size reported for *L. schmitti*. This information could also be useful in relation to the farming potential of *L. schmitti*.

The largest sizes reported in literature for natural populations of *Litopenaeus spp*. species are shown in Figure 8. According to Díaz et al. (2014), the largest collected size for white shrimp are reported in Venezuela (240 mm for female and 230 mm for a male). In the figure, the asymptotic Total length ($TL\infty$) growth parameter is estimated for each species (Andrade and Pérez 2004; Díaz et al. 2014; Tabash and Palacios 1996). We are considering the asymptotic total length as an indicator of its potential growth, at least for the populations studied. The Maximum total length corresponds to largest recorded specimen (mainly females) of *Litopenaeus spp*. captured in nature, according to Díaz et al. (2014) and F.A.O. (2018a). The largest total length reported for a species of shrimp from genus *Litopenaeus* corresponds to a specimen of *L. schmitti*. It can be seen that the maximum estimated sizes for this species is higher than that for *L. vannamei*. This is an indication that the growth potential of *L. schmitti* could theoretically be as high as *L. vannamei* (F.A.O. 2018b) and should draw attention to the possibilities for cultivating this native species.

There are several studies in the literature on the growth of *L. schmitti* in different locations of Venezuela and Brazil, which have identified populations with larger animals, differences in growth between sexes, and others (Andrade and Pérez 2004; Andrade and Pérez 2007; Carvalho 2013; Díaz et al. 2014; García-Pinto 1970; Santos et al. 2004; Santos et al. 2006). Western Venezuelan waters, specially the Gulf of Venezuela-Lake Maracaibo, are known to have exceptionally favorable environmental conditions for the species. Historically, the largest shrimp catches, the denser populations (Pérez-Farfante 1969) and the larger sizes reported for *L. schmitti* correspond to this area (Andrade and Pérez 2004; Andrade et al. 2009). This could be explained by the marked preference of *L. schmitti* for low salinity areas. This species is easily captured in river mouths and after heavy rains (Nikolic and Ruiz de Quevedo 1970; Pérez-Farfante 1969). The salinity in this region can seasonally reach values smaller than 12 (Díaz et al. 2014; Pérez-Farfante 1970b). In a finer scale, the available data suggests this area as possible region for selection of broodstock.

Regarding the markings found in the Cuban female´s samples, it interesting to point that there is no mention of a similar feature in the reviewed literature. Even in the classic works of Pérez-Farfante (1969); Pérez-Farfante (1970b), which described the most frequent colors in the different stages of *L. schmitti*, there is no mention of these spots. Also, in personal contacts with different researchers in Cuba, no one declared to have observed this during years of previous studies on natural populations of the species.

The reason this characteristic has not been previously mentioned may be related to the method of preservation. Pérez-Farfante (1970a) points that certain features, like coloration of exoskeleton can only appreciated in fresh or recently preserved. In the case of our work, the possibility of having live or freshly caught animals may have facilitated these observations.

For this reason, when analyzing morphological features, we recommend that fresh specimens should be used over the fixed ones. Where and when this phenotypic character first appeared in females is an aspect that deserves a more detailed study. It could represent some kind of differentiation in the external characters among populations geographically distant from the species, possibly due to the existence of geographical barriers.

4.1 Geographical barriers

It is expected that distant populations present different degrees of differentiation, due to their adaptation to their local environments. For instance, Barbosa-Saldaña et al. (2012) have find clinal morphological differentiation among four populations of the brown shrimp *Farfantepenaeus californiensis*, mainly related to the geographic distances along the Mexican Pacific coast.

Although, in the case of *L. schmitti*, it appears that differences between certain regions are much more due to the existence of localized environmental barriers than to a gradient of differentiation determined by a geographic distance. Luvesuto (2006), working with relatively close populations of *L. schmitti* in the coast of Rio Grande do Norte, Brazil, found significant genetic and morphological variability. In her work, the author points the possible influence of oceanic currents on the population structure, also indicating the need for a specific fishing management for each area, to contribute to the preservation of natural stocks. This result come to an agreement with Espinosa et al. (2002); Valle et al. (2015), and Borrell et al. (2004), regarding the existence of distinct populations of this species, even in relatively close localities and without geographical barriers of importance.

Genetic studies on *L. schmitti* mention the mouth of the Amazon River as an important barrier, which would have favored the divergence between the populations of the Brazilian and Caribbean geological provinces, especially during periods of eustatic sea level decrease (Lastrucci 2011; Maggioni et al. 2001). Furthermore, Maggioni et al. (2003), using microsatellite loci, found a high diversity in eight populations of *L. schmitti* from distinct localities along the Brazilian coast, with a greater differentiation in the zone near Cabo Frio (23 ° S), where divergent ocean currents create a geographical barrier.

Considering the extensive distribution zone of *L. schmitti*, and the relatively low cost of morphometric studies, it is recommendable that such studies be extended to other regions of the Atlantic coast. In this way, the preliminary knowledge about the populations and areas of greatest interest (such as the west coast of Venezuela, for example) could be completed and later confronted with genetic studies, which are more accurate but much more expensive. The methodology and knowledge obtained here may be useful for the conservation of the natural populations of the species. But it is also important for development of a technological package both for restocking and cultivation, especially in environmentally sensible areas. As the estuaries and mangroves inhabited by shrimp are considered among the most environmentally sensible ecosystems (Nuñez-Solís 2014), it is to be hoped that by increasing the knowledge and presence of this native species, the resilience of the ecosystem as a whole can be enhanced.

5. Compliance with Ethical Standards

Conflict of interest All authors declare that don´t have conflict of interest on the matter treated.

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8. Figures

Fig. 1 Map of Central and South America, with the location of the sampled *Litopenaeus schmitti* populations. Source of the map: modified from https://freevectormaps.com/.

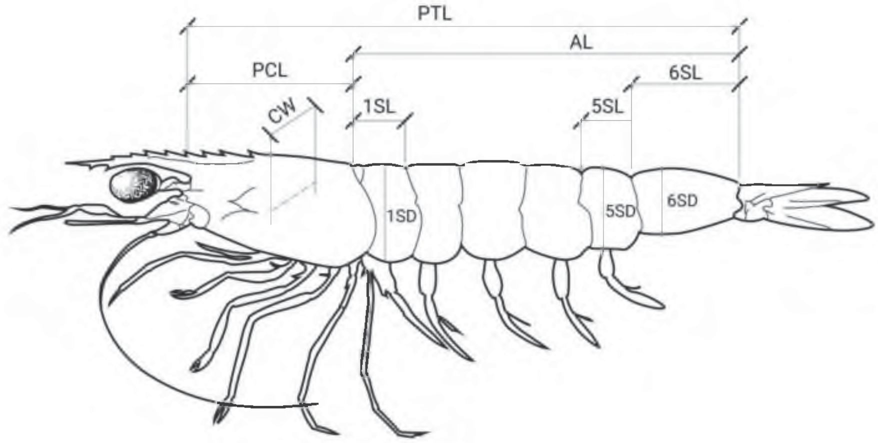

Fig. 2 *Litopenaeus schmitti*. Morphometric variables used in this work. Partial total length (PTL), Partial carapace length (PCL), Abdomen length (AL), Carapace width (CW), Length of the first abdominal segment (1SL), Depth of the first abdominal segment (1SD), Length of the fifth abdominal segment (5SL), Depth of the fifth abdominal segment (5SD), Length of the sixth abdominal segment (6SL), Depth of the sixth abdominal segment (6SD). Figure adapted from Fast and Lester (1992); Lester (1983).

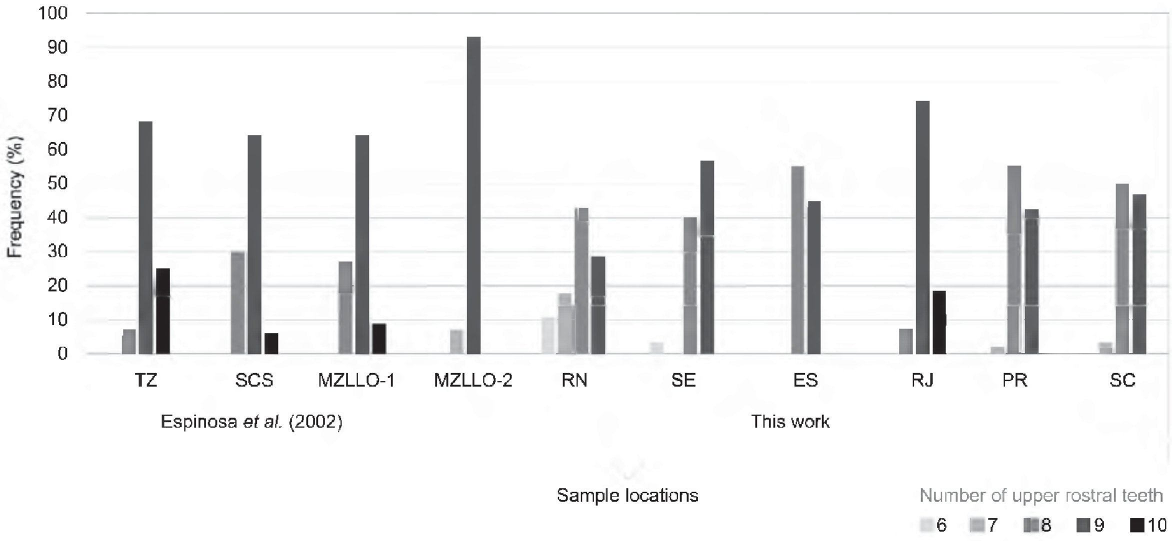

Fig. 3 Frequency of distribution of the number of rostral teeth in 239 specimens of *L. schmitti* (49% females and 51% males). The seven locations to the right of the figure correspond to this work: MLLO-2 (Manzanillo, Cuba); and RN (Rio Grande do Norte), SE (Sergipe), ES (Espirito Santo), RJ (Rio de Janeiro), PR (Paraná) and SC (Santa Catarina), all of Brazil. In the three populations to the left, the frequency reported by Espinosa *et al.*(2002) for Cuba: TZ (Tunas de Zaza), SCS (Santa Cruz del Sur) and MZLLO-1 (Manzanillo).

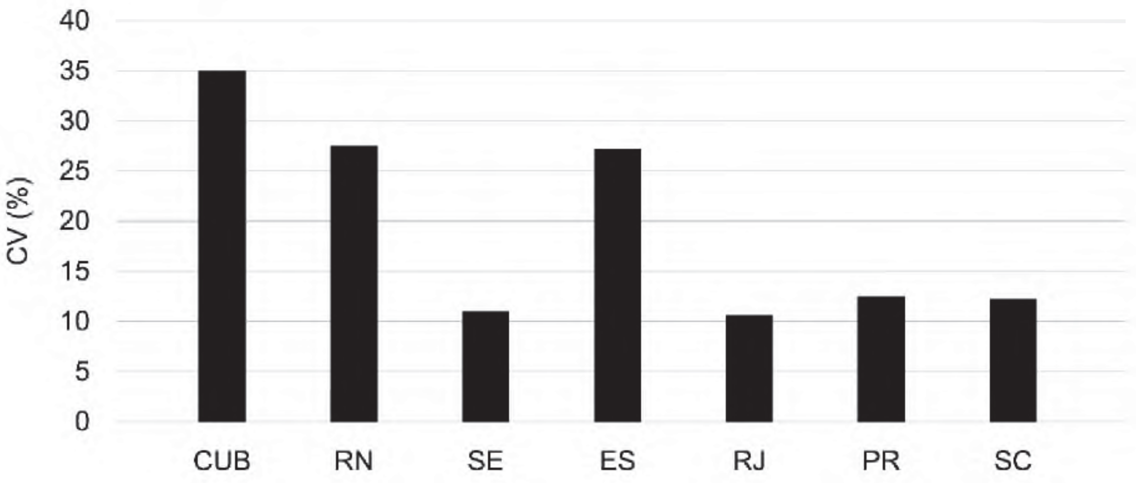

Fig. 4 Coefficient of variation (CV) of all the measured variables in *L. schmitti* populations, located in: CUB (Cuba), RN (Rio Grande do Norte), SE (Sergipe), ES (Espirito Santo), RJ (Rio de Janeiro), Paraná (PR) and (Santa Catarina).

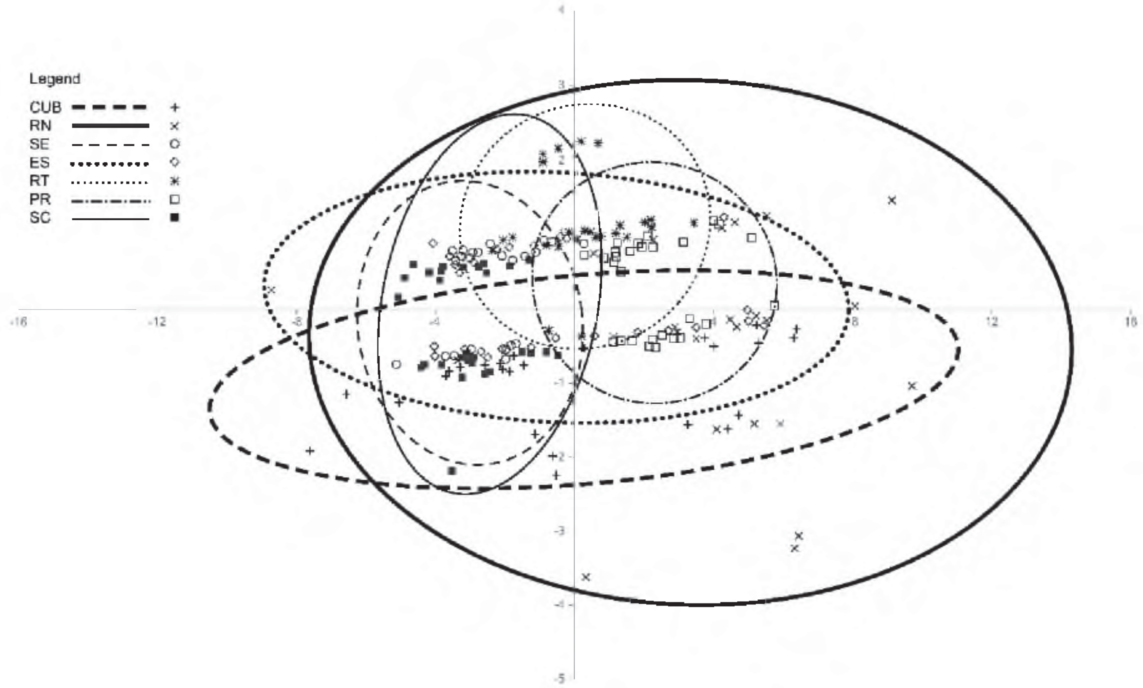

Fig. 5 Principal Component Analysis (PCA) of all transformed coefficients of variation (log10). Data from *L. schmitti* populations sampled in: CUB (Manzanillo, Cuba), RN (Rio Grande do Norte), SE (Sergipe), ES (Espirito Santo), RJ (Rio de Janeiro), PR (Paraná) and SC (Santa Catarina). The most scattered data are highlighted: CUB, RN and ES.

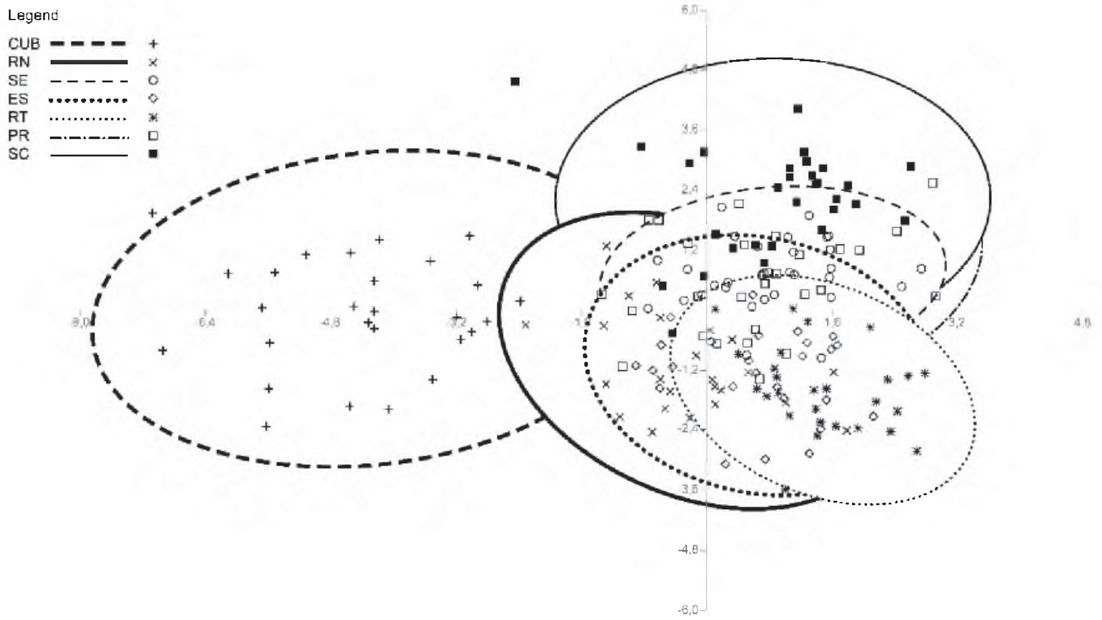

Fig. 6 Results of Correspondence Analysis (CVA) of the studied *L. schmitti* populations: CUB (Cuba), RN (Rio Grande do Norte), SE (Sergipe), ES (Espirito Santo), RJ (Rio de Janeiro), PR and SC (Santa Catarina).

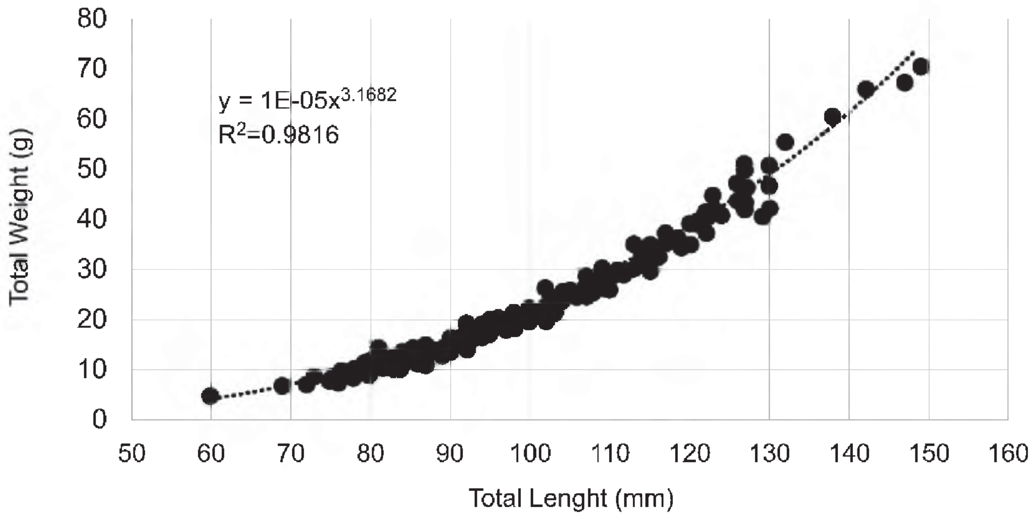

Fig. 7 Length-weight ratio for *L. schmitti*, considering data from all locations (n = 221).

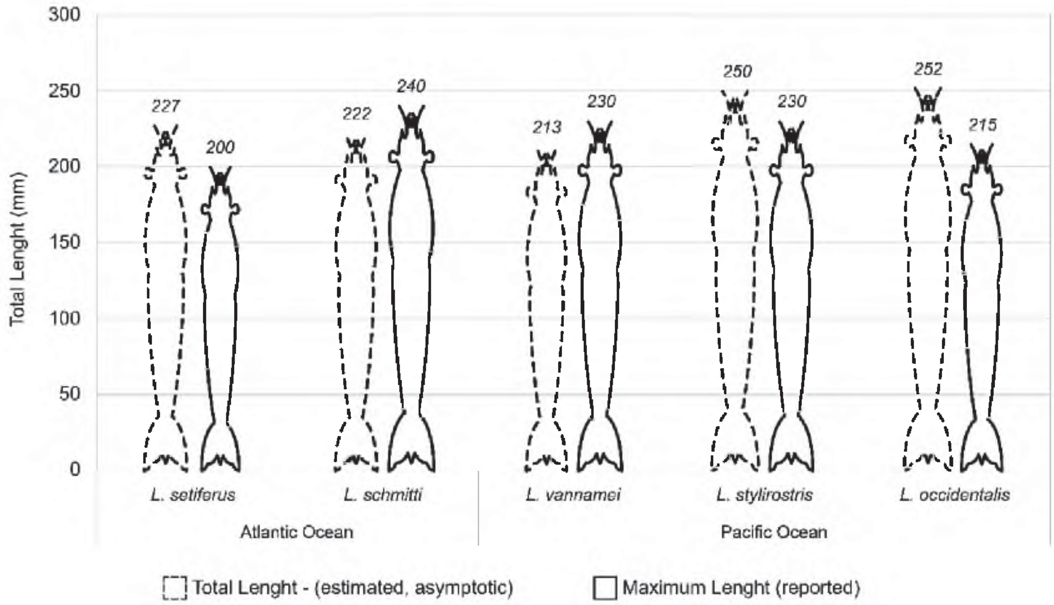

Fig. 8 Largest sizes reported for natural populations of *Litopenaeus spp.* Total length (TL∞, asymptotic) estimated as growth parameter according to Andrade and Pérez (2004); Díaz et al. (2014); Tabash and Palacios (1996); and Maximum Total Length (MTL) reported by Diaz et al. (2014); F.A.O. (2018a). Illustration by S. F. de Alaiza Amador, 2018.

