UNIVERSIDADE FEDERAL DO PARANÁ

GABRIELA BUSSI DE OLIVEIRA

SENCIÊNCIA EM *Penaeus vannamei* E ALTERNATIVAS PARA MITIGAÇÃO DE PONTOS CRÍTICOS DE BEM-ESTAR NA CARCINICULTURA

CURITIBA

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Dissertação apresentada ao Programa de Pós-Graduação em Ciências Veterinárias, Setor de Ciências Agrárias, Universidade Federal do Paraná, como requisito parcial à obtenção do título de Mestre em Ciências Veterinárias.

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Os membros da Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação CIÊNCIAS VETERINÁRIAS da Universidade Federal do Paraná foram convocados para realizar a arguição da dissertação de Mestrado de **GABRIELA BUSSI DE OLIVEIRA** intitulada: **Senciência em *Penaeus vannamei* e alternativas para mitigação de pontos críticos de bem-estar na carcinicultura**, sob orientação da Profa. Dra. CARLA FORTE MAIOLINO MOLENTO, que após terem inquirido a aluna e realizada a avaliação do trabalho, são de parecer pela sua APROVAÇÃO no rito de defesa.

A outorga do título de mestra está sujeita à homologação pelo colegiado, ao atendimento de todas as indicações e correções solicitadas pela banca e ao pleno atendimento das demandas regimentais do Programa de Pós-Graduação.

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“The question is not, Can they reason? Nor, Can they talk? But, Can they suffer?”

(Bentham, 1979)

RESUMO

O crescimento da indústria da carcinicultura em conjunto com o aumento dos estudos relacionados à senciência em crustáceos decápodes e à persistência de práticas desatualizadas e contrárias aos princípios de bem-estar no sistema de criação de camarões suscitam importantes questões éticas. Nesse contexto, o objetivo geral desta dissertação foi construir um panorama geral a respeito de questões relacionadas à senciência e ao bem-estar de camarões inseridos no sistema de produção, com particular ênfase na espécie *Penaeus vannamei*, a espécie mais criada mundialmente. Para isso, este trabalho foi dividido em cinco capítulos: (1) Introdução; (2) Brazilians' perception of shrimp sentience and welfare, capítulo baseado em respostas obtidas a partir de um questionário, com o objetivo de analisar a percepção de brasileiros acerca da senciência e bem-estar de camarões, a fim de correlacionar a frequência de respostas com possíveis padrões criados por fatores socioculturais, para então compreender se, e como, isso afeta o bem-estar dos camarões; (3) Como entender a distribuição da senciência no reino animal? Evidências científicas de senciência em invertebrados. Esse capítulo objetiva trazer para o idioma português a mais completa estrutura existente para avaliar a distribuição da senciência nos animais não humanos, incluindo uma contextualização para o cenário brasileiro e o exemplo de sua aplicação em dois táxons de invertebrados: os moluscos cefalópodes e os crustáceos decápodes, além de também analisar potenciais implicações de bem-estar das práticas atuais envolvendo tais animais; (4) Addressing Critical Welfare Concerns in White-Leg Shrimp (*Penaeus vannamei*): Current Challenges and Future Perspectives, com o objetivo de examinar as práticas de produção vigentes que prejudicam o bem-estar dos camarões da espécie *P. vannamei* na carcinicultura, bem como apontar soluções viáveis para reduzir esses impactos e melhorar o nível de bem-estar desses animais; e (5) Considerações finais sobre a dissertação como um todo. Nossos resultados reforçam a urgente necessidade da criação de medidas de proteção aos camarões, tanto no âmbito científico quanto no alimentício, pois a atual falta de regulamentações pode prejudicar seriamente o bem-estar de bilhões de seres possivelmente sencientes. Além disso, notamos que parte da população brasileira reconhece que camarões são seres sencientes e se importa com seu bem-estar, mas que fatores sociodemográficos podem exercer influência nessa percepção. Portanto, uma maior disseminação do conhecimento à população sobre as evidências de senciência nesse grupo taxonômico e sobre o sistema de carcinicultura pode servir como motor para a redefinição de práticas realizadas nos sistemas de produção com vistas a melhorar o bem-estar dos camarões.

Palavras-chave: camarão; crustáceo decápode; direito animal; invertebrados.