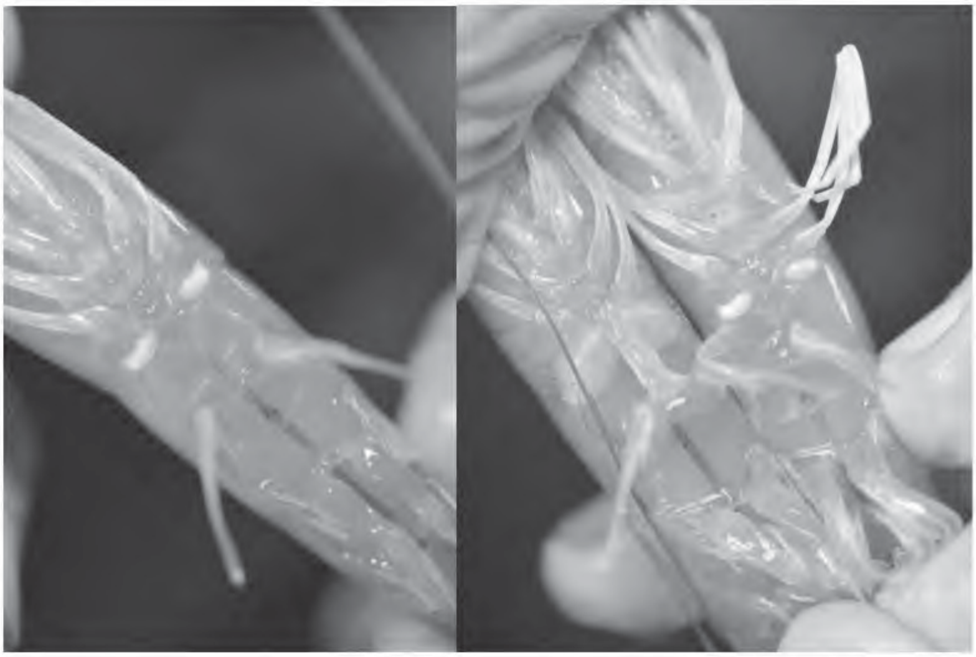

Fig. 9a Adult *L. schmitti* specimens captured in Shangri-Lá, Pontal do Paraná, PR, Brazil. Ventral region of adult female, where a pair of white spots are observed, located in the last thoracic sternite (sternite XIV). **Fig. 9b** It can be observed, in the male (on the left) the petasma and the mature spermatophores (whitishes), and in the female (on the right) the white spots that coincide in the position with the spermatophores (Photos: D.B. Hungria)

9. Tables

Table 1. *Litopenaeus schmitti* morphometric characters and other variables evaluated.

No.	Variable	U.M.	Description / Notes
1	Partial total length (PTL)	mm	It is the distance between the posterior margin of the orbital cavity to the posterior edge of the sixth abdominal segment, with the abdomen fully extended (Fig. 2).
2	Total weight (TW)	g	Wet weight
3	Sex (SX)	_	By observation of the reproductive organ (thelycum or petasma).
4	Maturity stage (MS)	_	According to Ramos and Primavera (1986).
5	Partial carapace length (PCL)	mm	It is the distance between the posterior end of the orbital cavity to the posterior border of the cephalothorax (Capparelli et al. 2012; Pérez-Farfante 1970b).
6	Carapace width (CW)	mm	It is the largest width, at the height of the last dorsal rostral tooth (Lester 1983).
7	First segment length (1SL)	mm	Distance from the posterior border of the cephalothorax to the posterior border of the first abdominal segment, with the abdomen fully extended.
8	First segment depth (1SD)	mm	Depth at the midpoint of the first segment.
9	Fifth segment length (5SL)	mm	Distance from the posterior margin of the fourth segment to the posterior margin of the fifth, with the abdomen fully extended.
10	Fifth segment depth (5SD)	mm	Depth at the midpoint of the fifth segment.
11	Sixth segment length (6SL)	mm	Distance from the posterior margin of the fifth segment to the posterior margin of the sixth, with the abdomen fully extended.
12	Sixth segment depth (6SD)	mm	Depth at the midpoint of the sixth segment.
13	Abdomen length (AL)	mm	It is the distance between the anterior margin of the first abdominal segment and the posterior border of the sixth abdominal segment, with the abdomen fully extended.
14	Weight of abdomen with exoskeleton (WAE)	g	It is the moist weight of the abdomen, just separated from the cephalothorax.
15	Weight of abdomen without exoskeleton (WAW)	g	It is the moist weight of the abdomen, just separated from the cephalothorax and peeled.
16	Number of upper rostral teeth (NDR)	-	Counted using a hand magnifier (especially in smaller animals), without considering the last tooth (epigastric) (Pérez-Farfante 1969).

Table 2. Principal component analysis (PCA).

PC	Eigenvalue	% variance
1	**11.58370**	**82.74 <=**
2	1.01228	7.23
3	0.62917	4.49
4	0.30167	2.15
5	0.16886	1.21
6	0.07636	0.55
7	0.05781	0.41
8	0.05436	0.39
9	0.04177	0.30
10	0.03506	0.25
11	0.02038	0.15
12	0.01339	0.10
13	0.00452	0.03
14	0.00063	0.00

Table 3. Average Partial total length (PTL) of shrimps in each locality

Studied populations	Mean PTL (mm) ± Standard deviation	n
Manzanillo, Cuba (CUB)	100 ± 19.9	32
Touros, Rio Grande do Norte (RN)	116 ± 20.0	32
Aracajú, Sergipe (SE)	84 ± 5.3	32
Vitoria, Espirito Santo (ES)	94 ± 14.5	32
Cabo Frio, Rio de Janeiro (RJ)	98 ± 6.5	31
Pontal do Paraná, Paraná (PR)	106 ± 7.6	30
Laguna, Santa Catarina (SC)	83 ± 4.7	32

Table 4. Characteristics of natural populations of *L. schmitti* reported in the literature, based on data from this work (name of the sampled locations underlined). AL: Abdomen length, PTL: Partial total length, AWE: Abdomen weight with exoskeleton, TW: Total weight, CW: Carapace width, PCL: Partial carapace length. Proportions tested using ANOVA and Tukey´s pairwise comparisons test, in columns. Values with the same letter do not differ. Populations previously studied by: (1) Borrell et al. (2004), (3) Valle et al. (2015), (4) Maggioni et al. (2003) and (5) Luvesuto (2006).

Region	Country	Identified Populations (from north to south)		Latitude	Proportions* (%) AL / PTL	AWE / TW	CW / PCL	Presence of white spots (in females, in the thoracic sternite XIV)	General	Author
		G. de Batabanó	(1)	22° N						(1) Borrell et al. (2004)
North	Cuba	B. de Cienfuegos	(1)	22° N				Absent		
		Tunas de Zaza	(1)	21° N						(2) This work
		Manzanillo	(1,2)	20° N	68.2c	66.6ab	53.0b			
		L. Navío Quebrado	(3)	11° N						
Central	Colombia	Cartagena-S. Marta	(3)	11° N				Absent	Differences were found among the 7 populations tested, from Cuba and Brazil, according to the MANOVA**	(3) Valle et al. (2015)
		G. de Morrosquillo	(3)	9° N						
		São Luís, MA	(4)	2° S						
		Camocim, CE	(4)	3° S						
		Fortaleza, CE	(4)	4° S						
		Diogo Lopes, RN	(5)	5° S						
		Touros, RN	(2,5)	5° S	69.7b	65.5bc	56.6a	Present		
		B. Formosa, RN	(5)	6° S						
		Recife, PE	(4)	8° S						(4) Maggioni et al. (2003)
South	Brazil	Aracajú, SE	(2)	10° S	70.5ab	63.8c	55.1ab	Present		
		Vitoria, ES	(2,4)	20° S	70.7ab	68.0a	57.0a			(5) Luvesuto (2006)
		Cabo Frio, RJ	(2)	22° S	69.6bc	67.1ab	57.0a			
		Santos, SP	(4)	24° S						
		P. do Paraná, PR	(2)	26° S	70.6ab	63.5c	55.6ab	Present		
		Guaratuba, PR	(4)	26° S				Present		
		Tijucas, SC	(4)	27° S						
		Laguna, SC	(2)	28° S	71.3a	68.5a	54.5ab			

*(Analysis of Variance: ProportionAL/PTL: $F(6,102) = 3.39$, $P = 0.0043$; proportion CW/PCL: $F(6,214) = 5.48$, $P = 2.66E-05$; proportionAWE/TW: $F(6,214) = 13.8$, $P = 3.06E-13$.
** (Multivariate Analysis of Variance, $F(6,214) = 12.42$, $P= 1.017E-106$)

CAPÍTULO III

Zootechnical performance and interaction between *Litopenaeus schmitti* (Burkenroad, 1936) and *Litopenaeus vannamei* (Boone, 1931) reared under laboratory conditions*

(Formatado conforme "Instruções aos Autores" em anexo III)

*Capítulo elaborado para submissão na revista Aquaculture Research. Autores: Rafael Fernández de Alaiza García-Madrigal, Ubiratã de Assis Teixeira da Silva, Eduardo Luis Cupertino Ballester.

Abstract

In order to compare the zootechnical performance of the brazilian native shrimp *Litopenaeus schmitti* and the exotic shrimp *Litopenaeus vannamei*, juveniles of similar size and weight were grown under controlled conditions in a clear water culture system. In the same room, both species were simultaneously cultivated (monoculture) in separate 70 L plastic tanks at two different densities: 30 and 50 shrimp/m². In addition, in other two treatments, both species were also cultivated together (mixed), with and without feeding, at 30 shrimps/m². During the whole experiment, *L. vannamei* generally showed a greater interest in food and voracity than *L. schmitti*. At the end, for both stocking densities of monoculture treatments, the mean growth rate observed for *L. vannamei* was 1.0 g/week while *L. schmitti* achieved only 0.1 g/week. The mean final weight was 10.4±2.0g; 10.7±2.1g for *L. vannamei* and 2.8±0.3g; 3.2±0.3g for *L. schmitti*, for respective densities of 50 and 30 shrimp/m². In the mixed treatment with feeding, while *L. vannamei* reached 11.9±1.4 g, *L. schmitti* reached only 2.6±0.4 in the same tank. The observed differences were 3.7, 3.4 higher in favor of *L. vannamei* in the monoculture treatment, and up 4.5 times higher in the mixed treatment. Under strict fasting conditions, both species practiced predation/cannibalism among themselves in a similar fashion. The results reflected the zoothechnical advantages expected of from a species so intensively engineered such as *L. vannamei*, but also corroborated the negative effect that high densities and lack of natural food in the cultivation can exert over native species. The study discusses the potential for *L. schmitti* cultivation in lower densities and the possible impact of the escape of *L. vannamei* into the natural environment.

Key words: Penaeid • shrimp farming • *Litopenaeus* • *schmitti* • *vannamei*

1. Introduction

The wide geographic distribution of populations of the white shrimp, *Litopenaeus schmitti* (Burkenroad, 1936) along the Atlantic coast of the Americas (F.A.O., 2016), is only one of the many reasons justifying the interest of researchers, mainly in Brazil, Venezuela, Mexico and Cuba. Biological aspects such as age, growth, distribution and population structure of white shrimp *L. schmitti* in natural populations has been studied in Venezuela (Andrade & Pérez, 2004, 2007; Gassman & Rojas, 2016), in Nicaragua (Velázquez-Chavarría, 1999) and in the Brazilian coast, in the states of Rio Grande do Norte, Paraíba, Pernambuco, Alagoas and Sergipe (M. Santos, Pereira, Ivo, & Souza, 2006) and in Rio de Janeiro (Carvalho, 2013).

In addition, studies over natural populations has been pointed out the decrease of the natural populations of this species, due to intensive fishing and the reduction of fresh water intake caused by river damming, which affects the populations of *L. schmitti*, highly linked to the fluvial contribution (Silva et al., 2018; Sosa, 2009).

Studies on *L. schmitti* also including more aquaculture oriented biological aspects were conducted, such as: growth (Carvalho, 2013; Fugimura, 2009), nutrition (Álvarez, 2007; Galindo-López, 2009; B. J. Jaime-Ceballos, 2006), metabolism (E. Barbieri, 2010; E. Barbieri, Bondioli, Melo, & Henriques, 2016; Girotto, 2010), the effects of pollution (D. B. Santos, Barbieri, Bondioli, & Melo, 2014) and the economic feasibility of production (Castilho-Barros, 2013).

Experiments with *L. schmitti* on pilot-commercial scale, nurseries and grow-out ponds were also carried out in Cuba (Fernandez de Alaiza, Funes, & Zaragoza, 1994; Fernandez de Alaiza & Jaime-Ceballos, 1990; Fernandez de Alaiza, Jaime-Ceballos, & Sosa-Rodríguez, 1994). In addition, given the importance of commercial cultivation of this species in that country for several years, aspects related to feeding and commercial feed formulation were also studied, with the objective of accelerating growth and reducing production costs (Fraga-Castro & Jaime-Ceballos, 2011; Fraga, Galindo, de Arazoza, & Sanchez, 2002; B. Jaime-Ceballos & Galindo-López, 2006). Also, genetic engineering techniques were applied, transferring to *L. schmitti* the tilapia growth hormone gene (Arenal, Pimentel, Pimentel, & Aleström, 2008).

Effect of stocking density on the growth of *L. schmitti* in captivity was studied by Marquez, Andreatta, Vinatea, Olivera, and Brito (2012), finding that densities of up to 50 shrimps/m^2 negatively affect the crop weight and the weekly weight increase, but allow a higher yield. Henriques, Alves, Barreto, and Souza (2014), studied the growth of the species in intensive cultivation for the production of live bait, concluding that the growth parameters of *L. schmitti* cultivated in these conditions were similar to those reported in the literature for natural populations. Likewise, de Barros, Barreto, and Henriques (2014) analyzed the economic viability of intensive white shrimp production as bait for sport fishing, the results indicated a commercial opportunity for small producers due to the attractive selling prices.

On the other hand, marine shrimp farming in Americas and in the world is currently dedicated to the cultivation of the pacific whiteleg shrimp *Litopenaeus vannamei*. From United States to Brazil, almost the totality of the farms along the entire coast cultivates this species, even though is considered an exotic species in Atlantic waters (Jory, 2017). Several studies have documented escapes of *L. vannamei* from farms to natural environment at least since 2000, in Brazil (E. Barbieri & Melo, 2006; Loebmann, Mai, & Lee, 2010; M. Santos, 2005; M. Santos & Coelho, 2002), 1988, in Texas, USA (Balboa, King, & Hammerschmidt, 1991) and since 2011, in Tabasco, Mexico (Wakida-Kusunoki, Amador-del Angel, Carrillo, & Quiroga, 2011).

As much as for *L. schmitti* in the past, *L. vannamei* has become a thoroughly studied species in recent years, manly in terms of aquaculture aspects (Arzola, Flores, Izabal, & Gutiérrrez, 2008; Brito et al., 2014; Fóes, Krummenauer, Lara, Poersch, & Wasielesky, 2016; Khanjani, Sajjadi, Alizadeh, & Sourinejad, 2016; Maciel, Francisco, & Miranda-Filho, 2018; Rosas et al., 2001; C. H. A. Santos, Lourenco, Baptista, & Igarashi, 2009; Tacon et al., 2002; Williams, Davis, & Arnold, 1996). Although a extensive literature about cultivation of both species is available, only one direct zootechnical performance comparison was found (Allessi, 2000).

The objective of this study was to evaluate the zootechnical potential of *L. schmitti* as a base for its cultivation on the Atlantic coast of Central and South America, compared to the performance of *L. vannamei* produced under the same experimental conditions. Also, the effect of interaction between these species, during a joint production, was evaluated.

2. Material and methods

2.1 Experimental organisms

For the experiment, juveniles of both species with similar size and weight were acquired. *Litopenaeus vannamei* post-larvae, with around 19 days after metamorphosis (PL19), were obtained from a commercial larviculture laboratory (Atlântico Sul Maricultura Ltda, Santa Catarina, Brazil) in November, 2016. The mean weight of PL's at arrival was 10.6 ± 0.6 mg. These post-larvae were breeded from nauplii produced in a different commercial hatchery (Aquatec Aquacultura Ltda, Rio Grande do Norte, Brazil). The nauplii were obtained from genetically selected (Speed Line) and Specific Pathogen Free (SPF) progenitors.

The *L. schmitti* juvenile shrimps were collected in January 2017 by artisanal fishermen using both a cast net of 5 - 6 mm mesh size and a traditional fishing net called "gerival". The sampling region, known as "Seco da Calçada", is located in the bay of Guaratuba, Paraná, Brazil (25.807°S, 48.601°E). The animals were positively identified according to the characteristics described by Perez-Farfante (1988) and Pérez-Farfante (1970). The weight and total length of juveniles at arrival were 1.14 ± 0.45 g and 57 ± 8.6 mm, respectively.

Post-larvae and juveniles of both species were transferred to the CAMAR Laboratory, which belongs to the Integrated Group of Aquaculture Environmental Studies (GIA) and the Federal University of Paraná (UFPR), in Pontal do Paraná, Paraná, Brazil.

Litopenaeus vannamei specimens arrived with transportation water at salinity of 15, and the juveniles of *L. schmitti*, with salinity of 20. The animals were acclimated to the salinity of the Laboratory, which in the rainy season (December to March), oscillates between 27 and 34. In both cases the salinity acclimation rate was 0.5/day. In the experimental tanks, the salinity was maintained between 30 and 31.

The both species were kept for 15 days in separate 1,000 l tanks to obtain better size standardization. During this resting period, the animals were adapted to the experimental routine, that is, daily water renewal of 50 - 75% and the use of feeding trays, at pre-established times.

During this stage, both species were fed with: "Epac XL" and "Stresspak 5/8" (45 and 40% protein, respectively), both of INVE Aquaculture - Health Division, and later with the commercial shrimp feed Guabi "POTI MIRIM QS 40J" (40% crude protein). The feed was supplied *ad libitum*, but using as a guide a feed rate of approximately 20-4% of the biomass, according to the size of the animals. After the established resting period, juveniles of both species of similar size and weight were obtained.

In order to further select shrimp of same size for both species, a method, commonly employed in Japanese shrimp hatcheries, were used. Plastic screens with 8 and 10 mm meshes were placed inside a strong aerated 1,000 plastic tank (Figure 1). The largest mesh was placed on top of the smaller, so when the juveniles were placed in the water, they immediately tried to cross both meshes, in order to reach the bottom of the tank.

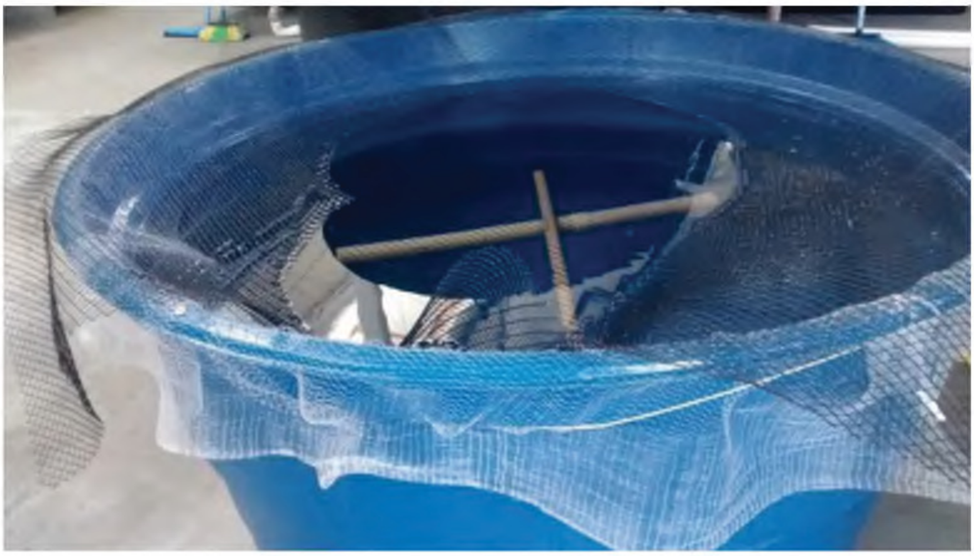

FIGURE 1 Tank with plastic meshes, used to separate live juveniles, according to their size. The upper mesh (black) is 10 mm, and the lower (white) 8 mm. Photo: R.F. Alaiza.

This method exploits shrimp's natural instinct to distribute themselves in the tank, searching for the site with the lowest possible congener density (Hitoshi Hayashida, Taiyo Co. Ltd. Technical Adviser, personal communication).

With the use of this method, different size shrimp were separated. At the end, the wet weight and the mean total length of the *L. schmitti* shrimp at the beginning of the experiment were 1.79 ± 0.4 g and 61 ± 0.4 mm and for *L. vannamei* were 1.71 ± 0.4 g and 61 ± 0.5 mm, respectively. As shown in the Figure 2, the outer appearance of the shrimps of both species is very similar. Nevertheless, some differences can be distinguished, which are discussed at the end of this paper.

FIGURE 2 Shrimp juveniles, during the acclimation process before the beginning of the experiment. On the left, specimens of *L. vannamei* and on the right, *L. schmitti*.

2.2 Experimental system

The experimental units consisted in rectangular white plastic boxes with 50 L of nominal (effective) capacity and bottom area of 0.2 m^2. The experimental setup was assembled in an experimental room, containing 30 tanks, each of them covered with a black plastic mesh of 1 mm and provided with artificial aeration (Figure 3). The experimental room were under light and natural photo-period (13L: 11D).

FIGURE 3 Tanks of 50 L capacity and 0.2 m^2 area each, used in the experiment. Photo: S. Amador.

The experimental system was filled with filtered (5 µm cartridge filters) seawater, in an open water exchange circuit. The total daily water exchange volume was at least 100%.

The following water quality variables were monitored daily: temperature (°C), with a thermometer, dissolved oxygen (mg/L) and oxygen saturation (%), with a digital oximeter (YSI-550A, USA), as well as salinity, with an optical refractometer (Instrutemp, Brazil) and pH, with a digital pH meter (AZ-86505, Taiwan). The concentration of nitrite (mg/L N-NO_2^-) (APHA, 1995) and total ammonia (mg/L N-AT) by the indophenol method (APHA, 2005), was obtained weekly, using a Spectronic 20 Genesys (USA) spectrophotometer.

The experiment was executed from February to April 2017, during a period of 60 days.

2.3 Treatments

The experimental setup was specially designed to evaluate the effect of different densities on the growth rates on each of the tested species. Two different densities were established in the experiment: 6 and 10 specimens/tank (equivalent to 30 and 50 shrimps/m^2) for each species, representing treatments 1 to 4 (Table 1). In addition, the design aimed to evidentiate the effect of intra-specific competition in presence and absence of feeding, representing treatments 5 and 6.

TABLE 1 Treatments applied during the experiment for 60 days. In the comparison in pairs (between species), in lines with the same stocking density, different letters indicate significant differences (P <0.05).

Treatment	Species	No. of shrimps / tank (n)	Density (shrimp / m^2)	Initial mean weight (± SD, g)	Food	No. of replicates
1	*L. schmitti* *	10	50	1.783 ± 0.33 a	Yes	5
2	*L. vannamei* *	10	50	1.713 ± 0.42 a	Yes	5
3	*L. schmitti* **	6	30	2.04 ± 0.30 b	Yes	5
4	*L. vannamei* **	6	30	1.91 ± 0.45 b	Yes	5

5	*L. schmitti* & *L. vannamei* ***	3 / 3	30	1.657 ± 0.31 c 1.586 ± 0.31 c	Yes	5
6	*L. schmitti* & *L. vannamei* ****	3 / 3	30	1.424 ± 0.199 d 1.413 ± 0.223 d	No	5

ANOVA: * F (1,98) = 0.85, P=0.359; ** F (1,58) = 1.80, P=0.184; *** (1,28) = 0.39, P=0.535; **** F (1,28) = 0.02, P=0.891

The experiment started with 110 specimens of each species randomly distributed in the experimental tanks. Dead animals were not replaced until the end of the 60 days of trial. The culture conditions were maintained the same for all tanks.

2.4 Food management

During the experiment, the animals were fed commercial shrimp feed (Guabi Poti Mirim QS 40J with 40% of crude protein). Since it was a growth study, the food was offered *ad libitum*. However, in order to prevent excess feeding which could affect the water quality, the amount of feed offered was adjusted according to the consumption observed. The food was given twice daily at 09:00 h and 20:00 h.

The shrimp were checked four times a day: at 08:00 h, when the residues of food and feces were siphoned and the water exchanged, at 11:00, at 14:00 h and 19:00 h, when a second water exchange was carried out to eliminate the floating foam before the last feeding of the day. The number of molts in each tank was also recorded daily.

2.5 Biometrics and analysis

Before the beginning of the experiment, the total length (mm) and the total wet weight (g) was measured using a digital caliper (Mitutoyo® Mod. 500-196-30) and digital scale (Marte®, Mod. AL 500C, with a precision of 0.001 g). Ethological observations were made during the daily handling of the shrimp, i.e. primarily during the day. Only one researcher recorded the observations, but details of the shrimp's behaviour were also discussed with the members of the work team.

After the beginning of the experiment, biometrics were performed every 10 days, in which the length and total weight were measured. In the last sampling, the sex of each specimen was determine.

The zootechnical variables colected at the end of the experiment were final weight (g), final length (mm), survival (%), feed conversion rate (FCR), growth rate (g/week) and productivity (kg/ha/cycle). To demonstrate morphological differences between *L. schmitti* and *L. vannamei*, 30 shrimps of each species were measured in length, weight and sex, hepatopancreas weight and volume and diameter of fecal strands, measured on the optical microscope.

The data obtained was analyzed and compared using a one-way ANOVA, with the use of PAST software.

3. RESULTS

3.1 Water quality variables

During the experiment, the water temperature ranged between 22.0 and 29.0 ° C, with an average of 26.1 °C (± 1.8). The mean values (± SD) of the physical and chemical variables recorded during the experiment are shown in Table 2. Variables such as temperature, salinity, dissolved oxygen and total ammonium did not present significant differences (P >0.05) among treatments. Other variables such as pH and nitrite concentration (mg / L N- NO_2^-), did present significant differences (P<0.05). The pH was significantly lower (7.80 ± 0.1; p <0.05) in tanks of treatment 2 and was significantly higher (8.06 ± 0.1 ; p <0.05) in treatment 6.

TABLE 2 Mean values (±SD) of chemical and physical water quality variables in the culture of Southern white shrimp and Whiteleg shrimp under 6 treatments during 60 days. Values with different letters on the same row indicate significant differences (P < 0.05, **).

Variables	With food					Fasting
	1-*L. schmitti* - 50 juv./m²	2-*L. vannamei* - 50 juv./m²	3-*L. schmitti* - 30 juv./m²	4-*L. vannamei* - 30 juv./m²	5-*L. schmitti*& *L. vannamei* (mixed) - 30 juv./m²	6-*L. schmitti*& *L. vannamei** (mixed) - 30 juv./m²
1.Temperature (°C)	26.0 ± 1.8 a	26.0 ± 1.8 a	26.0 ± 1.8 a	26.0 ± 1.8 a	26.0 ± 1.8 a	26.7 ± 1.3 a
2.pH	7.85 ± 0.1 a	7.80 ± 0.1 b	7.87 ± 0.1 a	7.86 ± 0.1 a	7.85 ± 0.1 a	8.06 ± 0.1 c
3.Dissolved Oxygen (mg.L-1)	4.5 ± 0.5 a	4.4 ± 0.5 a	4.5 ± 0.5 a	4.5 ± 0.4 a	4.4 ± 0.4 a	4.5 ± 0.4 a
4.Salinity	32 ± 1.2 a	32 ± 1.2 a	32 ± 1.2 a	32 ± 1.2 a	32 ± 1.2 a	31 ± 1.2 a
5.Total ammonia (N-AT mg L-1)	0.004 ± 0.0002 a	0.004 ± 0.0002 a	0.004 ± 0.0003 a	0.004 ± 0.0002 a	0.004 ± 0.0002 a	0.004 ± 0.0009 a
6.Nitrite (mg/L N-NO_2^-)	0.37 ± 0.04 a	0.40 ± 0.05 a	0.39 ± 0.04 a	0.40 ± 0.06 a	0.40 ± 0.08 a	0.56 ± 0.16 b

* On this treatment, after 38 days the experiment finished, with the death of the last specimen of *L. vannamei*.
** ANOVA: (1) $F_{(5,840)} = 0.395$, P=0.852; (2) $F_{(5,552)} = 106.2$, P=1.965E-78; (3) $F_{(5,612)} = 0.811$, P=0.541; (4) $F_{(5,888)} = 0.015$, P=0.999; (5) $F_{(5,39)} = 0.873$, P=0.508; (6) $F_{(5,39)} = 4.828$, P=0.0016.

3.2 Zootechnical indicators

The variation observed on main zootechnical indicators at the end of the experiment are shown in Table 3. Comparing survival rates between species the experiment did not showed significant differences (p < 0.05). The remaining indicators: total weight (g), estimated yield (kg / ha), feed conversion rate (FCR) and growth rate (g / week) were significantly higher for *L. vannamei*.

TABLE 3 Results at harvest. Final quantity of males and females, and zootechnical indicators obtained (in all treatments with food), after 60 days of culture. In the comparison in pairs (between species), in lines with the same stocking density, different letters indicate significant differences (ANOVA; p <0.05).

Treat-ment	Species – Density (juv. / m²)	Final ratio Males: females	Survival * (%)	Final weight (g)	Estimated yield (kg/ha)	FCR	Growth rate (g/week)
1	*L. schmitti* - 50	1.4 : 1	72.0 a	2.8 a	1015.4 a	11.5 a	0.12 a
2	*L. vannamei*- 50	0.9 : 1	88.0 a	10.4 b	4584.9 b	3.4 b	1.02 b

3	*L. schmitti* - 30	0.6 : 1	73.3 a	3.2 a	693.6 a	10.3 a	0.13 a
4	*L. vannamei*- 30	0.7 : 1	90.0 a	10.7 b	2884.2 b	3.4 b	1.02 b
5	*L. schmitti*- 30 (mixed, with food)	1.3 : 1	93.3 a	2.6 a	368.4 a	8.5	0.11 a
5	*L. vannamei*-30 (mixed, with food)	2.0 : 1	100 a	11.9 b	1789.6 b		1.21 b

* Includes deaths from "natural" causes or from handling problems associated with low domestication.

The values of weight increments are shown in Figure 4. With a growth rate of 1.0 g/week at stocking density of 50 juveniles/m², the final mean weight of *L. vannamei* was 3.7 times greater than that of *L. schmitti*, with only 0.1 g/week at the same density. In this specific case, starting from the same mean initial weight (1.78 g, *L. schmitti* and 1.71 g, *L. vannamei*; $p > 0.05$), in 60 days, the difference in final mean weight was 7.6 g.

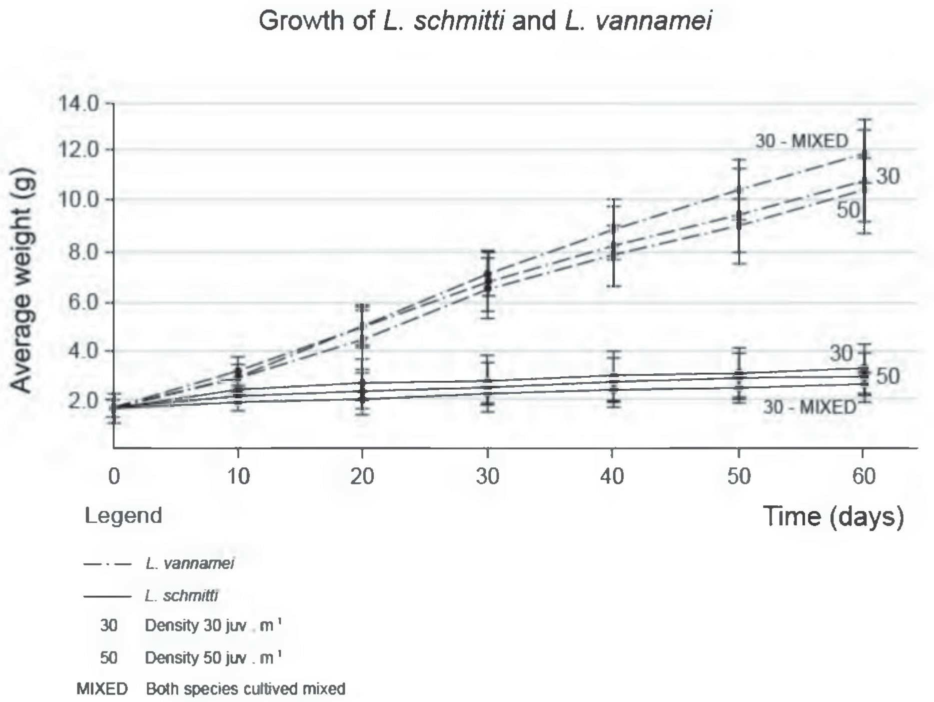

FIGURE 4 Average decennial growth of *L. schmitti* and *L. vannamei* shrimp for 60 days (all treatments with food) at densities of 30 and 50 specimens/m² (both species isolated or confined together).

Comparing the treatments with lower stocking density (30 specimens/m²), the results were very similar. The growth rates were also of 1.0 g/week for *L. vannamei* and 0.1 g/week for *L. schmitti.* The mean weight was 3.4 times higher for *L. vannamei* and difference in the final mean weight between both species was 7.5 g.

It is noteworthy that in the treatment where both species were cultivated together (mixed) with feeding, *L. vannamei* reached a even higher weekly growth and final mean weight (1.21 g/week and 11.9 g, respectively) when compared to treatments where it was cultivated as a single species Conversely, *L. schmitti* cultivated in the mixed treatment score lower numbers than as a single species.

The sex ratio determined at the end of the experiment is shown. As can be seen, the proportion of males and females was similar, except in the fifth treatment, where the number of males of *L. vannamei* doubled the number of females.

It should be noted the high survival achieved in the fifth treatment, when specimens of both species were confined together (mixed with feeding). In this treatment, only one *L. schmitti* died (final survival of 93.3%) while all *L. vannamei* survived.

3.3 Ethological observations in the mixed treatments with food

3.3.1 Agonistic behavior

The observation on the interaction between tested shrimp species during the experiment in mixed treatment reveled some interesting information. The conditions of the aquariums (rectangular plastic boxes, with white background) facilitated this type of observation.

In terms of agonistic behavior, it was not observed any signs of increased aggressiveness by the presence of both species in the same tank if compared to what was observed in monoculture treatments.

Even though, *L. schmitti* demonstrated much more nervous attitude in all times. Frequent jumps and blows against the walls were detected, in monoculture specially during siphoning (tank cleaning). Occasionally they were able to jump out of the water and fall to the ground. For this reason, *L. schmitti* specimens were frequently seen with melanized cuticular lesions on the dorsal part of the abdomen.

On the contrary, in monoculture treatment tanks with *L. vannamei*, the specimens were much quieter and less prone to jump. Due to the relative docility of the *L. vannamei*, they generally did not stir even during the cleaning of the boxes. In mixed treatment, *L. vannamei's* docility habits were some times negatively affected by the "nervousness" of *L. schmitti*. When the shrimps of the species *L. schmitti* jumped, a few shrimps of the *L. vannamei* species also jumped in reaction.

3.3.2 Feeding behavior

In mixed treatment with feeding, *L. vannamei* specimens always showed a much greater voracity and interest in the provided food than *L. schmitti* specimens did. As a consequence, almost every time when observed the *L. vannamei* shrimps had a full digestive tract (Figure 2).

During all time in the all feeding treatments, both mixed or monoculture, it was possible to spot the presence of exuvia. But even during in this extremely defenseless situation, no general mortality was recorded. In the mixed treatment with food, animals of both species prioritized the consumption of artificial food. In 4 of the 5 replicates of this treatment, no animal of any of the 2 species died.

3.4 Fasting treatment

No exuvia were recorded in the first days in the mixed treatment under fasting conditions, whereas in every other tanks which received regular feed, frequent molts were detected since the beginning of the experiment. In other hand, no deaths were recorded during the first 10 days.

The first molting process observed coincided with the first mortality record, on day 11. Freshly molted shrimp were always attacked and eaten (Figure 5). However, as the state of starvation advanced (day 21), the weak yet unmoulted animals began to be atacked. Although no food was supplied, the shrimp intestine (especially of *L. vannamei*) remained dark in color.

FIGURE 5 Predation (cannibalism) of a freshly molted shrimp in a tank with *L. schmitti* and *L. vannamei* mixed and fasted. Appendices and projections, such as eyes, pereiopods, and antennae were the first parts to be consumed. Photo S. Amador.

Between the days 11 and 38 all the animals of this treatment died. Important to note that even as cannibalism or predation was observed until only one animal was left in each tank, it was not observed predominance of one species over another. Of the 5 replicates, specimens of *L. schmitti* preponderated to the end in three tanks and *L. vannamei* in 2 tanks. In this treatment, as no food was provided, very little weight increment was observed (Figure 7).

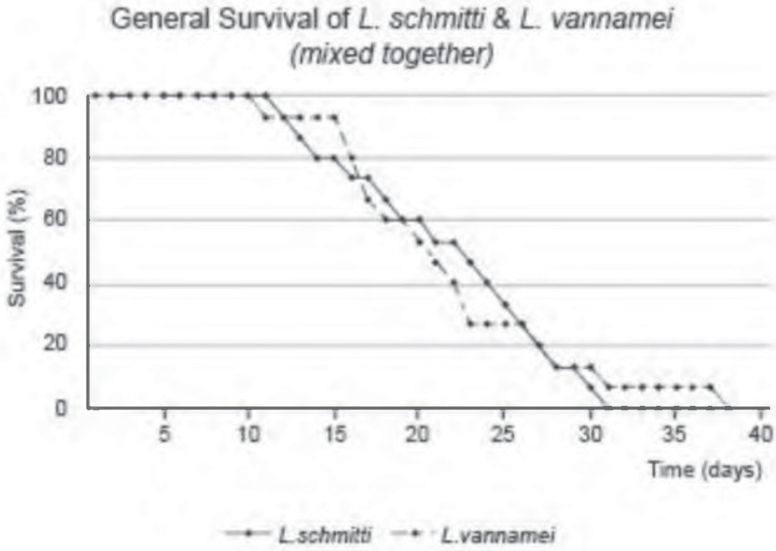

FIGURE 6 Total survival in 38 days in the 5 tanks where juveniles of the species *L. schmitti* and *L. vannamei* were confined and fasted. Stocking density: 30 juveniles/m^2 (3 specimens of each species / tank).

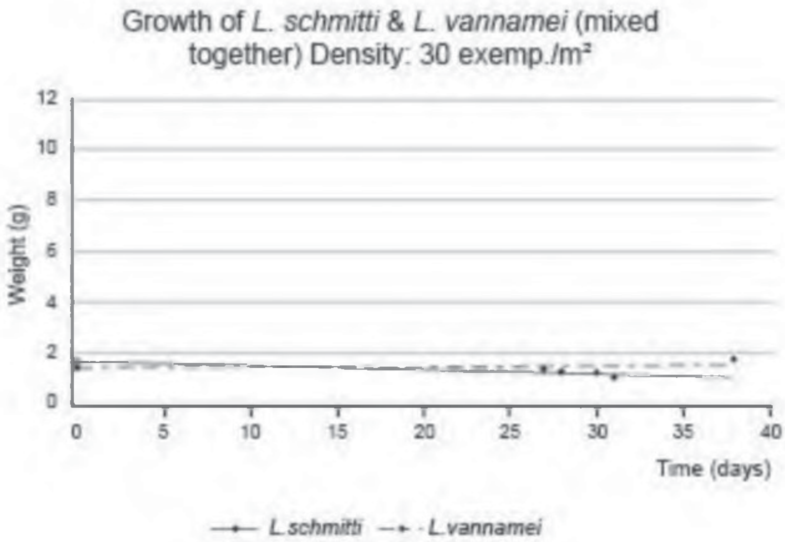

FIGURE 7 Final weight of shrimp *L. schmitti* and *L. vannamei* (fasted), which preponderated in each of the 5 tanks until day 38, when the last animal died. Initial weights: *L. schmitti*: 1.42 g; *L. vannamei*: 1.41 g.

3.5 Frequency of molting

An interesting information can be obtained when the data on molting events is crossed with the lunar cycle during the experimental period. Mean number of exuvia per animal colected was higher in the monoculture treatments, both at 30 and 50 shrimp/m^2, than in the mixed treatment (with food). In the mixed treatment with no food provided, molts were consumed by the starving animals precluding any analysis.

Overall, we observed a coincidence of the "peaks" of number of daily exuvia collected with changes in the lunar phase (Figure 8). As shown in the figure, during the first month of the experiment, the number of exuvia collected was higher in *L. vanamei* than in *L. schmitti*. However, considering total number of exuvia collected there was no significant differences between *L. schmitti* and *L. vannamei* (ANOVA; $p < 0.05$). This could indicate that the age of the specimens of both species was approximately similar, despite having different origins.