ABSTRACT

The growth of the shrimp farming industry, along with the increasing studies related to sentience in decapod crustaceans and the persistence of outdated and welfare-unfriendly practices in the shrimp aquaculture system, raise significant ethical questions. In this context, the general objective of this dissertation was to construct an overall panorama concerning issues related to the sentience and welfare of shrimp integrated into the production system, with a particular focus on the *Penaeus vannamei* species, the most widely farmed species globally. To achieve this, this work was divided into five chapters: (1) Introduction; (2) Brazilians' perception of shrimp sentience and welfare, a chapter based on responses obtained from a questionnaire, with the aim of analyzing the perception of Brazilians regarding the sentience and welfare of shrimp to correlate response frequencies with potential patterns created by sociocultural factors to understand whether, and how, this affects the welfare of shrimp; (3) How to understand the distribution of sentience in the animal kingdom? Scientific evidence of sentience in invertebrates. The objective of this chapter is to provide the most comprehensive framework in the Portuguese language for assessing the distribution of sentience in non-human animals, including a contextualization for the Brazilian scenario and the application example in two invertebrate taxa: cephalopod mollusks and decapod crustaceans, as well as analyzing potential welfare implications of current practices involving these animals; (4) Addressing Critical Welfare Concerns in White-Leg Shrimp (*Penaeus vannamei):* Current Challenges and Future Perspectives, with the aim of examining current production practices that harm the welfare of *P. vannamei* in shrimp farming, pointing out viable solutions to reduce these impacts and improve the level of welfare for these animals; and (5) Final considerations on the dissertation as a whole. Our results reinforce the urgent need for the creation of protective measures for shrimp, both in scientific and food-related contexts, as the current lack of regulations can seriously harm the welfare of potentially sentient beings. Additionally, we observed that a portion of the Brazilian population recognizes that shrimp are sentient beings and cares about their welfare, but sociodemographic factors may influence this perception. Therefore, greater dissemination of knowledge to the public about the evidence of sentience in this taxonomic group and about the shrimp farming system can serve as a driving force for redefining practices in production systems with the aim of improving the welfare of shrimp.

Keywords: animal rights; decapod crustacean; invertebrates; shrimp.

SUMÁRIO

1 INTRODUÇÃO

A senciência é caracterizada pela expressão de sentimentos positivos ou negativos e pela presença de algum nível de consciência, mesmo que de forma elementar (BROOM, 2007; BIRCH *et al*., 2021). A compreensão acerca da complexidade e da presença da senciência entre táxons ainda é um fator limitante para a criação de leis que englobem uma variedade de grupos (PROCTOR, 2012; BROWNING; BIRCH, 2022). Isto porque a descrição, mesmo que subjetiva, de experiências sensoriais e emocionais em animais não humanos é difícil em função dos desafios de sua mensuração (ROWE, 2018). Sendo assim, algumas espécies, principalmente de invertebrados, são frequentemente negligenciadas.

Os invertebrados correspondem a aproximadamente 98% de todas as espécies conhecidas (MATHER, 2019). Apesar disso, as considerações éticas em relação a eles são muitas vezes restritas a um papel instrumental (KELLERT, 1993; EISENHAUER *et al*., 2019; SÁNCHEZ-BAYO; WYCKHUYS, 2019; MIKHALEVICH; POWELL, 2020) e a falta de empatia é frequente (MARRIOTT; CASSADAY, 2022), o que torna a proteção legal a eles dirigida, em sua maioria, inexistente ou circunstancial (ROWE, 2018). Desta maneira, no processo de reconhecimento moral de invertebrados, a discussão acerca da senciência se torna crucial, principalmente quando se trata da proteção legal desses animais (POLLO; VITALE, 2019). Porém, para análise precisa da senciência, é necessária uma abordagem integrativa que combine conhecimento fisiológico e comportamental relevante para a realidade de cada espécie (CAVES *et al*., 2019).