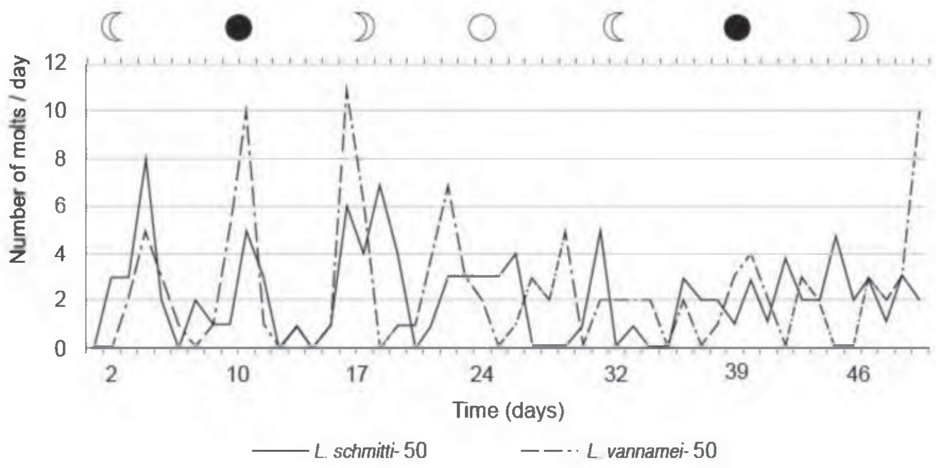

FIGURE 8 Total number of molts registered daily, in the treatments with *L. schmitti* and *L. vannamei* (with stocking density of 50 specimens / m^2) and lunar phases in the period.

3.6 Observed morphological differences

At the beginning of the experiment, it was difficult to differentiate the specimens of the native species and the exotic species by their external characteristics. With the daily observation of the shrimp, the differences described became more conspicuous. The main morphological differences are the form and size of the hepatopancreas, and the diameter, color and degree of intestinal fullness.

FIGURE 9 Top: *L. schmitti* specimen. Bottom: *L. vannamei* specimen. Note the differences in the shape and size of the hepatopancreas, and in the thickness of the intestine. Photo: Camila Tavares.

But a number of other subtle external differences can be establish especially where they were confined together (Figures 9 and 10).

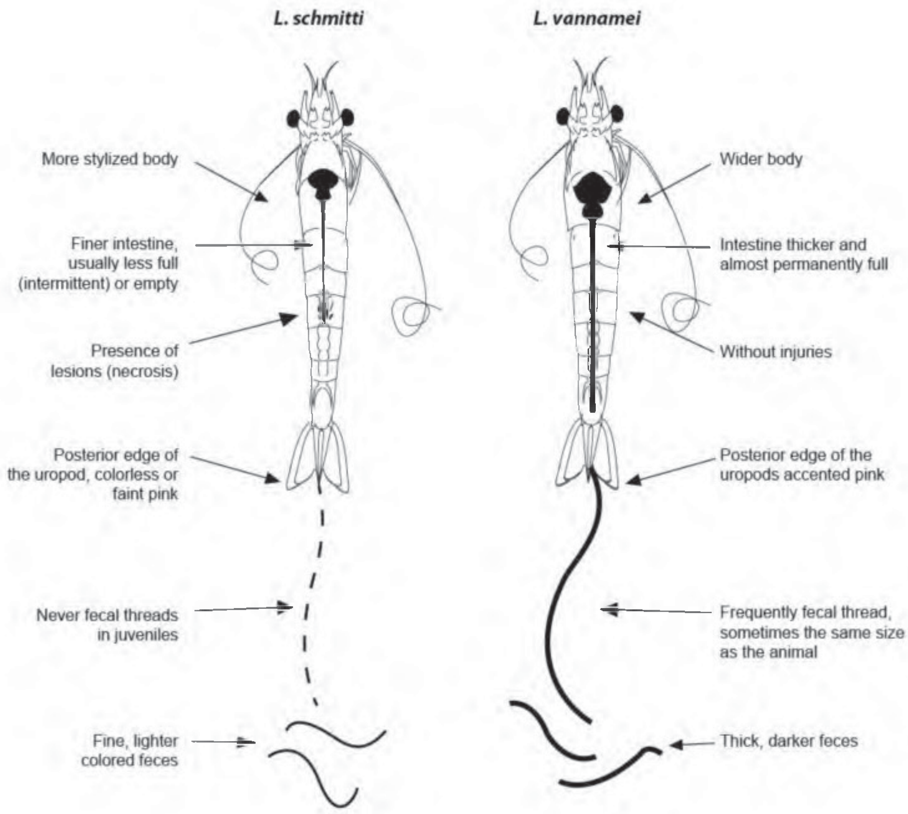

FIGURE 10 Main morphological differences observed in live shrimps of *L. schmitti* and *L. vanamei* species. Illustration by R.F. Alaiza Amador 2018.

Figure 11 shows the results of a regression analysis between the mean hepatopancreas weight and the total specimen weight for both species. The regression equations for *L. schmitti* and *L vannamei* corresponded to y = 0.0316x - 0.0008 and y = 0.0363x + 0.0411, respectively. The results for *L. vannamei* hepatopancreas were significantly different than of *L. schmitti*, demonstrating that this organ is generally bigger in the former species (ANOVA; $p < 0.05$).

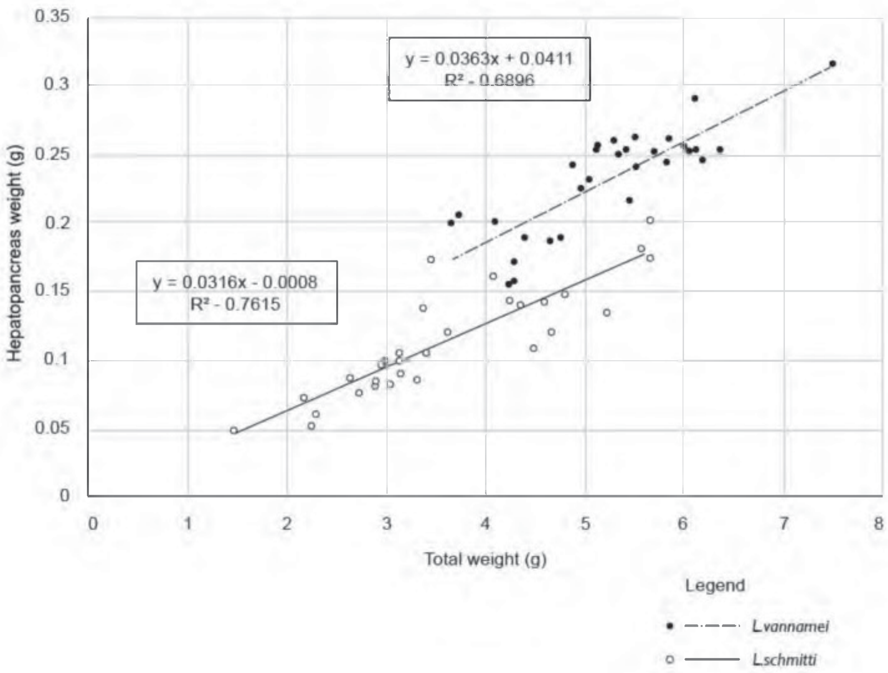

FIGURE 11 Regression between hepatopancreas weight and total weight of *L. schmitti* and *L. vannamei* (n = 30, for both species).

The comparison between diameter of the fecal threads, in shrimps of both species with total length between 60.0 and 100.0 mm showed that *L. vannamei* intestine was 23% thicker than that of *L. schmitti*.

4. Discussion

During all the experiment, main physical and chemical variables recorded during the experiment remained within the recommended values for shrimp cultivation (Fenucci, 1988). Furthermore, variables such as temperature, salinity, dissolved oxygen and total ammonium did not present significant differences ($P < 0.05$) among treatments, probably due to the high rate of daily water exchange (50 - 75%). As the water collected by the hatcheries inlet pipes present known oceanic conditions, the variables of water contributed to standardize the experimental conditions.

In other hand, differences in other variables such as pH and nitrite in the different treatments may be explained by the amount of organic matter present in the water.

For example, in the tanks with *L. vannamei*, which contained up to 10 shrimps of 10.7 g of average weight, receiving 6.2 g of food/day it was observed pH decrease if compared with the fasting treatment water completely clear (in the absence of food and almost also of wastes), where pH was significantly more alkaline (8.06), although within the normal range for cultivation. Nitrite reached 0.56 mg / L N- NO2- in the mixed fasting treatment, but this concentration is much lower than what considered unsafe for the cultivation of another species of penaeid, *Farfantepenaeus paulensis*, of 2.55 mg/L NO2-(Wasielesky, Poersch, Martins, & Miranda-Filho, 2017). However, the fact that this treatment lasted much less time (38 days to the harvest of the last tank) than the other five treatments (60 days), evidently also affected this comparison.

The final biomass in the tanks with *L. vannamei*, stocked at the density of 50 shrimp/m^2, reached 91.7 g (equivalent to 0.46 kg/m^2), while in tanks with *L. schmitti*, stocked at the same density, biomass was 20.3 g (equivalent to 0.10 kg/m^2, 4.5 times lower).

The greater weight gain observed for *L. vannamei* is probably due to the high degree of domestication of this species, as it appeared to immediately adapt to the experimental conditions, although the fact that it did not differ significantly from that of *L. schmitti*, may indicate that these conditions were adequate even for the less domesticated species. This species has been target of an intense selective breeding process through genetic crosses for decades, which surely contributed for the high tolerance to live and grow at high stocking densities. In top of that, the species has been adapted to eat the formulated feed that in its turn, is formulated especially for this species.

For that reason, in the comparison of the growth of *L. vannamei* with the native species *Farfantepenaeus paulensis* carried out by Peixoto et al. (2003), to avoid possible inequalities, besides the pelletized food they included fresh frozen mixture.

The adaptive feature mentioned above was observed as under the conditions described and with the food supplied, as *L. vannamei* showed the same growth rate (1.0 g/week) for both densities. Even thought, the mean weekly weight increment observed in our experiment was lower than reported for *L. vannamei* shrimp by the literature. For example, Wyban (2007) reported a growth rate of 1.2-1.7 g/week for *L. vannamei* commercial crops in Thailand.

Growth rate is a determinant factor in the cultivation of any species, so this variable was analyzed for *L. schmitti* in several studies. In this study, the growth rates in the treatments with *L. schmitti* averaged 0.1 g/week, ten times lower than what was observed for *L. vannamei*. Several factors may explain this but, most importantly, these are wild animals without any type of family selection or domestication, which have been maintained in containers without shelter, with transparent water and formulated feed as the only food.

However, it is important to note that this growth rate was exceedingly low even if we consider the species. In comparison, Fernandez de Alaiza, Jaime-Ceballos, et al. (1994), reported growths of 0.6 - 0.8 g/week with this species in Santa Cruz del Sur, Cuba, in earthen ponds stocked at 17-20 shrimps/m^2. Likewise, Artiles (2002), comparing crops of this species at densities of 25, 50 and 75 shrimp/m^2 in Yaguanabo, Cuba, reported a weekly growth of 0.6 g/week for all ponds in 120 days. On the other hand, Fraga et al. (2002), reported growths of between 0.4 and 1.0 g / week in experimental pens within earthen ponds in Tunas da Zaza, Cuba, stocked at densities between 10 and 25 shrimp/m^2. Studying the abundance of zoobenthos in this experiment, these authors estimated a contribution of natural food to the *L. schmitti* growth of 58.2 - 87.9%, in the tested treatments. Likewise, they reported a potential growth of 22.7 g, achieved by specimens of the species in a 72-day period, which had been stocked to 1 shrimp/m^2 and consumed only natural food.

On the other hand, *L. schmitti* production data published by Allessi (2000) indicate that commercial ponds stocked at a mean density of 13.9 PL/m^2 in Paranaguá (PR), Brazil, grew at a mean of 0.6 g/week. The high influence of stocking density on *L. schmitti* growth was later corroborated by Marquez et al. (2012) in Santa Catarina, Brazil, who compared crops in fiberglass tanks (with a phytoplankton bloom), stocked at 8, 20 and 50 shrimp/m^2, and obtained growths of 0.5, 0.3 and 0.4 g/week, respectively, in 105 days. These authors also agree that high stocking densities affect growth (possibly by spatial competition and lack of natural food), obtaining the best result with the density of 8 shrimps/m^2, even with an average temperature of 24.6 ° C, which they considered low for the species.

Another aspect that influences shrimp growth is the molting frequency. Bonilla-Gómez, Chiappa-Carrara, Galindo, Cuzón, and Gaxiola (2013), compared the molting frequency and other physiological indicators in *Farfantepenaeus duorarum*, finding that the protein concentration in the cultivated animals was significantly higher than that of the wild shrimps of this species. In the case of the experiment reported here, the molting frequency was not a significant element in the comparison of species, but as already mentioned, the difference in the degree of domestication does seem to have had an important influence.

In this study, the growth observed for *L. vannamei*, when cultivated together with *L. schmitti*, was higher than in monoculture. This does not coincide with that reported by Martinez-Cordova and Peña-Messina (2005). In their work, the authors report a higher growth of *L. vannamei* in monoculture than when cultivated with blue shrimp, *Litopenaeus stylirostris*.

The 60-day duration of the experiment, could lead us to ask: what would the growth of *L. schmitti* be like if the experiment had continued, for example, twice as long?

To answer this question, we should refer to the work already mentioned of Allessi (2000). Although the author has relied on commercial crop data, her comparison of the growth of *L. schmitti* and *L. vannamei* may provide information of interest. For *L. schmitti*, the average weight reported after 60 days of cultivation was approximately 1.5 g and at 120 days of 7.3 g. In that same period, the average weight of *L. vannamei* was 9.4 g and 13.4 g, respectively. It should be noted that, in spite the fact that the final mean weight of *L. vannamei* in this work was almost twice that of *L. schmitti* at the harvest, several factors favored the exotic species. Among them, differences in earthen ponds conditions, type of food and use of partial harvests.

The possibility of establishment of a reproductive population in the coastal areas where the natural populations of *L. schmitti* are distributed is one of the most worrisome potential environmental impacts that can be determined by the escape of *L. vannamei* from farms.

As it is well known, in the extensive coastal areas naturally inhabited by *L. schmitti*, hundreds of shrimp farms cultivating *L. vannamei* operate. There are numerous reports of the presence of *L. vannamei* in natural areas where it is considered an exotic species, from: Brazil (Edison Barbieri, Coa, & Rezende, 2016; E. Barbieri & Melo, 2006; Loebmann et al., 2010; M. Santos & Coelho, 2002), the United States (Balboa et al., 1991), Mexico (Wakida-Kusunoki et al., 2011), Thailand (Senanan et al., 2007) and others. In addition, this species is also marketed as live bait in northeastern Brazil (Leão, Almeida, Dechoum, & Ziller, 2011), so there is a permanent risk of its dissemination in the natural environment.

Some of the most very interesting results of this study came from the interaction between both species when cultivated together at relatively high densities. As mentioned, at the end of the experiment the final mean weight of *L. vannamei* cultured together with the native species was even greater than the one obtained in the monoculture treatments.

We believe that two aspects could be involved: *L. vannamei* species are markedly voracious, even more than other species of penaeid shrimp (Chavanich, Viyakarn, Senanan, & Panutrakul, 2016), and in this case they had more food available, calculated for them and also corresponding to the specimens of *L. schmitti*, which at all times showed less interest in the food. Being distinct, confined species, it seems that interspecific competition occurs and, as a consequence, a greater difference in size. The result of this coexistence, in terms of growth, was beneficial for *L. vannamei* (which reached a higher average weight) and harmful for *L. schmitti*.

Even being much larger, when food was supplied *L. vannamei* did not attack *L. schmitti*. At first, this behavior might seem understandable, as the specimens of the two species were about the same size. However, at the end of the experiment, when the *L. vannamei* shrimp reached an average weight 4.5 times higher than those of *L. schmitti* (Figure 4, both named as "mixed"), the high survival rate was also maintained.

Martinez-Cordova and Peña-Messina (2005), have already highlighted the greater voracity of *L. vannamei* (also expressed in a higher rate of stomach fullness) compared to *L. stylirostris*. Subsequently, Chavanich et al. (2016) compared the food intake of *L. vannamei* with that of 5 species of Asian penaeid shrimp, finding that this species proved to be more voracious than these native species, among them *Penaeus monodon*.

It does seem to indicate that in a future (and hypothetical) coexistence of both species in the natural environment, with sufficient food resources, interspecific competition would tend to be low. Could this data be extended to their behavior in nature?

Intraspecific interactions of wild and cultivated *Penaeus plebejus* shrimps were studied to determine the differential effect of food and shelter limitations on the survival of both groups (Ochwada-Doyle, Gray, Loneragan, Suthers, & Taylor, 2012). These authors emphasized the importance of the refuge, in this case macroalgae, to carry out repopulations in natural areas of Australia. This result, referring to the interaction of cultivated and wild animals of the same species, draws attention to the complexity of this type of behavioral studies, which can subsidize information about possible impacts of an exotic species on the natural environment.

In the case of our work, we also compared the species in an "extreme" situation, with wild shrimps confined together with a farmed shrimps from a non-native species in absence of shelter and food. In this case, the "domesticated" *L. vannamei* specimens proved to be as capable of defending themselves (with depredation/cannibalism) as the "wild" *L. schmitti*. With final weights averaging 1.3 g for *L. schmitti* and 1.5 g for *L. vannamei* (Figure 7), both species were about the same size, which it makes sense that no species have prevailed in this treatment.

Throughout the above, it would be necessary and opportune to continue and extend this research to include other aspect of this interaction. Loebmann et al. (2010) pointed out the coincidence in habitat and food between *L. vannamei* and native species such as *L. schmitti*, as well as the possibility of transmission of viral diseases that already affected the exotic species in captivity. On the other hand, Balboa et al. (1991) have recommended the study of competition and disease transmission as possible ecological interactions of *L. vannamei* with populations of native species. In fact, the Taura syndrome virus, which caused large losses to shrimp farming on a global scale, has already been detected in wild populations of *L. schmitti* in Venezuela (Fajardo et al., 2010).

Additionally, in accord to the personal communication of fishermen who commercialize both species as live bait for sport fishing in the state of Paraná, Brazil: "*L. vannamei* does not represent any risk in the natural environment, since, being more domesticated animals, the shrimps do not have reflexes of escape-defense and are easily depredated”. The results presented here contradict the above, and indicate the need for these studies and even greater environmental control.

The results of this work reaffirm the zoothechnical advantages of *L. vannamei* for commercial shrimp farming, already shown in several previous studies. Its cultivation is generally carried out by large well established companies, and it is recognizable as a job-creating economic activity especially important in the tropical belt of the world. Global production of this species in 2016 was approximately 3.0 million tons, generating more than US $ 18.0 billion (Jory, 2017).

With all the economic aspects considered, it is also vastly known that the introduction of this exotic species may lead to the several environmental problems, such as genetic pollution and spread of diseases to natural stocks, producing considerable economic losses and social affections (F.A.O., 2013; Fernández de Alaiza García Madrigal, da Silva, Tavares, & Ballester, 2017).

Based on these facts, several studies have highlighted the potential of cultivation of native species and recommended their study and use, especially when social and environmental values are considered (Henriques et al., 2014; Occhi, Faria, & Vitule, 2017). We consider that the major potential of *L. schmitti* at the present is for low-density cultivation of organic crops in coastal lagoons, aiming niche markets. Also, as demonstrated by Preto et al. (2009) with *Farfantepenaeus paulensis,* the production of live bait for the sport fishing and stock repopulation to subsidize artisanal fishing, and others ends mostly linked to coastal communities. The benefits *L. schmitti* "domestication" would be the establishment of broodstocks, genetic improvement and the development of formulated feeds related to the requirements of this native species, which could contribute greatly to the improvement of its zootechnical performance.

We consider that the results obtained by this work could greatly contribute with information of interest for this important subject.

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2. CONSIDERAÇÕES FINAIS

Esta pesquisa traz como principal novidade científica a comparação entre as populações de camarão branco, *Litopenaeus schmitti* de Cuba e do Brasil sob ponto de vista biológico, usando técnicas de morfometria. A metodologia e o conhecimento obtidos poderão ser aplicados para a conservação das populações naturais de *L. schmitti* e para o possível desenvolvimento de do conhecimento necessário para seu cultivo em cativeiro.

Como resultado dos trabalhos realizados (e tendo também em conta a informação publicada sobre o tema), podemos chegar à duas conclusões principais:

1. Foram encontradas diferenças morfológicas significativas entre as populações do *L. schmitti* amostradas ao longo da distribuição geográfica da espécie, refletindo os diferentes processos evolutivos a que a espécie foi submetida nos últimos milhões de anos.

2. Nas condições experimentais descritas na presente tese, ficou demonstrado que o desempenho zootécnico de exemplares <u>cultivados</u> do *L. vannamei* é significativamente superior ao de exemplares <u>silvestres</u> de *L. schmitti*, refletindo os diferentes processos de domesticação e seleção genética que a espécie foi submetida nas últimas décadas.

Várias inferências de tipo prático poderiam ser assumidas, a partir das conclusões anteriores:

1. A diferenciação morfológica que existe entre populações naturais do *L. schmitti* pode ser usada com êxito em um programa de melhoramento genético, com vistas ao aprimoramento do desempenho zootécnico da espécie em cultivo. Baseado nas observações deste estudo e nos dados da literatura, o potencial de crescimento desta espécie nativa é tão alto quanto o do *L. vannamei*.

2. Com o atual estágio alcançado pelo pacote tecnológico desenvolvido para o *L. vannamei,* não se vislumbra razão econômica para que a carcinicultura industrial passe a cultivar outra espécie de camarão marinho, salvo em condições muito específicas.

O cultivo da espécie exótica *L. vannamei*, no modelo em que se pratica atualmente na costa Atlântica da América do Sul e do Caribe, gera um nível inaceitável de riscos, que não devem continuar sendo ignorados. Entre os mais importantes, o risco de escapes, por meio do transporte de animais, da fuga para o meio natural durante as despescas ou pela venda como isca viva.

Isto foi detalhado por Santos (2005), quem relata capturas da espécie exótica *L. vannamei* por pescadores artesanais nos estados de Rio Grande do Norte, Pernambuco e Sergipe. Conforme dita autora, entre as principais causa de desses escapamentos estão a estrutura precária e baixa altura dos diques dos viveiros e os métodos de despesca inadequados. Por estes motivos, depois de fortes chuvas em Rio Grande do Norte em 2004, chegaram-se a capturar no ambiente natural até 85 kg/canoa/dia e 180 kg/embarcação motorizada/dia, só do *L. vannamei*. Por sua parte, segundo Santos e Freitas (2004), dita espécie constituiu o 6,5 % dos desembarques camaroeiros mensais na lagoa Papari, Rio Grande do Norte, entre 2000-2002 devido à frequente rompimento de diques. As autoras incluso chegam a reportar a reprodução desta espécie exótica em estuários de Rio Grande do Norte e Pernambuco.

Além disso, *L. vannamei* aparece no "Informe de espécies exóticas invasoras marinhas no Brasil", o qual considera a maricultura como o atual vetor de dispersão da espécie e à água de lastro, as aves migratórias e as correntes marinhas como vetores potenciais (Lopes et al., 2009).

Outro risco associado ao uso de dessa espécie é a transmissão de doenças virais, como já foi explicado no Capítulo 1 da presente tese (epígrafe 3.3, Consequências da introdução de espécies: Disseminação de doenças), além do possível estabelecimento de populações reprodutivas, com graves danos à biodiversidade. Os governos, assim como as grandes empresas e associações de produtores, têm responsabilidade na situação atual e devem atuar para acautelar ou mitigar seus efeitos negativos.

Existe uma contradição social e comercial com relação ao produto "camarão". As populações ribeirinhas, que habitam zonas de estuários e mangues onde o existe o *L. schmitti*, exploravam artesanalmente a comercialização do camarão, apesar de sofrer com a pobreza, desemprego, desigualdade de gênero e falta de oportunidades em geral. Como alimento de luxo, só uns poucos, nem mesmo a própria comunidade, poderia consumir.

Atualmente, em função do êxito da própria carcinicultura, os preços do produto baixaram a ponto de tornar este alimento muito mais acessível para o consumidor. Para as comunidades, no entanto, não houve melhora em suas condições, já que não tem acesso a tecnologia de cultivo e ainda perdeu o mercado para seu produto.

Além do enfoque ecológico, outras realidades do nosso cotidiano corroboram o exposto acima. Por esta razão, é necessário continuar apoiando a realização das investigações para desenvolver o uso de espécies nativas como *L. schmitti*, como alternativa viável de cultivo. O desenvolvimento de linhas de progenitores com maior crescimento e tolerância às enfermidades e a produção de pós-larvas para a venda e o repovoamento dos estoques nativos precisam ser consideradas estudos fundamentais para atingir este objetivo.

O desenvolvimento de alternativas para as técnicas de cultivo sustentáveis, porém rentáveis, pode contribuir à conservação desta importante espécie e também beneficiar os habitantes costeiros. Através do cultivo tradicional em viveiros, utilizando baixas densidades e com maior aproveitamento do alimento natural, é possível produzir o camarão nativo "orgânico", com excelentes retornos advindo de mercados de nicho. No Brasil, a empresa PRIMAR em Rio Grande do Norte, é exemplo na produção orgânica de camarões e ostras, certificados pelo Instituto Biodinâmico (IBD) (Baldi e Lopes, 2008).

Também é interessante, o cultivo ou manutenção em gaiolas para a venda de camarão como isca viva, já que segundo Henriques et al. (2014), no Sudeste do Brasil existe uma crescente demanda de camarões como isca viva para a pesca esportiva, a qual é suprida com a sobrepesca do *L. schmitti* ou com a venda ilegal de juvenis da espécie exótica *L. vannamei*, práticas igualmente prejudiciais.

Cultivos em gaiolas para a venda de camarão como isca viva, bem como programas de repovoamento com foco na sustentabilidade da pesca artesanal, poderiam se somar às outras atividades como cultivo de ostras e outras modalidades de turismo rural, como forma de geração de renda para comunidades tradicionais.

Entretanto, deve mencionar-se que não existe consenso sobre a efetividade e o verdadeiro impacto do repovoamento de camarões marinhos. Uma análise completa sobre o melhoramento ou a restauração da produtividade de populações naturais de invertebrados marinhos foi elaborada pelo Caddy e Defeo (2003). A necessidade de aprofundar no conhecimento do habitat, de aspectos genéticos e dos métodos de avaliação do impacto de sortes ações são ressaltadas por ditos autores.

A informação disponível sobre o assunto, indica que só liberar semente no meio natural não garante o êxito das ações de repovoamento. É também necessário atuar sobre as regulações pesqueiras e ainda considerar outras medidas de manejo do ambiente a ser restaurado (Hamasaki e Kitada, 2008; Vitale et al., 2013; Kittaka, 1983).

Em resumo, se a necessidade de retomar o uso de espécies nativas como *L. schmitti* for enfocado somente pela lógica do mercado, nada disso importa. A carcinicultura vai continuar cultivando o *L. vannamei* como espécie líder e única de camarões peneídeos em todo o planeta. Continuarão ocorrendo cada vez mais escapes, possivelmente até que a própria comunidade comece a pescar estes camarões exóticos no ambiente em grandes quantidades.

Porém esta não é única lógica possível. É preciso também pensar também no amanhã. A biodiversidade natural é de suprema importância sim e precisa ser preservada. Por esta razão, é necessário dar oportunidades às espécies nativas.

Consideramos que uma política justa sobre este assunto, apoiada em critérios científicos e ecológicos, poderia contribuir para mudar esta realidade, só seguindo os Objetivos de Desenvolvimento Sustentável (U.N., 2017), as Metas de Aichi para a Biodiversidade (Lima Jr. et al., 2018) e alguns dos elementos aqui expostos.

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CASTILHO-WESTPHAL, G. G.; GARCÍA-MADRIGAL, R F de A. Doenças que afetam camarões cultivados. In: Antonio Ostrensky e Nathieli Cozer. (Org.). A PRODUÇÃO INTEGRADA NA CARCINICULTURA BRASILEIRA: PRINCÍPIOS E PRÁTICAS PARA SE CULTIVAR CAMARÕES MARINHOS DE FORMA MAIS RACIONAL E EFICIENTE. 1ed. Curitiba: 2017, v. 2, p. 84-124.

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Doenças que afetam camarões cultivados

Gisela Geraldine Castilho-Westphal & Rafael Fernández de Alaiza García-Madrigal

1) Introdução

Os crustáceos, grupo do qual os camarões fazem parte, são invertebrados que possuem um eficiente sistema imunológico, capaz de protegê-los contra a invasão por agentes causadores de doenças (agentes patogênicos ou patógenos). Característica esta que explica parte do sucesso deste grupo zoológico ao colonizar e sobreviver na Terra, sendo um dos mais bem-sucedidos e antigos, com mais de 500 milhões de anos de história evolutiva[1; 2]. No entanto, esse sistema imunológico difere daqueles apresentados por nós, humanos.

Os camarões, assim como os demais invertebrados, possuem apenas um sistema imune inato (nascido com eles). Ou seja, não são capazes de produzir memória imunológica (imunidade adquirida) após o primeiro contato com um patógeno e, consequentemente, não produzem anticorpos. Como resultado disto, não são capazes de responder à vacinação, reagindo sempre à presença de um mesmo patógeno como se fosse a primeira vez, ainda que este contato já tenha ocorrido por diversas vezes no passado.

> ***Atenção!***
> *Como a vacina não é uma ferramenta eficiente para camarões, o uso de substâncias imunoestimulantes tem sido uma valiosa alternativa para aumentar a imunocompetência destes crustáceos. Principalmente porque as enfermidades estão entre os fatores limitantes para a carcinicultura mundial, especialmente as de etiologia (causa) viral, que não são facilmente tratadas por medicamentos.*

Justamente por não apresentarem a imunidade adquirida, os mecanismos que compõem a imunidade inata precisam ser eficientes e diversificados. Segundo Vazquez *et al.* [2], podem ser citados como principais mecanismos de defesa conhecidos em crustáceos:

- As barreiras físicas, como o próprio exoesqueleto do animal;
- A coagulação da hemolinfa para impedir seu extravasamento, evitando o que equivaleria à uma hemorragia em vertebrados;
- A melanização mediada pelo sistema pró-fenoloxidase, que é responsável pela formação de substâncias que atuam na destruição de patógenos e, ao mesmo tempo, criam áreas com coloração marrom escura no corpo do animal;
- O reconhecimento e a aglutinação de células (bactérias, por exemplo), mediadas por glicoproteínas chamadas lectinas, impedindo que os micro-organismos consigam se espalhar pelo corpo do camarão;
- Os sistemas antibacterianos, antifúngicos e antivirais mediados por:
  - Moléculas resultantes da ligação de aminoácidos, os chamados peptídeos, e com função semelhante ao detergente, que quebra a gordura que compõem muitos micro-organismos (vírus, bactérias e protozoários) e, consequentemente, causam sua morte.
  - RNA de interferência, que atua em um processo genético responsável pela inibição da síntese de proteínas, dificultando a sobrevivência do agente patogênico.
  - Proteínas de reconhecimento padrão, que são capazes de reconhecer o que não é próprio ao animal e, assim, desencadear mecanismos que resultem na destruição e/ou neutralização de micro-organismos e parasitos invasores.
- Formação de mecanismos citotóxicos e/ou degradativos intracelulares, pela produção de moléculas com capacidade microbicida (Espécies Reativas de Oxigênio e de Nitrogênio, por exemplo), ou seja, com a capacidade de destruir micróbios (micro-organismos);
- O sistema fagocítico (realiza a fagocitose) nada mais é que o englobamento e digestão de partículas sólidas e micro-organismos por células da hemolinfa (os hemócitos); e,
- Formação de cápsulas e nódulos em torno de partículas estranhas, isolando o agente patogênico do restante do corpo do animal.

Apesar de todos esses variados e complexos mecanismos de defesa que os camarões são capazes de dispor em casos de infecções ou infestações, ainda há muitas perdas econômicas relacionadas a surtos de doenças.

Abordaremos neste capítulo as principais doenças que afetam camarões cultivados no mundo, além das doenças já registradas no Brasil e as de notificação obrigatória pela Organização Mundial de Saúde Animal - OIE (do inglês "World Organisation for Animal Health"), bem como, a importância da produção integrada na redução de problemas relacionados à presença destas enfermidades no cultivo. Não serão abordados aqui os procedimentos de Boas Práticas de Manejo (BPM) para prevenção das enfermidades, já que este tema é tratado no Volume II.

2) A Produção Integrada e a sanidade dos camarões

Espera-se que a Produção Integrada (PI) minimize desperdícios e impactos, sejam eles ambientais, sociais ou econômicos, e ainda maximize os lucros. Isto porque sem lucro para os todos os agentes envolvidos, o próprio sistema não se sustentaria. Para isto, a PI na carcinicultura é estruturada para que o produto (o camarão) tenha qualidade, seja rastreado, que em sua produção seja promovida a redução na utilização de insumos poluentes, sejam empregadas as boas práticas de manejo e que sejam adotadas medidas em conformidade com a legislação sanitária vigente no país. Tudo isto sem deixar de lado a saúde dos camarões.

Para que a saúde dos animais produzidos de forma integrada seja mantida, métodos de controle e profilaxia acabam sendo a melhor opção, por evitar a entrada e a disseminação de doenças na fazenda e, principalmente, por evitar que enfermidades sejam disseminadas para o ambiente natural e infectem espécies de vida livre. O que seria um cenário catastrófico para o empreendimento e para o ecossistema, já que muitas destas enfermidades podem causar a mortalidade de até 100% do plantel em poucos dias, após sua introdução no cultivo. Em muitos casos, o uso de medicamentos acaba sendo a melhor opção para tratar enfermidades e reduzir as perdas produtivas, porém, nestas situações os fármacos e demais substâncias químicas (imunoestimulantes, desinfetantes, sanitizantes, entre outros) devem ser usado racionalmente (dose, tempo de carência, recomendações de uso, descarte de resíduos, etc.). Isto para que não haja poluição ambiental, com a manutenção da qualidade da água, do solo, do ambiente ou até intoxicação da espécie cultivada ou do próprio consumidor.

Por todos esses motivos, a PI por si só já apresenta eficientes mecanismos de controle sanitário, como a rastreabilidade e a implantação das boas práticas, por exemplo, que dificultam a introdução e a disseminação de doenças, uma vez que há um rigoroso controle de processos para a manutenção da qualidade da produção. Mas, para que o controle seja mais eficaz é importante se conhecer as principais doenças e os fatores que determinam sua ocorrência e disseminação na produção.

3) Disseminação de enfermidades

Apesar dos benefícios econômicos associados à globalização de mercados, o aumento das trocas comerciais entre países também eleva a possibilidade do intercâmbio internacional de agentes causadores de enfermidades [4]. O trânsito internacional de camarões vivos ou seus produtos pelo comércio formal ou informal é um dos principais mecanismos de introdução e disseminação de patógenos (organismos causadores de doenças) em áreas até então livres de enfermidades.

Como o comércio transfronteiriço é a maior fonte econômica para muitos países e um comércio de sistema complexo e dinâmico, medidas que regulamentam transações comerciais de animais e seus produtos têm sido implementadas, para que enfermidades não tenham a disseminação favorecida. Para minimizar os malefícios da globalização de mercados, sob o ponto de vista sanitário, a OIE determina os padrões sanitários internacionais.

***Conceitos epidemiológicos importantes*[3]**
Endemia: *doença localizada em um espaço limitado (faixa endêmica), de duração contínua.*
Epizootia: *quando uma doença contagiosa, que se propaga com rapidez, acomete um grande número de animais ao mesmo tempo e na mesma região. O termo equivalente em medicina humana é* ***Epidemia****.*
Pandemia: *é uma epizootia que atinge grandes proporções, podendo se espalhar por um ou mais continentes ou por todo o mundo, causando inúmeras mortes.*
Virulência: *é a capacidade do agente patogênico (causador da doença) de produzir efeitos graves ou fatais no paciente/animal (ex.: camarão).*

1.1 Pandemias na carcinicultura mundial

Vírus, como IHHNV (Vírus da Necrose Hipodérmica Hematopoiética Infecciosa), YHV (Vírus da Cabeça Amarela), TSV (Vírus da Síndrome de Taura) e WSSV (Vírus da Síndrome da Mancha Branca), são responsáveis por pandemias que afetam negativamente a indústria mundial de cultivo de camarões peneídeos.

Um dos mais dramáticos eventos promovidos por enfermidades na carcinicultura mundial, foi a pandemia provocada pela Síndrome de Necrose Hepatopancreática Aguda (AHPNS) – também conhecida por Síndrome da Mortalidade Precoce (EMS) – que provocou, somente na Ásia, perdas estimadas em um bilhão de dólares [5].

No tratado internacional celebrado pela Organização das Nações Unidas para Alimentação e Agricultura (FAO) no Vietnam em 2013, evidenciou-se que:

1. A importação de camarões vivos, em geral, está contribuindo para a disseminação de enfermidades, principalmente as virais.
2. A principal espécie não-nativa e com maiores vantagens para o cultivo, *Litopenaeus vannamei*, é mais suscetível às enfermidades do que *Penaeus monodon* e *Fenneropenaeus chinensis*. Uma das principais recomendações deste tratado foi suspender o comércio de camarões vivos de países afetados por determinadas enfermidades [6]. Essa medida foi adotada por vários países [7] e, principalmente, porque há evidências de que o comércio de camarões vivos tem incrementado a diversidade genética dos vírus. Somente no caso do YHV que afeta *P. monodon* na região Ásia-Pacífico, 30% dos vírus são recombinantes [8].

Na Figura 1, é apresentado esquematicamente um resumo do surgimento e da disseminação das principais enfermidades virais que afetam a carcinicultura mundial. Além das doenças representadas, sabe-se que há um intercâmbio de enfermidades desconhecidas, que apareceram no cultivo de camarões na Ásia e na América, além do papel negativo do Havaí na disseminação de IHHNV [9].

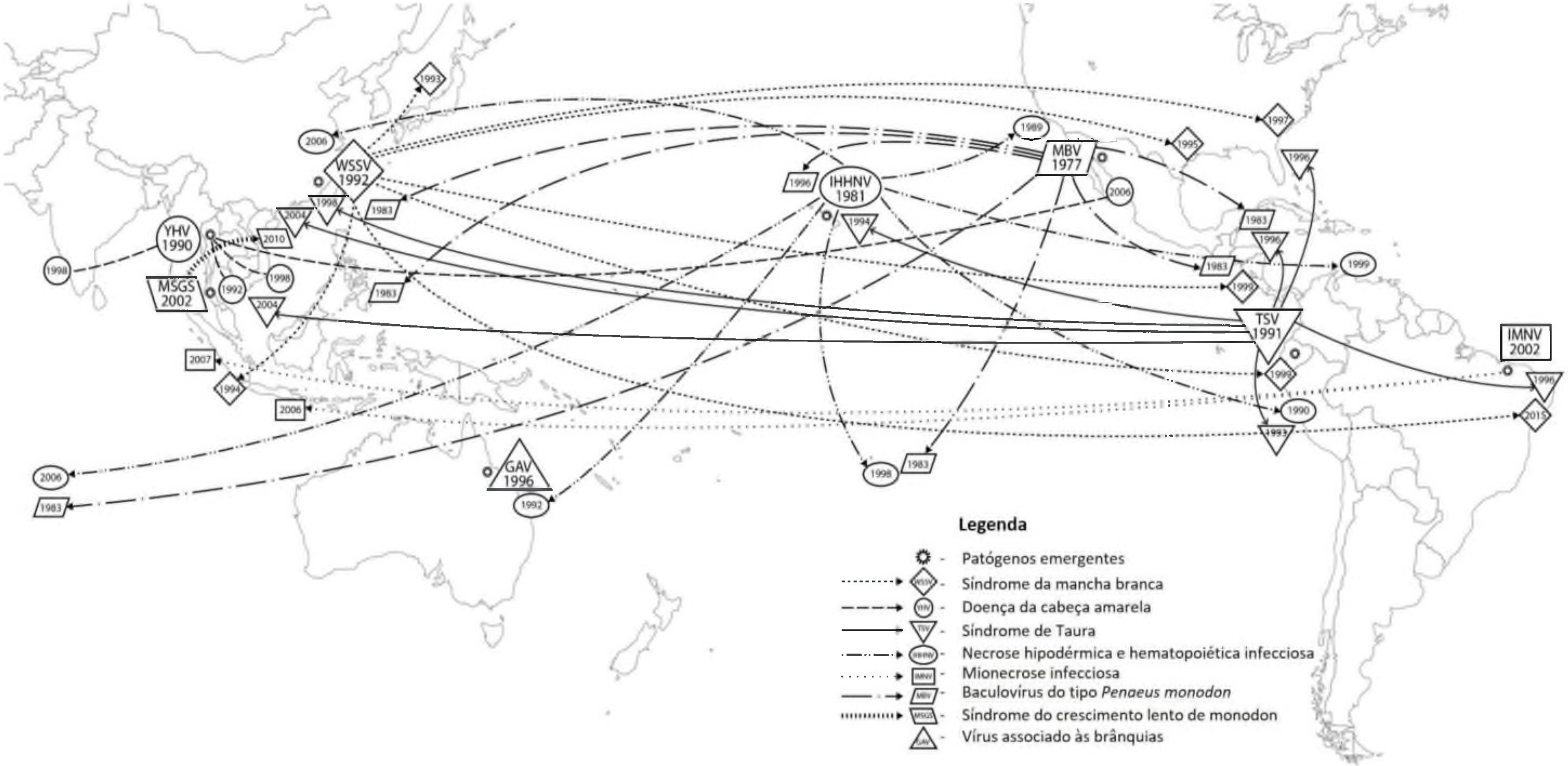

Figura 1. Resumo histórico do surgimento e disseminação das principais enfermidades virais que afetam camarões cultivados. Fonte: Lightner [10; 11; 12; 13; 14; 15; 16; 17; 18]. Figura modificada de Walker e Mohan [14].