Invertebrados da ordem dos decápodes são capturados durante atividades pesqueiras ou produzidos pela aquicultura em larga escala para suprir as demandas do mercado, de modo que bilhões desses crustáceos são mortos anualmente em prol do consumo humano (ELWOOD, 2012). O camarão *Penaeus vannamei* correspondeu a 51,7% do total de crustáceos produzidos na aquicultura em 2020 (FAO, 2022). Estima-se que mais de 167 bilhões de camarões desta espécie sejam produzidos anualmente, mas o número total de camarões criados anualmente é muito maior e chega a cerca de 440 bilhões (ALBALAT *et al*., 2022; WALDHORN; AUTRIC, 2022; PEDRAZZANI *et al*., 2023). Isso sem considerar o número de animais capturados pela pesca extrativista. Apesar disso, existem fortes evidências de senciência em crustáceos decápodes (BIRCH *et al*., 2021), que atendem a critérios neuroanatômicos, farmacológicos e comportamentais consistentes com uma resposta à dor (ROWE, 2018). Especificamente em relação aos camarões, existem poucas evidências em torno de sua senciência, o que decorre da escassez de estudos com esse animal (BIRCH *et al*.,

2021). Isso dificulta a criação de normas de proteção, o que culmina em nenhuma proibição de procedimentos extremamente aversivos, como a ablação do pedúnculo ocular em fêmeas reprodutoras (BIRCH *et al*., 2021; SAINZ-HERNÁNDEZ *et al*., 2008). No entanto, cientistas não recomendam a realização de incisões, de procedimentos mutiladores, a venda de crustáceos vivos e a utilização métodos de abate que possam causar extrema dor e sofrimento (BIRCH *et al*., 2021).

A captura de cefalópodes também é uma prática comum e crescente em comunidades costeiras (SAUER *et al*., 2019). Além disso, devido ao *Octopus vulgaris* ser visado como um candidato para a aquicultura marinha (GARCÍA *et al*., 2014), juntamente com o aumento na demanda por polvos, uma multinacional espanhola anunciou a inauguração da primeira criação comercial de polvos em larga escala (MARSHALL, 2021). Essa notícia provocou diversas críticas relacionadas à exploração e preocupações com o bem-estar desses animais (MARSHALL, 2021), em razão do crescente reconhecimento de sua senciência e de recomendações acerca da inviabilidade de uma fazenda com alto índice de bem-estar (BIRCH *et al*., 2021).

Com base no exposto, o objetivo principal deste estudo foi traçar um panorama abrangente das informações atuais sobre a senciência em invertebrados, com foco em moluscos cefalópodes e crustáceos decápodes, as condições de bem-estar na criação de *P. vannamei* e a percepção pública em relação ao bem-estar de camarões. Além da introdução e das considerações finais, que consistem no primeiro e último capítulo, respectivamente, este trabalho foi estruturado em três capítulos distintos, cada um com objetivos específicos e abordagens metodológicas particulares.

No capítulo 2, o objetivo foi investigar a percepção de brasileiros acerca da senciência e bem-estar de camarões, com vistas a discutir possíveis correlações na frequência de respostas sobre o tema, com possíveis padrões criados por fatores sociais e culturais, para então compreender se, e como, isso pode afetar o bem-estar dos camarões. O estudo foi elaborado com base nas respostas coletadas por meio de um questionário criado através do Google Forms. Analisar a percepção da população quanto a senciência e bem-estar de animais que se encontram em um maior foco atual de pesquisas torna-se importante visto que a forma como o público constrói níveis de importância e atratividade para determinados grupos taxonômicos, como sentimento de afeto, utilidade ou empatia, é diretamente proporcional ao comportamento direcionado a eles (SERPELL, 2004; MARRIOTT; CASSADAY, 2022). Assim, a discussão do artigo fundamentou-se nos elementos socioculturais que influenciam a

percepção relacionada à senciência do camarão, proporcionando uma ampla visão das dinâmicas que afetam o tratamento e consideração desses animais em nossa sociedade.

No capítulo 3, o objetivo foi trazer para o idioma português a mais abrangente estrutura disponível para avaliar a distribuição da senciência em animais não humanos. Isso incluiu uma parceria com autores do mais recente relatório sobre senciência em invertebrados, juntamente com a discussão em relação a dois grupos de invertebrados, uma breve contextualização para o cenário brasileiro e uma atualização com estudos recentes acerca do tema. Além disso, o capítulo explorou as possíveis implicações para o bem-estar animal decorrentes das práticas atuais envolvendo esses animais.