Além da grande capacidade de disseminação, evidenciada na Figura 1, as enfermidades virais apresentam outra característica bastante desfavorável à carcinicultura: elas podem prevalecer nas zonas de cultivo por 20 ou 30 anos após terem sido relatadas pela primeira vez. Em amostras obtidas de fazendas marinhas de sete países latino-americanos onde se cultiva *L. vannamei,* foram encontradas 12 enfermidades diferentes, sendo que metade delas era causada pelos vírus: IHHNV, WSSV, IMNV, TSV, BP e LvNV [16]. Chama a atenção que a propagação destas enfermidades afete por igual, tanto países em que *L. vannamei* é espécie **nativa** (como México, Guatemala, Nicarágua e Honduras), quanto aqueles em que a espécie foi introduzida pela carcinicultura (como Belize, Venezuela e Brasil).

Embora tanto os camarões adultos, quanto os juvenis pareçam ser afetados igualmente pelas maioria das epizootias, vírus como WSSV, IHHNV e TSV têm predileção por juvenis [19]. Isto pode causar um problema ainda maior nas populações naturais, considerando a maior sensibilidade e suscetibilidade dos estágios iniciais de vida dos crustáceos a patógenos e estressores ambientais [20]. Exemplo disto, é uma das principais vias de transmissão de vírus que afetam os camarões peneídeos, caracterizada pela contaminação de larvas a partir de progenitores infectados e pelo canibalismo [21].

Na Ásia, há poucas evidências de que as enfermidades virais contribuam para o declínio das populações de camarões de vida livre. Isto possivelmente porque há baixas densidades populacionais no meio natural e baixa ocorrência de fatores estressantes, que aumentariam a predisposição dos animais às enfermidades [14; 22]. Êxitos recentes no diagnóstico de enfermidades de organismos aquáticos – combinando as tecnologias moleculares, os métodos clássicos e a cooperação internacional – também têm promovido a obtenção de diagnósticos mais rápidos e precisos, facilitando o manejo de enfermidades no ambiente marinho [23].

Como exemplo da introdução de doença em populações naturais de camarões, pode-se citar a disseminação de IHHNV proveniente de fazendas marinhas do noroeste do México, que infectou estoques naturais do golfo da Califórnia, em fins da década de 80 e início dos anos 90 [11]. Isto agravou as consequências socioeconômicas desta epizootia, já que além de provocar perdas significativas no cultivo de *Litopenaeus stylirostris,* ocasionou um colapso da pesca da espécie no golfo de Califórnia [11; 12]. Além, disso, tais doenças podem afetar outros crustáceos de interesse econômico, como o lagostim *Procambarus clarkii,* cujas populações naturais e cultivadas na Louisiana foram infectadas por WSSV em 2007 [10].

Como surtos virais podem afetar a pesca comercial

- ***De forma direta:*** *pela ação dos patógenos sobre os camarões de vida livre.*
- ***De forma indireta:*** *pelo atraso no crescimento ou pelo aumento no risco de predação de camarões de vida livre.*

Para evitar a disseminação de doenças, países produtores têm restringido o transporte de camarões em suas terras. Por exemplo, Owens [24] percebeu que o estreito de Torres (localizado ao norte da Austrália) constitui em uma barreira zoogeográfica para as populações naturais de várias espécies de camarões e dos parasitos que os atacam. Em função disso, este autor recomendou limitar a movimentação de camarões através desta barreira, para "preservar o possível status de *Livre de Enfermidades* e a identidade genética das populações de camarões".

De forma similar, considerando que a situação das enfermidades nas populações de vida livre de camarões é incerta e que há zonas de “risco”, o governo da Austrália Ocidental elaborou uma “política nacional de translocação” para camarões vivos e outras espécies aquáticas [25]. Este documento limita a movimentação de camarões dentro do país e exige análises de risco e medidas de manejo nos pedidos de transferência.

Essa necessidade de controle das fronteiras e da movimentação dos camarões é resultado do aumento das transações comerciais mundiais nos últimos anos e, consequentemente, da possibilidade de introdução de doenças.

Doenças como as apresentadas aqui, que causam grandes impactos sobre países produtores de camarões da Ásia e das Américas, têm sido listadas pela OIE. Nesta lista, são relacionadas as doenças de notificação obrigatória, que ameaçam de forma severa os crustáceos oriundos de cultivos e do ambiente, com graves consequências para o comércio internacional e o trânsito de crustáceos infectados. Com o objetivo de reduzir a disseminação de tais doenças, a OIE divulga uma lista de enfermidades passíveis de disseminação por meio do trânsito e do comércio internacional de animais e de seus produtos, que por sua importância econômica, epidemiológica e/ou zoonótica, requerem notificação obrigatória às autoridades [4].

4) Doenças de notificação obrigatória que afetam camarões marinhos

1.2 Doenças de notificação obrigatória à Organização Mundial para a Saúde Animal (OIE)

Anualmente a OIE publica uma lista de Doenças de Notificação Obrigatória (DNO) para diferentes grupos animais. Com este monitoramento, tem-se um amplo mapa da ocorrência de surtos e da presença de doenças em diferentes partes do mundo. Este processo facilita a disseminação de informações, auxiliando na tomada de decisões para o trânsito animal internacional e nacional.

Além disso, as DNO causam prejuízos econômicos associados ao controle, erradicação e impactos nas transações comerciais internacionais. A alteração do status sanitário de um país devido à suspeita ou à presença de uma doença de notificação obrigatória pode comprometer as vendas externas para países ou grupos de mercados, causando também o enfraquecimento do comércio interno, aumento de desemprego e consequente escassez de renda [4].

No ano de 2017 foram relacionadas pela OIE como doenças de notificação obrigatória em crustáceos:

- Necrose Hepatopancreática Aguda (Acute Hepatopancreatic Necrosis Disease)
- Crayfish Plague (*Aphanomyces astaci*)
- Doença da Cabeça Amarela (Infection with Yellowhead Virus)
- Necrose Infecciosa Hipodermal e Hematopoiética (Infectious Hypodermal and Haematopoietic Necrosis)
- Mionecrose Infecciosa (Infectious Myonecrosis)
- Hepatopancreatite Necrosante (Necrotising Hepatopancreatitis)

- Síndrome de Taura (Taura Syndrome)
- Síndrome da Mancha Branca (White Spot Disease)
- Doença da Cauda Branca (White Tail Disease)

Algumas das doenças relacionadas já foram descritas no Brasil, como identificado na Tabela 1.

Tabela 1. Situação do Brasil em relação ao relato de doenças de notificação obrigatória a OIE, que afetam camarões marinhos. Dados atualizados para o período de janeiro a junho de 2016.

Doença	Situação segundo OIE	Animais de cultivo	Animais do ambiente
Doença da Cabeça Amarela (YHD)	Doença nunca reportada.	Não	Não
Hepatopancreatite Necrosante (NHP)	Sinais clínicos demostrados. Suspeita da presença da doença, mas não confirmada.	Sim	Sim
Mionecrose Infecciosa (IMN)	Sinais clínicos demostrados, doença presente.	Sim	Sim
Necrose Hepatopancreática Aguda (EMS ou AHPNS)	Doença nunca reportada.	Não	Não
Necrose infecciosa Hipodermal e Hematopoiética (IHHN)	Doença nunca reportada.	Não	Sim
Síndrome da Mancha Branca (WSD)	Sinais clínicos demostrados, doença presente.	Sim	Sim
Síndrome de Taura (TS)	Suspeita da presença da doença, mas não confirmada.	Sim	Sim

Dentre as DNO listadas na **Tabela 1**, cinco já foram relatadas no país e provocaram impactos importantes na carcinicultura, são elas: quatro doenças virais (Mionecrose Infecciosa, Necrose Infecciosa Hipodermal e Hematopoiética, Síndrome de Taura e Síndrome da Mancha Branca) e uma bacteriana (Hepatopancreatite Necrosante).

A seguir são descritas as doenças de notificação DNO.

Tabela 2. Descrição das Doenças de Notificação Obrigatória pela OIE, que afetam camarões marinhos (*L. vannamei* em especial).

Doença	Sigla	Reportada no Brasil pela primeira vez*	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
Doença da Cabeça Amarela	YHD	Nunca	Vírus YHV, genótipo I e, em alguns casos, genótipo GAV.	*P. monodon*, *L. vannamei*, *P. stylirostris*, *Palaemonetes pugio* e *Metapenaeus affinis*	Geralmente juvenis.	Doença é altamente contagiosa de transmissão horizontal (injeção do vírus, ingestão de tecidos infectados, imersão em água contendo extrato de tecidos filtrados ou coabitação com camarões infectados). Não há vetores. Porém, os mecanismos de transmissão ainda são desconhecidos.	Os sinais clínicos da doença aparecem entre 7 e 10 dias após a infecção e, após 3 a 5 dias de seu aparecimento causa 100% de mortalidade. Aumento no consumo de alimentos. • Queda súbita no apetite, parando de se alimentar 2-4 dias após o aparecimento dos sinais. • Os animais passam a nadar próximo a borda do viveiro, com mortalidades logo a seguir. • Coloração amarelada do cefalotórax e brânquias.	Até 100%	Não há tratamento. Adotar medidas de controle sanitário em casos de surtos, tais como abate sanitário, vazio sanitário e desinfecção de materiais, estruturas, equipamentos e veículos.	O vírus é inativado à 60°C por 15 minutos ou em cloro (0,03 mg/mL). Evitar estresse fisiológico, mudanças de pH e níveis de oxigênio dissolvido inadequados.	Em casos de surtos, as mortalidades ocorrem rapidamente. O vírus é capaz de sobreviver em água salgada por 72 horas.
Hepatopancreatite	NHP	2015	Bactéria intracelular	Camarões marinhos, mas	Principalmente em	Vertical e horizontal (canibalismo,	A infecção resulta em um quadro agudo,	Até 100%	Antibióticos (oxitetraciclina e florfenicol	Antissepsia de ovos e larvas.	A bactéria apresenta maior multiplicação em

Doença	Sigla	Reportada no Brasil pela primeira vez*	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
Necrosante			obrigatória, pleomórfica (forma variável), gram-negativa do tipo *Rickettsia* (Rickettsial-Like Organismo - RLO),	principalmente *L. vannamei*.	juvenis e adultos. Não são observados os sinais clínicos em pós-larvas.	ingestão de material contaminado ou coabitação e disseminação da bactéria pela coluna d'água).	normalmente catastrófico. • Proliferação bacteriana em células do hepatopâncreas. • Hepatopâncreas atrofiado e pálido • Letargia • Anorexia • Exoesqueleto amolecido • Corpo flácido • Cutícula frouxa • Brânquias e pleópodos escurecidos		50%) na ração, fornecida a cada 8 horas, por 10 dias. Resultados mais eficientes quando há diagnóstico precoce.		temperaturas superiores a 29°C e salinidades entre 20 e 38 ups.
Mionecrose Infecciosa	IMN	2006	Vírus IMNV	*L. vannamei*, *P. stylirostris* e *P. monodon*.	Adultos de todas as espécies suscetíveis e juvenis e subadultos de *L. vannamei*.	Horizontal (de animal para animal em um cultivo por canibalismo ou através da água, por exemplo) e vertical (para a progênie por via transovariana ou pela contaminação	• Aumento da taxa de conversão alimentar (redução da eficiência), que salta de 1,5:1 para valores iguais ou superiores a 4,0:1. • Opacidade dos músculos abdominais	40 a 80%	Não há tratamento. Adotar medidas de controle sanitário em casos de surtos, tais como abate sanitário, vazio sanitário e desinfecção de materiais, estruturas,		Os crustáceos cultivados em águas salinas, salobras e de baixa salinidade parecem ser mais severamente afetados pela doença.

Doença	Sigla	Reportada no Brasil pela primeira vez*	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
						dos ovos). Não há vetores.			equipamentos e veículos.		
Síndrome da Mortalidade e Precoce ou Síndrome Aguda da Necrose Hepatopancreática (AHPNS)	EMS ou AHPNS	Nunca	Bactéria do clado *Vibrio harveyi*, próximo à bactéria *Vibrio parahaemolyticus*.	*L. vannamei*, *P. monodon* e *F. chinensis*.	Principalmente na fase inicial de crescimento.	Vertical e horizontal (por via oral e através da água, devido a convivência dos animais no mesmo ambiente). Não há vetores.	• Morbidade e mortalidade em até 10 dias após o povoamento. • Despigmentação do hepatopâncreas, ficando pálido a branco, devido à perda de pigmento da cápsula de tecido conjuntivo. • Atrofia do hepatopâncreas. • Pontos ou manchas pretas no hepatopâncreas, podendo ser visualizados a olho nu. • Rigidez hepatopancreática, com o órgão não se desfazendo facilmente ao ser pressionado entre os dedos.	Até 100%	Não há tratamento. Adotar medidas de controle sanitário em casos de surtos, tais como abate sanitário, vazio sanitário e desinfecção de materiais, estruturas, equipamentos e veículos.	Desinfecção de materiais, equipamentos, veículos, água e antissepsia dos trabalhadores. Uso de água e alimentos livres de contaminação. Controle para que a água apresente boa qualidade física, química e biológica.	Doença emergente, recentemente (2010) descrita em camarões. A ingestão de algumas cepas da bactéria pelo consumo do crustáceo cru ou malcozido, pode causar gastroenterite aguda em humanos.

Doença	Sigla	Reportada no Brasil pela primeira vez*	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
							• Camarões moribundos ficam geralmente no fundo do viveiro.				
Necrose Infecciosa Hipodermal e Hematopoiética	IHHN	2009	Vírus IHHNV - Parvovirus	Camarões peneídeos, principalmente *P. monodon*, *L. vannamei* e *P. stylirostris*	Todos os estágios de desenvolvimento de *L. vannamei* (ovos, larvas, pós-larvas, juvenis e adultos)	Horizontal (por canibalismo ou pela água) e vertical (ao infectar os ovos). Animais sobreviventes à infecção tornam-se portadores, podendo transmitir a doença por toda a vida para seus descendentes.	Síndrome da Deformidade e do Nanismo (RDS) (nem sempre presente em infecções crônicas): • Deformidades cuticulares e abdominais. • Rostro deformado, curvado para a esquerda ou para a direita. • Antenas enrugadas e frágeis. • Desuniformidade acentuada do plantel, com muitos animais abaixo do tamanho esperado.	90%	Não há tratamento. Adotar medidas de controle sanitário em casos de surtos, tais como abate sanitário, vazio sanitário e desinfecção de materiais, estruturas, equipamentos e veículos.	Seleção de animais resistentes e a antissepsia dos ovos e náuplios. Usar produtos desinfetantes em materiais, equipamentos e veículos.	O vírus infecta e se replica em camarões em temperaturas de 24 e 32°C. Fazer a desinfecção de materiais, equipamentos e veículos, embora à 24°C as taxas de vírus circulantes no corpo dos animais tendam a ser maiores. Camarões infectados podem não apresentar sinais clínicos evidentes.
Síndrome da Mancha Branca (Doença das	WSD (WSBV ou WSSV)	2005	Vírus WSDV – complexo Baculovir	Crustáceos decápodes marinhos e de água salobra.	Todos os estágios de vida de camarões	Horizontal (pela água contaminada e pelo consumo de tecidos	• Progressiva queda do consumo de alimento pelos animais, até sua parada total.	Até 100%	Não há tratamento. Recomenda-se apenas a colocação de	Lavar e fazer antissepsia de ovos e náuplios com iodo ou	Enfermidade de avanço rápido e pode causar altas taxas de mortalidade a

Doença	Sigla	Reportada no Brasil pela primeira vez*	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
Manchas Brancas)			us, recentemente incluído na família Nimavirus.		marinhos ou de água salobra (ovos a reprodutores).	infectados por canibalismo ou predação) e vertical (pelo ovo). Não há vetores.	• Presença de animais moribundos, nadando próximo à superfície nas bordas dos viveiros. • Manchas circulares que variam de pequenos pontos a discos de vários milímetros, principalmente no cefalotórax. • Animais doentes também podem apresentar coloração avermelhada.		30 ppm de cloro na água de viveiros ou tanques infectados, para abater os camarões doentes, desinfetar o ambiente e adotar medidas de controle sanitário em casos de surtos.	formalina. Usar água a 60°C na limpeza de materiais (redes, tarrafas e comedouros, por exemplo). O ideal é que a água de cultivo esteja acima de 30°C. Evitar ou minimizar situações de estresse (ablação do pedúnculo ocular, desova, muda, mudanças de salinidade, temperatura ou pH da água e ainda durante *blooms* de plâncton).	partir do surgimento dos primeiros sinais clínicos. O vírus pode sobreviver fora do camarão por 30 dias à 30°C em água salgada (em condições de laboratório) e na água de viveiros por 3-4 dias.

Doença	Sigla	Reportada no Brasil pela primeira vez*	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
Síndrome de Taura	TS	1997	Vírus TSV pertencente à família Picornaviridae	*L. vannamei* e *P. stylirostris*. Entretanto, podem ser portadores do vírus, sem desenvolver sinais clínicos: *Penaeus setiferus*, *Litopenaeus schmitti*, *P. monodon*, *F. chinensis*, *Marsupenaeus japonicus*, *Penaeus aztecus*, *Penaeus duorarum*, *Fenneropenaeus indicus* e *Metapenaeus ensis*).	Pós-larvas, juvenis e adultos	Horizontal (canibalismo e através da água contaminada) e vertical (transmissão transovariana). São vetores da doença: aves piscívoras, insetos aquáticos e produtos congelados a base de camarões infectados pelo vírus da TS.	Há diversos sinais clínicos que variam de acordo com a fase de desenvolvimento da doença (aguda, transição ou crônica). Geralmente o diagnóstico ocorre na fase aguda, quando os sinais são mais evidentes (**Tabela 3**).	40-90%	Não há tratamento. Adotar medidas de controle sanitário em casos de surtos, tais como abate sanitário, vazio sanitário e desinfecção de materiais, estruturas, equipamentos e veículos.	A transmissão vertical não é experimentalmente confirmada. De qualquer forma, por precaução, recomenda-se realizar a antissepsia de ovos e larvas.	Surtos de TS são mais frequentes quando a salinidade está abaixo de 30 ups.

(*) Segundo dados da OIE (jan-jun 2016).

Tabela 3. Descrição dos sinais clínicos apresentados em cada uma das fases da Síndrome de Taura.

Fase da doença	Sinais Clínicos
Aguda	• Expansão de cromatóforos vermelhos, com urópodos e pleópodos vermelhos (por este motivo incialmente chamada de a "Doença da Cauda Vermelha"). • Necrose epitelial focal de apêndices (pleópodos e urópodos). • Amolecimento da cutícula. • Trato gastrintestinal vazio (anorexia). • Alteração comportamental, pois, os camarões se agrupam na superfície e nas bordas do viveiro. • Mortalidade durante a ecdise.
Transição	• Lesões cuticulares irregulares, melanizadas, multifocais e dispostas aleatoriamente. Os pontos de melanização correspondem a áreas onde há acúmulo de hemócitos em regiões de lesão cuticular. • Pode ou não haver amolecimento da cutícula e expansão de cromatóforos vermelhos. • Comportamento e ingestão de alimentos podem estar normais.
Crônica	• Não demonstram sinais óbvios da doença. • Camarões *L. vannamei* cronicamente infectados podem apresentar menor resistência a estressores ambientais normais, quando comparados aos animais saudáveis.

i) **Doenças virais**

Figura 2. MIONECROSE INFECCIOSA (IMN). Camarões com perda da transparência de alguns segmentos indicado pelas setas. Fonte: Amalia [26]

Figura 3. MIONECROSE INFECCIOSA (IMN). Camarões com diferentes níveis de necrose muscular, observada pela intensidade em que o abdome aparece na cor branco leitoso. Fonte: Yangtze [27]

Figura 4. NECROSE INFECCIOSA HIPODERMAL E HEMATOPOIÉTICA (IHHNV). Juvenis de *Litopenaeus vannamei* infectados por IHHNV e com a Síndrome da Deformidade e do Nanismo (RDS). Animal com anormalidade cuticular da porção final do abdome. Fonte: Sitto Vietnam [28]

Figura 5. NECROSE INFECCIOSA HIPODERMAL E HEMATOPOIÉTICA (IHHNV). Juvenis de *Litopenaeus vannamei* infectados por IHHNV e com a Síndrome da Deformidade e do Nanismo (RDS). Animal com deformidade no rostro. Fonte: Sitto Vietnam [28]

Figura 6. SÍNDROME DE TAURA (TS). Camarões *Litopenaeus vannamei* com urópodos e pleópodos vermelhos (acima) e um animal saudável (abaixo). Fonte: Gunawan [29].

Figura 7. SÍNDROME DE TAURA (TS). Camarões *Litopenaeus vannamei* com urópodos e pleópodos vermelhos. Fonte: OBP [30].

Figura 8. SÍNDROME DE TAURA (TS). Melanização na superfície do corpo de um camarão na fase crônica da TS. Fonte: Aquavietnam [31].

Figura 9. SÍNDROME DA MANCHA BRANCA (WSD). Camarão peneídeo com manchas brancas circulares no exoesqueleto. Fonte: Ciba [32].

Figura 10. SÍNDROME DA MANCHA BRANCA (WSD). Camarão peneídeo com manchas brancas circulares no exoesqueleto e cefalotórax soltando-se do corpo. Fonte: CGHP [33]

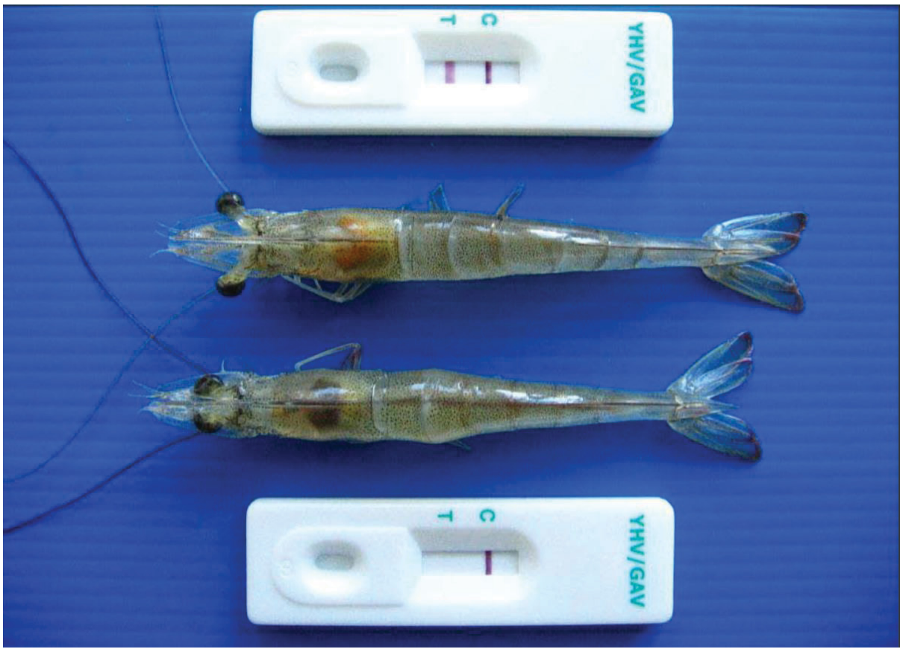

Figura 11. DOENÇA DA CABEÇA AMARELA (YHD). Teste rápido para YHV/GAV. É considerado positivo o teste que apresentar duas linhas roxas, como demonstrado pelo camarão *Litopenaeus vannamei* colocado na porção superior da imagem e que também apresenta hepatopâncreas e brânquias de coloração amarelada. Animal na porção inferior da imagem, com uma linha roxa no teste é considerado negativo para a doença. Fonte: Songsok *et al.* [34].

Figura 12. DOENÇA DA CABEÇA AMARELA (YHD). Camarões da espécie *Penaeus monodon* com cefalotórax e brânquias amarelados, nadando próximos as margens do viveiro. Fonte: Songsok *et al.* [34].

Figura 13. DOENÇA DA CABEÇA AMARELA (YHD). Mortalidade de camarões da espécie *Penaeus monodon*. Fonte: Songsok *et al.* [34].

ii) Doenças bacterianas

Figura 14. HEPATOPANCREATITE NECROSANTE (NHP). Camarão e hepatopâncreas (HS) saudáveis (acima). Camarão e hepatopâncreas (HD) infectados pelo vírus da hepatopancreatite necrosante (abaixo). Fonte: CRL [35].

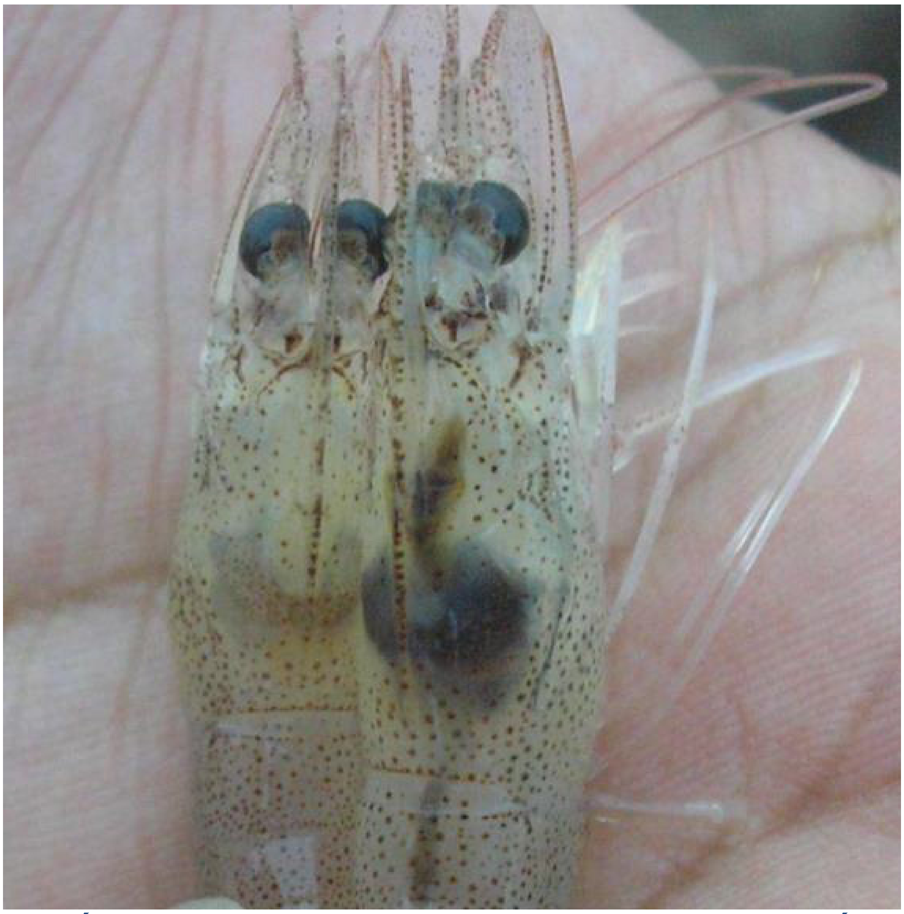

Figura 15. SÍNDROME DA MORTALIDADE PRECOCE (EMS) ou SÍNDROME AGUDA DA NECROSE HEPATOPANCREÁTICA (AHPNS). Juvenis de *Litopenaeus vannamei*. Animal doente com hepatopâncreas atrofiado e despigmentado (esquerda) e animal saudável com hepatopâncreas escuro e de tamanho normal (direita). Fonte: Lightner *et al.* [36].

1.3 Doenças de notificação obrigatória no Brasil

Segundo a Instrução Normativa MAPA nº 53, de 02 de julho de 2003 são doenças de notificação obrigatória as exóticas e as que ameaçam a economia do país, a saúde pública e o meio ambiente. Sendo que, o médico veterinário, proprietário ou qualquer outro cidadão que tenha conhecimento ou suspeita da ocorrência das doenças de notificação obrigatória deverá notificar imediatamente o Serviço Veterinário Oficial (SVO).

A Portaria n°19, de 04 de fevereiro de 2015 define a lista de doenças de notificação obrigatória de animais aquáticos ao SVO do Ministério da Agricultura, Pecuária e Abastecimento. Desta fazem parte 13 doenças que afetam o grupo: *L. vannamei, Penaeus* spp. e outras espécies da família Penaeidae, conforme apresentado na Tabela 4.

Tabela 4. Doenças de notificação obrigatória de animais aquáticos ao Serviço Veterinário Oficial (SVO) do Ministério da Agricultura, Pecuária e Abastecimento, conforme Portaria n°19, de 04/02/2015.

Doenças de Notificação Obrigatória no Brasil	Notificação obrigatória na OIE
Doença da Cabeça Amarela (YHD)	Sim
Necrose Hipodérmica Hematopoiética Infecciosa (IHHN)	Sim
Mionecrose Infecciosa (IMN)	Sim
Hepatopancreatite Necrosante (NHP)	Sim
Síndrome de Taura (TS)	Sim
Doença das Manchas Brancas ou Síndrome da Mancha Branca (WSD)	Sim
Síndrome da Mortalidade Precoce (EMS) ou Síndrome Aguda da Necrose Hepatopancreática (AHPNS)	Sim
Vírus da Necrose da Glândula Intestinal do tipo Baculovírus (BMN)	Não
Parvovirose Hepatopancreática (HPD)	Não
Infecção pelo Vírus Mourilyan (MVD)	Não
"Vírus Spawner - isolado de mortalidade" (SMV)	Não
Baculovírus do tipo *Penaeus monodon* (BVM)	Não
Baculovírus Penaei Tetraédrico (TBP)	Não

A seguir são descritas todas as doenças de notificação exclusivamente obrigatória no Brasil (Tabela 5).

Tabela 5. Doenças de notificação exclusivamente obrigatória no Brasil, conforme Portaria n°19, de 04/02/2015.

Doença	Sigla	Reportada no Brasil	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
Necrose da Glândula Intestinal do tipo Baculovírus (Enfermidade da Glândula do Intestino Médio Turvo ou Enfermidade do Fígado Turvo)	BMN	Nunca	Vírus Baculovírus entérico (PjNOB I)	*M. japonicus, P. monodon, F. chinensis, Penaeus semisulcatus, Penaeus plebejus.*	Infecta estágios larvais e pós-larvas (Gaspar, 2013),	Horizontal (pelos ovos). Não há vetores.	• Embranquecimento do hepatopâncreas, provocado pela necrose do epitélio tubular. • Larvas ficam inativas na superfície da água dos viveiros.	Alta mortalidade	Não há tratamento. Eliminar animais doentes por abate sanitário e desinfetar as estruturas de cultivo, bem como materiais, equipamentos e veículos.	Abate sanitário de animais infectados e desinfecção de equipamentos e tanques/viveiros. Lavagem dos ovos fertilizados em água salgada limpa. Separação dos ovos das fezes, lavagem e antissepsia com iodo e/ou formalina dos ovos e náuplios.	A fonte de infecção comprovada é por fêmeas ovadas capturadas em vida livre.
Parvovirose Hepatopancreática	HPD ou HPV	Sim	Parvovírus (Brevidensovirus) - *Penaeus monodon* densovirus (PmDNV)	Camarões peneídeos marinhos e de água salobra,	Pós-larvas, juvenis e adultos.	Horizontal (através da água contaminada e do canibalismo) e vertical	Sinais clínicos inespecíficos, podendo haver infecções concomitantes com outros vírus.	Mortalidade nas fases iniciais de vida do camarão e durante momentos de maior gasto energético	Não há	Adquirir animais de estoques livres da doença e não transportar animais	Não há dados que indiquem a associação da doença com fatores ambientais.

Doença	Sigla	Reportada no Brasil	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
				tanto em animais de vida livre, quanto animais de cultivo.		(ovos contaminados durante a desova, quando entram em contato com a água e material fecal de fêmeas contaminadas). Não há vetores.		(maturação gonadal, por exemplo).		infectados (em qualquer fase de vida) para áreas livres da doença.	
Infecção pelo vírus Mourilyan	MVD ou MoV	Nunca	Mourilyan vírus (não classificado taxonomicamente, possível membro de Bunyaviridae).	*P. monodon* e *M. japonicus*	Juvenis e adultos	Horizontal (ingestão de tecidos infectados). A via vertical não foi relatada, mas não pode ser descartada. Não há vetores.	Doença viral aguda. Não há dados consistentes sobre a observação de sinais clínicos, lesões macroscópicas, bem como da mortalidade crônica causados por esta doença em camarões.	Severa	Não há	Animais infectados não devem ser transportados para áreas sabidamente livres da doença.	O vírus sobrevive tanto em água salgada, quanto em água salobra.
"Vírus Spawner - Isolado de Mortalidade"	SMV	Nunca	DNA vírus não envelopado,	Camarões peneídeos,	Todas as fases de vida.	Horizontal (canibalismo) e vertical.	Sinais clínicos não são específicos, principalmente porque outros vírus	Próxima a 100%, principalmente de pós-larvas.	Não há	Eliminar reprodutores positivos para a presença do	O vírus é eliminado pelas fezes dos

Doença	Sigla	Reportada no Brasil	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
(Spawner-Isolated Mortality Virus)			semelhante a um Parvovírus.	principalmente *P. monodon* e *M. japonicus*		Não há vetores.	podem estar associados à doença. • Despigmentação • Vermelhidão de exoesqueleto e pleópodos. • Fezes avermelhadas • Letargia • Incrustações • Anorexia			vírus e medidas de controle sanitário (desinfecção e vazio sanitário, por exemplo).	animais infectados.
Baculovírus do tipo *Penaeus monodon* (Baculoviros e Esférica)	BVM	Sim	Vírus Baculovirus penaei Couch; tipo-A PvSNPV	*P. monodon, Penaeus merguiensis, Penaeus semisulcatus, Penaeus kerathurus, L. vannamei, Penaeus esculentus, Fennerop*	Todos os estágios de vida de *P. monodon*, embora larvas, pós-larvas e juvenis tenham se mostrado o mais suscetívei	Horizontal (através da água contaminada por fezes) e vertical (transvoariana). Não há vetores.	•Letargia •Anorexia •Coloração escura da superfície do corpo. •A infecção aguda causa perda de túbulos do hepatopâncreas e do epitélio intestinal e, como consequência, provoca disfunção destes órgãos	Altas mortalidades (acima de 90%) em pós-larvas e juvenis. Epizootias crônicas ou agudas, com presença de portadores (sem sinais clínicos aparentes).	Não há	Rigoroso controle sanitário durante a reprodução, larvicultura, berçário e engorda. Desinfecção de materiais e equipamentos com desinfetantes alcalinos.	Juvenis e adultos são mais resistentes à doença. Animais em situação de estresse e nutrição inadequada são mais suscetíveis. Pode haver co-ocorrência de Reolike Vírus (REO ou RLV).

Doença	Sigla	Reportada no Brasil	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
				enaeus penicillatus, *Penaeus plebejus*, *Metapenaeus ensis* e *Macrobrachium rosenbergii*.	s à doença.		seguida usualmente de infecção secundária por bactérias. • Alimentação e taxa de crescimento temporariamente reduzidos. • Aumento de incrustações na superfície do corpo.				
Baculovírus Penaei Tetraédrico (Baculoviros e Tetraédrica)	TBP	Sim	Baculovirus Penaei (PvSNPV - nucleopoliedrovirus de envoltura única de *L. vannamei*)	Espécies dos gêneros: *Penaeus*, *Litopenaeus*, *Farfantepenaeus*, *Fenneropenaeus*, *Melicertus*, *Trachypenaeus* e *Protrachypene*.	Todos os estágios de desenvolvimento, exceto ovos e náuplios.	Horizontal (ingestão de tecidos infectados-canibalismo, fezes ou detritos contaminados em água). Não há vetores.	Causa danos no hepatopâncreas e no epitélio intestinal dos camarões, com a destruição das células durante a liberação de novos vírus (ciclo lítico). A infecção pode não se desenvolver em camarões mais velhos que pós-larvas com nove dias (PL-9). Em camarões juvenis e adultos geralmente não há sinais	Alta mortalidade de larvas e pós-larvas de camarão. Epizootia leve ou aguda.	Não há	Higienização de materiais e equipamentos com desinfetantes, substâncias de baixo pH ou irradiação UV.	Mortalidade principalmente em cultivo em alta densidade, quando o desenvolvimento e a disseminação da doença são favorecidos.

Doença	Sigla	Reportada no Brasil	Etiologia	Espécies suscetíveis	Estágio suscetíveis	Transmissão	Sinais Clínicos	Mortalidade	Tratamento e Controle	Profilaxia	Particularidades
							clínicos externos que sejam úteis para o diagnóstico. Sinais clínicos perceptíveis: • Intestino médio esbranquiçado em estágios iniciais de larvas e pós-larvas, devido à presença de corpúsculos de inclusão viral e detritos celulares nas fezes. • Alimentação e taxas de crescimento podem estar temporariamente reduzidas. • A superfície das brânquias pode estar aumentada.				

5) Ferramentas para controle e prevenção de doenças na carcinicultura

1.4 Instrumentos legais vigentes no Brasil

Há em vigência no Brasil uma série de instrumentos legais que visam o controle sanitário e a prevenção de doenças na carcinicultura. Entretanto, tais documentos não são específicos para a produção integrada.

- INSTRUÇÃO NORMATIVA Nº 10 24/09/2015 - Prorroga o prazo para implantação da IN 4 MPA 04/02/2015 para 22 de setembro de 2017.
- INSTRUÇÃO NORMATIVA Nº 04 04/02/2015 - Institui o Programa Nacional de Sanidade de Animais Aquáticos de Cultivo – "Aquicultura com Sanidade", com a finalidade de promover a sustentabilidade dos sistemas de produção de animais aquáticos e a sanidade da matéria-prima obtida a partir dos cultivos nacionais.
- PORTARIA Nº 19 04/02/2015 - Define na forma do anexo à Portaria, a lista de doenças de notificação obrigatória de animais aquáticos ao Serviço Veterinário Oficial.
- INSTRUÇÃO NORMATIVA Nº 01 06/01/2015 - Altera a redação do art. 3º da IN 23, de 11 de setembro de 2014. Esta alteração modifica o início da vigência da IN 23 para 31 de agosto de 2015.
- INSTRUÇÃO NORMATIVA Nº 30 30/12/2014 - Institui o Programa Nacional de Monitoramento de Resistência a Antimicrobianos em Recursos Pesqueiros.
- INSTRUÇÃO NORMATIVA Nº 29 22/12/2014 - Institui o Programa de Controle Higiênico-Sanitário de embarcações pesqueiras e infraestrutura de desembarque de pescado.
- INSTRUÇÃO NORMATIVA Nº 26 12/11/2014 - Estabelece normas para a habilitação de profissionais privados para a realização de coleta e remessa de amostras oficiais para laboratórios da Rede Nacional de Laboratórios do Ministério da Pesca e Aquicultura – RENAQUA, e dá outras providências.
- INSTRUÇÃO NORMATIVA MPA Nº 23 11/06/2014 - Determina a obrigatoriedade da Guia de Trânsito Animal (GTA) para amparar o transporte de animais aquáticos e matérias-primas de animais aquáticos provenientes de estabelecimentos de aquicultura e estabelecimentos registrados em órgão oficial de inspeção e aprova o modelo de Boletim de Produção.
- INSTRUÇÃO NORMATIVA MPA Nº 22 11/09/2014 - Institui o Plano Nacional de Certificação Sanitária de Estabelecimentos de Aquicultura - Produtores de Formas Jovens de Animais Aquáticos – "Plano Forma Jovem Segura".
- INSTRUÇÃO NORMATIVA Nº 21 11/09/2014 - Estabelece critérios e procedimentos para o controle do trânsito de organismos aquáticos com fins de ornamentação e aquariofilia no território nacional.
- INSTRUÇÃO NORMATIVA Nº 17 11/08/2014 - Dispõe sobre a Licença de Empresa que Comercializa Organismos Aquáticos Vivos – ECOAV, no Registro Geral da Atividade Pesqueira – RGP.
- INSTRUÇÃO NORMATIVA Nº 4 30/05/2014 - Estabelece a Nota Fiscal do Pescado, proveniente da atividade de pesca ou de aquicultura.
- INSTRUÇÃO NORMATIVA Nº10 11/07/2013 - Institui a Rede de Colaboração em Epidemiologia Veterinária do Ministério da Pesca e Aquicultura - AquaEpi.

- INSTRUÇÃO NORMATIVA Nº 03 13/04/2012 - Institui a Rede Nacional de Laboratórios do Ministério da Pesca e Aquicultura - RENAQUA.
- INSTRUÇÃO NORMATIVA Nº 18 13/05/2008 - Estabelece os procedimentos para importação de animais aquáticos para fins ornamentais e destinados à comercialização.
- INSTRUÇÃO NORMATIVA Nº 53 02/07/2003 - Aprova o Regulamento Técnico do Programa Nacional de Sanidade de Animais Aquáticos.
- PORTARIA Nº 573, de 04/06/2003 - Institui o Programa Nacional de Sanidade de Animais Aquáticos.
- INSTRUÇÃO NORMATIVA Nº 39 04/11/1999 - Suspende temporariamente a entrada no território nacional de todas as espécies de crustáceos, seja de água doce ou salgada, em qualquer etapa do seu ciclo biológico, inclusive seus produtos frescos e congelados, assim como os cozidos, quando inteiro em suas carapaças ou partes delas, de qualquer procedência.

1.5 Programa Nacional de Sanidade de Animais Aquáticos (PNSAA)

O PNSAA, assim como os instrumentos legais citados, não é específico para a produção integrada, já que trata da sanidade de organismos aquáticos, independente de qual regime e qual sistema sejam cultivados.