No capítulo 4, o objetivo foi identificar pontos críticos de bem-estar na carcinicultura do camarão *P. vannamei* em fazendas brasileiras e propor alternativas para complementar o sistema de produção existente e mitigar os impactos negativos aos animais. A cadeia produtiva do camarão engloba três principais etapas: (1) a larvicultura, onde ocorre a reprodução da espécie e a criação dos estágios larvais; (2) a engorda, que visa o crescimento do animal até o momento da despesca e do abate; (3) e o beneficiamento, onde ocorre o processamento do animal para posterior comercialização (CAMARA *et al*., 2011). Com o foco nas implicações ao bem-estar dos animais, as etapas da larvicultura e engorda foram abordadas no presente trabalho. Para a construção do estudo, foram realizadas visitas a fazendas no nordeste brasileiro. A criação de camarões para alimentação não dispõe de normas padrões, focadas no bem-estar dos animais; portanto, existe uma necessidade urgente de estabelecer novas normas para o transporte, abate e criação desses crustáceos decápodes mantidos por seres humanos (EUROGROUP FOR ANIMALS, 2021), visto as atuais informações sobre senciência no grupo (BIRCH *et al*., 2021).

No capítulo 5 encontram-se as considerações finais sobre os resultados encontrados, levando em consideração uma análise integrada dos capítulos 2, 3 e 4.

2 BRAZILIANS' PERCEPTION OF SHRIMP SENTIENCE AND WELFARE

ABSTRACT

With the increase in research aimed at improving the welfare of animals raised in production systems and the recognition of sentience in decapod crustaceans, the welfare of shrimp has become a cause for concern. In shrimp farming, practices contrary to the principles of animal welfare are used and largely unknown to the consuming public. This study aimed to assess the views of Brazilians on the importance of incremental animal welfare improvements in shrimp farming, considering the social and cultural aspects of the respondents. To this end, 300 adult Brazilian participants answered questions on welfare, sentience, and eyestalk ablation of shrimp. Among the respondents, 75.7% expressed concern about the welfare of shrimp, believing that they can experience fear (63.0%), pain (84.0%), and pleasure (47.7%). The latter finding suggests a relative reluctance to recognize positive feelings in shrimp. Regarding eyestalk ablation, 81.7% of respondents were unaware of the procedure, but after a brief explanation, 81.3% considered it unacceptable, with 84.0% believing that shrimps suffer from the practice. Most respondents associated terms such as "painful, cruel, suffering, mercantilist, disrespectful, and mutilating" with the practice of ablation. Furthermore, by using Pearson's chi-square test, it was observed that gender, age, region, education, socio-economic status, profession, and frequency of consumption may be related to the respondents' opinions about shrimp welfare and their perception of shrimp sentience. Therefore, by recognizing that public concern drives changes in production methods, increasing knowledge about shrimp sentience and farming practices can help advance socially acceptable methods.

Keywords: animal welfare; aquaculture; eyestalk ablation; shrimp farming; questionnaire

2.1 INTRODUCTION

Animal ethics and the recognition of animal rights are constantly evolving. However, despite all the advances achieved, the intrinsic tendency of human beings to pay relatively more attention to species considered popular, i.e., mostly mammals, tends to marginalize 98% of the existing fauna on the planet (MATHER, 2019). Invertebrate animals, despite their behavioral, cognitive and evolutionary diversity, are often grouped into a single category and often excluded from animal welfare considerations, so that ethical considerations towards them are often restricted to an instrumental role, connected to ecological factors (EISENHAUER *et al*., 2019; SÁNCHEZ-BAYO; WYCKHUYS, 2019; MIKHALEVICH; POWELL, 2020). Thus, species more closely related to us attract sympathy and, on the other hand, phylogenetically more distant animals, such as invertebrates, are neglected (BROOM, 2013; HORVATH *et al*., 2013). This bias persists due to factors such as lack of public knowledge and little attention from public policy makers, and reflects the scarce scientific research dedicated to the sentience of invertebrates (HORVATH *et al*., 2013; MATHER, 2019). So, the way the public builds levels of importance and attractiveness to certain taxonomic groups of animals, such as feelings of affection or usefulness, is directly proportional to the behavior intended for them (SERPELL, 2004). In the case of shrimp, the public relationship with them is commonly instrumental, in which the animals have no intrinsic value (KELLERT, 1993; DEPLAZES-ZEMP, 2023); thus, issues of cognitive dissonance, when there are inconsistencies between a person's beliefs and actions (FESTINGER, 1962), as well as those related to the meat paradox, a term that reflects a person’s moral conflict between craving animal meat and having ethical concerns for animal welfare (LOUGHNAN *et al*., 2010), tend to become even less evident than in the case of vertebrates used for food production.

Historically, issues related to shrimp welfare have received little attention due to disregard for the possible sentience of decapod crustaceans (SHERWIN, 2001). However, studies have shown that several species of decapod crustaceans exhibit neuroanatomical, pharmacological, and behavioral criteria consistent with a response to pain (ROWE, 2018). With this in mind, making incisions, mutilations and selling live crustaceans, as well as slaughter methods associated with extreme pain to the animals are not recommended. However, such practices are still carried out, especially in countries without legislation aimed at protecting invertebrate animals (BIRCH *et al*., 2021). Thus, aversive and invasive practices remain in systematic use in shrimp farming. Ocular ablation, a procedure technically referred to as eyestalk ablation,

consists of extirpation of the ocular peduncle of shrimp, removing one or both eyes and affecting an important part of the animal's neuroendocrine complex, the x-organ/sinus gland complex (LIMA *et al*., 2015). The practice aims to induce ovarian maturation and thus increase the frequency of spawning, but by removing a region of important endocrine function, the procedure has side effects and causes several physiological and morphological changes in the animal, and causes an increase in the mortality rate (SAINZ-HERNÁNDEZ *et al*., 2008). As it is an invasive procedure, it causes pain of an intensity and duration that have not yet been adequately studied, in addition to partial blindness, if one eye is removed, or total blindness, if both eyes are. More recent studies have proposed that eyestalk ablation offers no production benefits (MENEZES *et al*., 2019; ZACARIAS *et al*., 2019).

According to the 2022 edition of the SOFIA Report (The State of World Fisheries and Aquaculture), the production of the white-leg shrimp *Penaeus vannamei* for human consumption reached a level of 5.8 million tonnes, equivalent to 51.7% of the total crustaceans produced in aquaculture in 2020. Thus, *P. vannamei* was the most produced species in world aquaculture as measured in total live weight (FAO, 2022). As the prioritization of welfare issues refers to each individual animal, and to put it into perspective, it's estimated that over 400 billion shrimp are farmed worldwide annually (PEDRAZZANI *et al*., 2023).

In view of the above, understanding the current ethical consideration of the human population in relation to shrimp, and their knowledge of animal sentience, seems fundamental to taking the next steps in improving the welfare of shrimp. The present work aimed to study the perception of Brazilians regarding the sentience and rights of shrimp used for human consumption, seeking social and cultural patterns that may affect the welfare of farmed shrimp. Our hypothesis was that the perception of shrimp sentience is generally low, leading to a lack of recognition of their rights. We also expected to find some variation in perception based on respondents' sociodemographic variables and frequency of consumption.

2.2 MATERIALS AND METHODS

2.2.1 Ethical approval

This research was approved by the Human Research Ethics Committee of the Health Sciences Sector of the Federal University of Paraná, Brazil, registered under number 5.389.533/2022 and with CAAE number 55445522.6.0000.0102.

2.2.2 Questionnaire and respondents

Brazilians over 18 years of age were invited to participate in the survey entitled “Analysis of popular perception of shrimp sentience and welfare” during the period from March 19, 2022, to December 7, 2022. In the invitations, there was introductory information about the research, the anonymity of participants and the voluntary nature of participation. The questionnaire, in "Google Forms", was made available by email, Instagram, WhatsApp, LinkedIn and Facebook. The questionnaire was divided into two sections and composed of a total of 16 open and closed questions. The first section (questions 1 to 7) consisted of demographic questions covering gender, age, region of birth, education, socioeconomic status, religion and professions (Table 1). The latter factor (professions) was organized by areas of knowledge recognized by the Brazilian National Council for Scientific and Technological Development (CNPq), e.g., human sciences, applied social sciences, agricultural sciences, among others, besides students and teachers/professors, who didn't specify their field of expertise enough to be categorized into any of the aforementioned areas, and “others” (professions like traders, service providers, military, self-employed, housewives, retirees and entrepreneurs). The second section (questions 8 to 16) explored opinions on the sentience of shrimp and their welfare in the face of current production practices. In this way, questions were asked about the ability of shrimp to feel hunger, pain, fear, pleasure or suffering, whether their welfare matters to the respondent, the frequency with which the respondent consumes shrimp, whether they have heard of the practice of eyestalk ablation in breeding females and, after a brief contextualization, if the respondent considers this practice acceptable.