Este programa foi instituído pelo Ministério da Agricultura, Pecuária e Abastecimento (MAPA), pela Portaria nº573, de 4 de junho de 2003 e posteriormente aprovado pela Instrução Normativa MAPA nº53, de 2 de julho de 2003. O programa prevê o controle sanitário de estabelecimentos de aquicultura que desenvolvem atividades relacionadas com a reprodução, o cultivo, a comercialização e outras atividades dos animais aquáticos, bem como impedir a introdução de doenças exóticas e controlar ou erradicar aquelas existentes no país.

O PNSAA também visa padronizar as ações profiláticas, métodos de diagnósticos e o saneamento dos estabelecimentos de aquicultura [37]. Contém ainda, informações sobre a caracterização e o cadastro de estabelecimentos de aquicultura, a notificação de suspeita ou ocorrência de doença, a fiscalização e o controle sanitário de estabelecimentos de aquicultura sobre a importação e exportação de animais, os procedimentos a serem adotados em um foco de doença e sobre o trânsito dos animais.

Na IN nº53 são apresentadas as competências do PNSAA, cabendo ao Departamento de Defesa Animal (DDA), da Secretaria de Defesa Agropecuária (DAS), do Ministério da Agricultura, Pecuária e Abastecimento (MAPA) sua normalização, coordenação e execução das atividades do programa. As ações de campo são de responsabilidade do Serviço/Seção/Setor de Sanidade Animal, da Delegacia Federal de Agricultura - DFA, e das Secretarias Estaduais de Agricultura ou de seus órgãos de defesa sanitária animal, por meio de convênios firmados com o MAPA.

São disposições do PNSAA:

- O DDA coordena medidas de prevenção das doenças de notificação obrigatória pela Portaria nº19, de 04 de fevereiro de 2015, para impedir a introdução de doenças exóticas e controlar ou erradicar as existentes no território nacional.
- Proíbe a entrada em todo o território nacional de animais aquáticos acometidos ou suspeitos de estarem acometidos de doenças, direta ou indiretamente transmissíveis, mesmo estando aparentemente hígidos (saudáveis) e, ainda, dos portadores de

parasitos externos ou internos, cuja disseminação possa constituir ameaça à população nacional de animais aquáticos.

- Proíbe o ingresso em território nacional de produtos, subprodutos, despojos de animais aquáticos, vísceras, alimento vivo ou qualquer outro material presumível veiculador dos agentes etiológicos de doenças contagiosas.
- Animais aquáticos procedentes de países onde haja doenças endêmicas de notificação obrigatória pela Portaria n°19, de 04 de fevereiro de 2015, só poderão ingressar no país mediante prévia autorização do DDA.

Todo o estabelecimento de aquicultura está sujeito à fiscalização do SVO e caso sejam identificados casos de inobservância das exigências da Instrução Normativa MAPA n°53, de 2 de julho de 2003, poderão ser adotadas as seguintes sanções:

- Suspensão da autorização para importação, exportação, comercialização e da emissão da Guia de Trânsito Animal (GTA).
- Interdição do estabelecimento.
- Aplicação de outras medidas sanitárias estabelecidas pelo DDA.

Na IN 53 são definidas as regras para a importação e exportação e o trânsito de animais, bem como as medidas a serem tomadas sempre que houver a notificação de suspeita de foco de doença de notificação obrigatória. Sendo estas:

1. **Visita ao foco:** visita inicial, coleta de material e remessa ao laboratório, com preenchimento de formulários próprios;
2. **Rastreamento epidemiológico:** baseado na obtenção de informações que levem o profissional médico veterinário a encontrar a origem do foco, visando definir sua extensão, evolução, difusão e consequências;
3. **Interdição da área focal e perifocal:** conforme a gravidade da doença, os estabelecimentos ou zonas de cultivo serão interditados, assim como as propriedades vizinhas e microbacias;
4. **Comunicação do foco:** o foco será comunicado ao SVO local e este comunicará ao estadual, por meio de formulário próprio, para a apreciação epidemiológica e tomada de decisão frente à gravidade requerida; a comunicação deverá ser imediata quando a suspeita for de doenças previstas no art. 8° da IN 53;
5. **Abate sanitário:** dependendo da doença, os animais existentes no estabelecimento ou zona de cultivo serão abatidos e o aproveitamento condicional será definido pelo SVO;
6. **Tratamento terapêutico:** nos casos em que for viável, irá se proceder o tratamento dos animais doentes;
7. **Desinfecção:** constatando-se a necessidade de desinfecção, será feita a despesca, com esvaziamento completo e desinfecção adequada, pelo período necessário ao extermínio do agente causador da doença, tomando-se todas as medidas necessárias para impedir que este agente chegue aos corpos d'água naturais;
8. **Acompanhamento do foco:** o estabelecimento ou zona de cultivo, bem como os demais estabelecimentos pertencentes à área perifocal e microbacia, deverão ser periodicamente visitados para monitorar à evolução da doença e à execução das medidas que foram recomendadas bem como à adoção de outras providências, visando o controle ou erradicação total da doença existente;
9. **Encerramento do foco:** uma vez constatada a inexistência de agentes patogênicos, bem como o tempo de despovoamento dos estabelecimentos (vazio sanitário) ou zona de

cultivo e o sucesso das desinfecções realizadas, o foco será encerrado e a interdição suspensa.

6) Benefícios da Produção Integrada para o controle e a prevenção de doenças na carcinicultura

Como foi visto neste capítulo, existem vários fatores que estão relacionados à sanidade de camarões. Dentre eles, pode-se destacar a incapacidade biológica do grupo em desenvolver memória imunológica e, associado a isto, a grande variedade de enfermidades infecciosas relatadas. Por estes motivos, enfermidades em camarões podem se disseminar com rapidez, principalmente em situações de estresse ambiental.

As doenças de notificação obrigatória, quando introduzida em um cultivo, geralmente resultam em perdas econômicas e restrições de mercado, já que na maioria dos casos não são tratáveis. Neste cenário, o controle e a prevenção de doenças na carcinicultura têm papel fundamental na redução de perdas e desperdícios por mortalidades ou desuniformidade dos camarões produzidos.

Para reduzir tais problemas, a produção deve ser sustentada por princípios fundamentais relacionados à qualidade ambiental, laboral e à gestão do processo produtivo. Entretanto, cada um dos princípios básicos da PI, apresentados no Capítulo I (Volume I) deste livro, pode promover a higidez dos camarões durante o cultivo, minimizando perdas, conforme apresentado na **Tabela 6**.

Tabela 6. Princípios fundamentais da Produção Integrada (PI) na carcinicultura e seus benefícios para a sanidade dos animais produzidos.

Princípios básicos	Descrição	Benefícios
1. Estabilidade ambiental	A PI deve assegurar a estabilização dos ecossistemas, isto é, garantir a menor perturbação possível desses recursos para que seu equilíbrio possa ser mantido.	Com o equilíbrio ambiental, o efeito imunossupressor da exposição a fatores estressantes para os camarões produzidos passa a ser menor e, consequentemente, a predisposição às doenças oportunistas é reduzida. Ao mesmo tempo, também são reduzidas as alterações na qualidade da água da área de produção e do entorno, bem como o desequilíbrio da cadeia trófica no entorno do cultivo, que poderiam facilitar o aparecimento de patógenos emergentes.
2. Redução de perdas e desperdícios	O regime de PI deve garantir a melhoria e o desenvolvimento contínuo do empreendimento, assegurar eficiência e eficácia do sistema de produção, reduzir perdas no processo produtivo e melhorar a sua gestão e ainda, tornar a organização altamente competitiva, com produtos em conformidade com as normas técnicas.	O aumento da eficiência e eficácia produtivas envolve a adequação às boas práticas de manejo e à nutrição equilibrada, por exemplo, resultado na produção de animais saudáveis e, consequentemente, menos suscetíveis a enfermidades.
3. Capacitação	A atualização e a capacitação técnica dos produtores e demais profissionais envolvidos com a PI devem ser continuas.	Os técnicos devem transmitir aos produtores conhecimento sobre educação ambiental, princípios da produção integrada e avanços nos processos das cadeias produtivas como pré e pós-colheita, com o intuito de obter e manter a certificação de qualidade dos produtos. Ao aprimorar o conhecimento dos produtores é possível não só enfatizar a importância de uma produção de camarões que atenda aos padrões de qualidade sanitária, mas também implementá-la.
4. Manejo Integrado	A aplicação de medidas de controle deve dispor das ferramentas mais avançadas disponíveis, como por exemplo, os métodos de prognóstico e os limiares cientificamente validados.	O uso de fertilizantes, pesticidas, antibióticos, entre outros, deve ser o último recurso, utilizado unicamente se as perdas forem economicamente inaceitáveis e não puderem ser impedidas por mecanismos reguladores naturais. Deste modo, os animais produzidos terão mínimo risco de contaminação química em seu organismo e, portanto, menor influência negativa destes compostos sobre parâmetros fisiológicos e imunológicos.
5. Diversidade biológica	A diversidade biológica, que inclui a diversidade genética das espécies e das comunidades biológicas, na área de produção e em seu entorno devem ser consideradas em um regime de PI.	Isso não significa, por exemplo, que não se possa utilizar espécies exóticas em um sistema da PI, mas que devem ser assegurados mecanismos para garantir que as espécies cultivadas não interfiram na diversidade biológica natural local ou regional. Havendo, em consequência desta interferência, intercâmbio de agentes patogênicos.
6. Excelência	A PI deve estimular a busca pela excelência, levando em consideração os parâmetros ecológicos, sociais e econômicos do sistema de produção e os requisitos estabelecidos para a certificação do processo.	Com a excelência na PI, haverá maior qualidade e inocuidade do produto final, do processo produtivo, de uso dos recursos naturais, de abate, de transporte dos produtos ao longo da cadeia produtiva e das condições de trabalho das pessoas envolvidas no processo.

Princípios básicos	Descrição	Benefícios
7. Rastreabilidade	A PI deve ser realizada e operada de forma holística, ou seja, as cadeias de produção e distribuição devem ser gerenciadas de maneira sistêmica, com o monitoramento, a caracterização e a rastreabilidade de todas as etapas que as envolvem (desde a produção até o consumidor final).	Dessa forma, quando ocorrer algum problema com lotes do produto, será possível identificar onde e porque esse problema ocorreu, viabilizando a sua correção.

Em suma, com a produção integrada pode-se reduzir problemas com doenças pela implantação das Boas Práticas de Manejo (BPM), redução da carga ambiental, arraçoamento correto e eficiente balanço nutricional da ração, monitoramento e preservação da área do entorno a propriedade, diminuindo a probabilidade de disseminação de doenças e garantindo a sustentabilidade da atividade. Em outras palavras, a ocorrência de doenças é ainda mais grave e elas são mais facilmente disseminadas quando os cultivos são realizados em alta densidade, deficiência na implantação das BPM, falta de rastreabilidade da cadeia produtiva, deficiência no manejo higiênico-sanitário com produção e lançamento de altas cargas de efluentes no ambiente, por exemplo.

Ao integrar o cultivo com o ambiente, melhorando sua qualidade, haverá um menor nível de estresse e, consequentemente, os camarões serão mais saudáveis e terão um sistema imune mais eficiente. Minimizando, assim, as perdas decorrentes de enfermidades.

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ANEXOS:
Normas das Revistas Científicas
(Instruções aos autores)

Anexo I: Normas da Revista "Reviews in Aquaculture"

REVIEWS IN Aquaculture

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CONTENTS

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We look forward to your submission.

2. AIMS AND SCOPE

The primary aim of *Reviews in Aquaculture* is to provide a forum of reviews on developments in aquaculture techniques, policies and planning. The Journal will publish fully peer-reviewed review articles, invited or otherwise, on major aspects pertaining to aquaculture, including: global, regional and/or national production and market trends; aquaculture practices and technological developments; aquaculture–environment interactions; indigenous and alien species in aquaculture; the biology and culture of aquaculturally important and emerging species; utilization of primary and secondary resources in aquaculture; developments in artificial propagation of individual species and/or groups; developments in feeds and feeding; genetics and aquaculture; health management in aquaculture; policy developments pertaining to aquaculture; aquaculture product quality and traceability; and socio-economics of aquaculture and impacts.

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(v) references, (iv) appendices, (v) tables (each table complete with title and footnotes), (vi) figure legends. Figures and supporting information should be submitted as separate files. Footnotes to the text are not allowed and any such material should be incorporated into the text as parenthetical matter.

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Articles must have a brief abstract that states in 250 words or fewer the purpose, basic procedures, main findings and principal conclusions of the study. The abstract should not contain abbreviations or references.

Five key words (for the purposes of indexing) should be supplied below the abstract in alphabetical order.

Text

The text should be organized into an introductory section, conveying the background and purpose of the paper, and then into sections identified with subheadings, as appropriate.

Acknowledgements

The source of financial grants and other funding must be acknowledged, including a frank declaration of the authors' industrial links and affiliations. The contribution of colleagues or institutions should also be acknowledged. Personal thanks and thanks to anonymous reviewers are not appropriate.

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The Harvard (author, date) system of referencing is used (examples are given below). In the text give the author's name followed by the year in parentheses: Smith (2000). If there are two authors use 'and': Smith and Jones (2001); but if cited within parentheses use '&': (Smith & Jones 2001). When reference is made to a work by three or more authors, the first name followed by *et al.* should be used: MacDonald *et al.* (2002). In the reference list, references should be listed in alphabetical order.

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Authors are responsible for the accuracy of the references.

Journal article

Utting SD (1986) A preliminary study on growth of *Crassostrea gigas* larvae and spat in relation to dietary protein. *Aquaculture* **56**: 123–135.

Online article not yet published in an issue

An online article that has not yet been published in an issue (therefore has no volume, issue or page numbers) can be cited by its Digital Object Identifier (DOI). The DOI will remain valid and allow an article to be tracked even after its allocation to an issue. Glencross BD (2009) Exploring the nutritional demand for essential fatty acids by aquaculture species. *Reviews in Aquaculture* doi: 10.1111/j.1753-5131.2009.01006.x

Book

Ringsven MK, Bond D (1996) *Aquaculture Systems in Thailand*, 2nd edn. Delmar Publishers, Albany, NY.

Chapter in a book

Chapman DW (1971) Production. In: Ricker WS (ed.) *Methods of the Assessment of Fish Production in Freshwater*, pp. 199–214. Blackwell Scientific Publications, Oxford.

Tables

Tables should be self-contained and complement, but not duplicate, information contained in the text. Number tables consecutively in the text in Arabic numerals. Type tables on a separate page with the legend above. Legends should be concise but comprehensive – the table, legend and footnotes must be understandable without reference to the text. Vertical lines should not be used to separate columns. Column headings should be brief, with units of measurement in parentheses; all abbreviations must be defined in footnotes. Footnote symbols: †, ‡, §, ¶, should be used (in that order) and *, **, *** should be reserved for *P*-values. Statistical measures such as SD or SEM should be identified in the headings.

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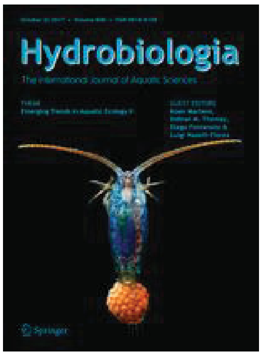

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Instructions for Authors

Hydrobiologia

GENERAL

Hydrobiologia publishes original articles in the fields of limnology and marine science that are of interest to a broad and international audience. The scope of Hydrobiologia comprises the biology of rivers, lakes, estuaries and oceans and includes palaeolimnology and −oceanology, taxonomy, parasitology, biogeography, and all aspects of theoretical and applied aquatic ecology, management and conservation, ecotoxicology, and pollution. Purely technological, chemical and physical research, and all biochemical and physiological work that, while using aquatic biota as test−objects, is unrelated to biological problems, fall outside the journal's scope.
THERE IS NO PAGE CHARGE, provided that manuscript length, and number and size of tables and figures are reasonable (see below). Long tables, species lists, and other protocols may be put on any web site and this can be indicated in the manuscript. Purely descriptive work, whether limnological, ecological or taxonomic, can only be considered if it is firmly embedded in a larger biological framework.

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CATEGORIES OF CONTRIBUTIONS

MANUSCRIPT SUBMISSION

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- Engel, S. & S. A. Nichols, 1994. Aquatic macrophytes growth in a turbid windswept lake. Journal of Freshwater Ecology 9: 97−109.
- Horne, D. J., A. Cohen & K. Martens, 2002. Biology, taxonomy and identification techniques. In Holmes, J. A. &A. Chivas (eds), The Ostracoda: Applications in Quaternary Research. American Geophysical Union, Washington DC: 6−36.
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- All tables are to be numbered using Arabic numerals.
- Tables should always be cited in text in consecutive numerical order.
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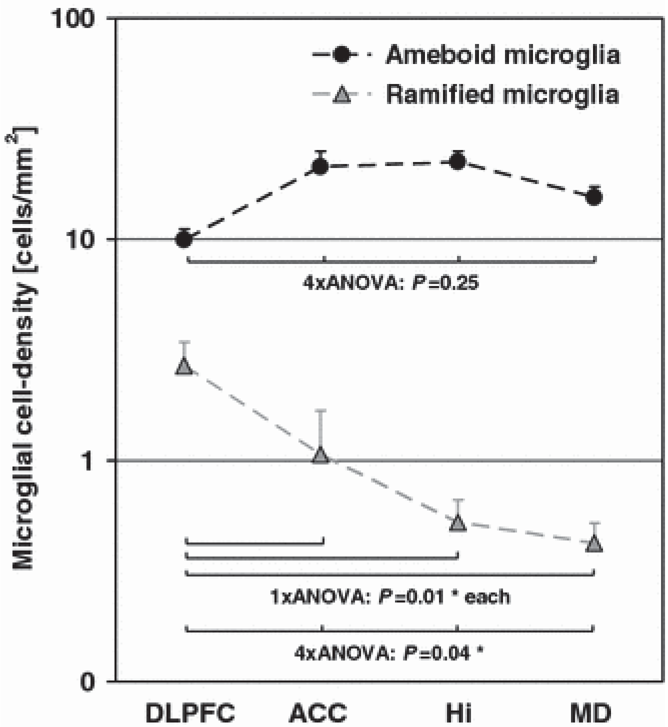

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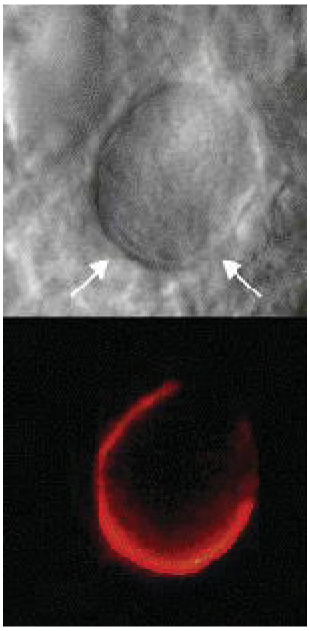

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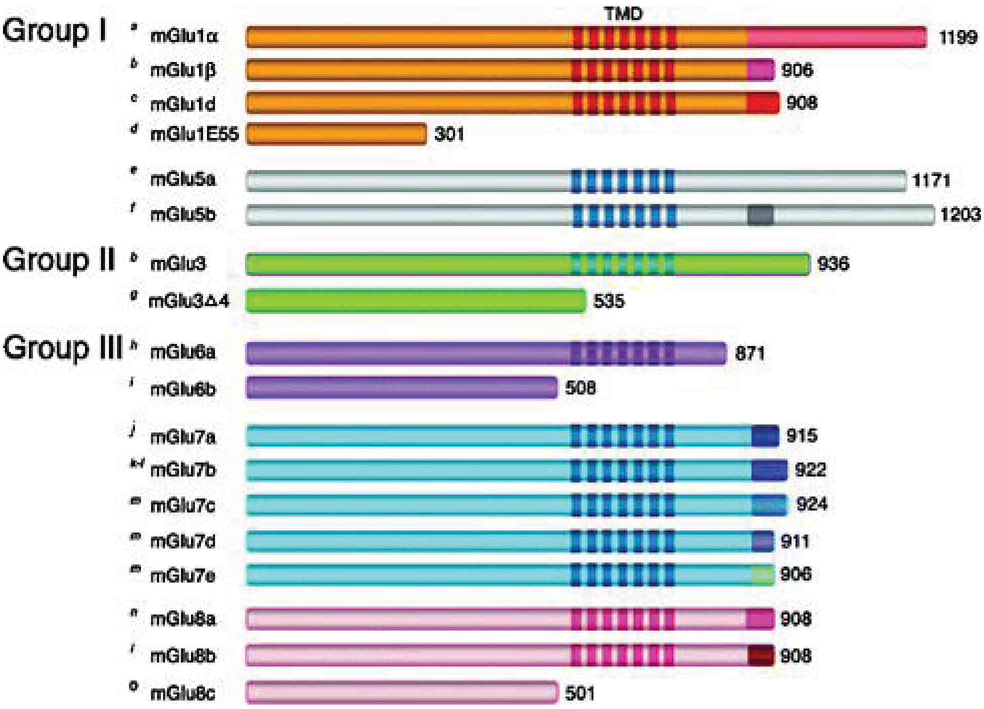

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