2.2.3 Analysis of answers to closed questions

Closed responses were analyzed and graphs that express the percentage of each response (Figure 1A, Figures 3A1, 3B1, 3C1 and Figures 5A, 5B, 5C) were made. In addition, to observe possible associations between variables of gender, age, region of birth, level of education, socioeconomic status, religion, profession and consumption patterns with different answers (yes, no or I don't know) to several questions, the Pearson's chi-squared test was performed using the software IBM SPSS Statistics, considering 95% confidence. A post hoc analysis was then conducted for significant variables, based on adjusted standardized residuals, with the Bonferroni correction. The questions were: "In your opinion, does the

welfare of shrimp matter?", "In your perception, shrimp are capable of feeling negative emotions, such as fear?", "In your perception, shrimp are capable of feeling positive emotions, such as pleasure?", "In your perception, can shrimp feel pain?", "Do you consider the practice of eyestalk ablation in shrimp acceptable?", "Do you think that shrimp suffer from the production system that performs this procedure?". Categories with a representation of less than 5% were merged with other ones or excluded. One answer was removed from the gender variable, because only one participant preferred not to inform their gender. Regarding age, the categories 55-64, 65-74, and ≥75 were grouped for the chi-squared test, forming the category "≥55". The North and Midwest regions were also grouped. The elementary school category was grouped with high school, forming "up to high school". Regarding socioeconomic status, the categories "more than 20" and "from 10 to 20" were merged, forming the new category "more than 10". In the professional field, the categories of humanities and applied social sciences were merged, as well as the categories of biological sciences and health sciences. The category "1 or more times a week", related to consumption frequency, was merged with "at least two times a month". Graphs (Figures 2, 4 and 7) were created using the relative frequency of the variables that showed significance in the statistical analysis, resulting in association between some of the abovementioned sociodemographic and consumption variables and the questions regarding welfare and sentience. The p-values from the chi-squared test were shown in Tables 2, 3 and 4.

2.2.4 Categorization of answers to open questions

The answers to open questions were analyzed in two different ways. Questions about the reasons why the welfare of shrimp matters (or not) to respondents were allocated into categories according to the answers obtained descriptively. The same was done for questions related to sentience, such as situations in which the animal may experience fear, pleasure or pain. The frequency of these categorized responses is expressed in Figures 1B, 1C and 3A2, 3B2 and 3C2. The only answer that followed a different pattern of analysis was the one about why the respondents considered the eyestalk ablation procedure in shrimp farming to be acceptable or unacceptable. For this question, the answers obtained were summarized in keywords and displayed in a cloud of terms (Figure 6). The term mercantilist was used in the word cloud to categorize responses that justified considering ablation unacceptable because it is a practice that prioritizes profit and production maximization at the expense of animal welfare.

2.3 RESULTS

2.3.1 Demography

The survey was completed with a total of 300 respondents, as shown in Table 1, with a predominance of females (73.7%) and from the southern region of Brazil (56.7%). Among the respondents, the largest proportions were between 25 and 34 years old (36.0%) or between 18 and 24 years old (33.7%). Regarding the level of education, there was a predominance of people with complete or incomplete higher education (52.7%) and postgraduate degrees (35.7%). The dominant socioeconomic condition was one to two minimum wages (20.7%), followed by 3 to 5 (16.3%), 5 to 10 (15.7%) and 14.3% of respondents without income. The religions most followed by respondents were Catholic (28.3%) and Evangelical (12.0%), with 14.7% being atheists. Undergraduate and postgraduate students without a specified area, i.e., students that didn't fit into any of the other areas, were the majority (30.7%) of the respondents, followed by professionals in the field of agricultural sciences (13.7%), by varied descriptions grouped in a category called "others" (traders, service providers, military, self-employed, housewives, retirees and entrepreneurs) which represented 13.3%, followed by professionals from the applied social sciences field (10.7%). More than a third (39.7%) of the respondents stated that they never consume shrimp, while 20.7% of them reported that they consume it at least once a year. Among participants who never consume shrimp, 41.8% gave ethical reasons, 22.1% reported personal taste, 12.3% declared themselves vegan/vegetarian and 11.5% addressed the cost. Other points also mentioned were allergy (7.4%), health (2.5%), religion (1.6%) and lack of opportunity (0.8%).

Table 1 - Demographic information of the 300 respondents who participated in the survey on shrimp sentience and welfare, from March to December 2022; IBGE - Brazilian Institute of Geography and Statistics.

Variables	Levels	Number of respondents	Percentage (%)	IBGE (%)
Gender;	Female	221	73.7	51.1
IBGE, 2021	Male	78	26.0	48.9
	Rather not answer	1	0.3	-
Age;	18-24	101	33.7	14.9
IBGE, 2022a, (First IBGE	25-34	108	36.0	15.9
category includes 15-24	35-44	43	14.3	15.5
years)	45-54	25	8.3	12.6
	55-64	18	6.0	10.1
	65-74	2	0.7	6.4
	≥75	3	1.0	4.1
Region;	South	170	56.7	14.8
IBGE, 2022b	Southeast	82	27.3	42.0
	Northeast	30	10.0	26.7
	North	11	3.7	8.6
	Midwest	7	2.3	7.9

Level of education; IBGE, 2019 (≥25 years)	Postgraduate	107	35.7	-
	University education	158	52.7	17.4
	High School	32	10.7	27.4
	Elementary School	3	1.0	46.6
Socioeconomic condition in minimum wages; IBGE, 2010 (by domicile)	No income	43	14.3	4.4
	Up to 1	25	8.3	4.2
	From 1 to 2	62	20.7	10.5
	From 2 to 3	35	11.7	21.5
	From 3 to 5	49	16.3	34.3
	From 5 to 10	47	15.7	15.5
	From 10 to 20	29	9.7	6.4
	More than 20	10	3.3	3.4
Religion; IBGE, 2010	Catholic	85	28.3	64.8
	Atheism	44	14.7	-
	I prefer not to inform	39	13.0	-
	Evangelical	36	12.0	22.1
	Spiritism	31	10.3	2.0
	None	21	7.0	8.0
	Spiritualist	18	6.0	0.03
	Others	26	8.7	-
Profession (occupation area)	Students	92	30.7	-
	Agricultural Science	41	13.7	-
	Applied Social Sciences	32	10.7	-
	Teachers/ Professors	25	8.3	-
	Exact Sciences and Engineering	19	6.3	-
	Biological Sciences	16	5.3	-
	Linguistics, Letters and Arts	15	5.0	-
	Health Sciences	14	4.7	-
	Human Sciences	6	2.0	-
	Others	40	13.3	-
Consumption frequency	1 or more times a week	4	1.3	-
	At least 2 times a month	11	3.7	-
	At least 1 time a month	28	9.3	-
	At least once every 3 months	33	11.0	-
	At least once every 6 months	43	14.3	-
	At least 1 time a year	62	20.7	-
	Never	119	39.7	-

2.3.2 Perceptions of shrimp welfare

In the question “Does the shrimp welfare matter to you?”, 75.7% of the population answered yes, while 18.3% said they did not know and 6.0% said they did not care (Figure 1). Almost half of the 227 (48.0%) respondents who claimed to care about the welfare of shrimp were motivated by thinking that the welfare of every living being matters, even for animals without signs of sentience. Another reported motivation was that the welfare of sentient animals matters (22.4%), therefore, it is not right to cause suffering of any kind to animals that have evidence of sentience. A more instrumentalist view was observed in respondents who claimed to be concerned with shrimp welfare because shrimp play an important ecological role (11.8%) or because welfare is considered essential to ensure good production rates and a quality product at the consumer’s table (13.4%). The category defined as “others” included people who cited the “benefit of the doubt” (2.8%); factors such as empathy (0.8%) and ethics (0.8%) were also cited by some respondents.

Among the 18 participants who said they did not care about shrimp welfare, 30.0% said they had never thought about the topic. In addition, lack of knowledge (30.0%), whether about the general characteristics of shrimp life, their biological function, production conditions or the meaning and applicability of welfare measures in shrimp farming, served as contributing factors to the normalization of indifference toward the welfare of shrimp. Spatial distance, with little or no daily contact with the animal (15.0%) was also cited. Other factors, such as speciesism (15.0%), may be linked to some justifications listed by respondents in the free-text field, such as: “It is not an animal that I sympathize with”, “Despite being a vegan, I confess that I only care about the well-being of more complex animals (in general, phylum cordata). I don't eat shrimp to avoid the suffering of other species” and “...I've never considered the welfare of a shrimp and, thinking about it, I don't think it's something I really care about”. Finally, the “food chain” was also mentioned in 10.0% of the responses, with phrases such as “...I believe that shrimp are part of a very comprehensive food chain where they feed on small animals and can be preyed on by other species, among them and disproportionately by man himself” and “They are animals with a very low level of understanding and intellectuality, at a low level in the food chain, and their role is consumption by other species”.

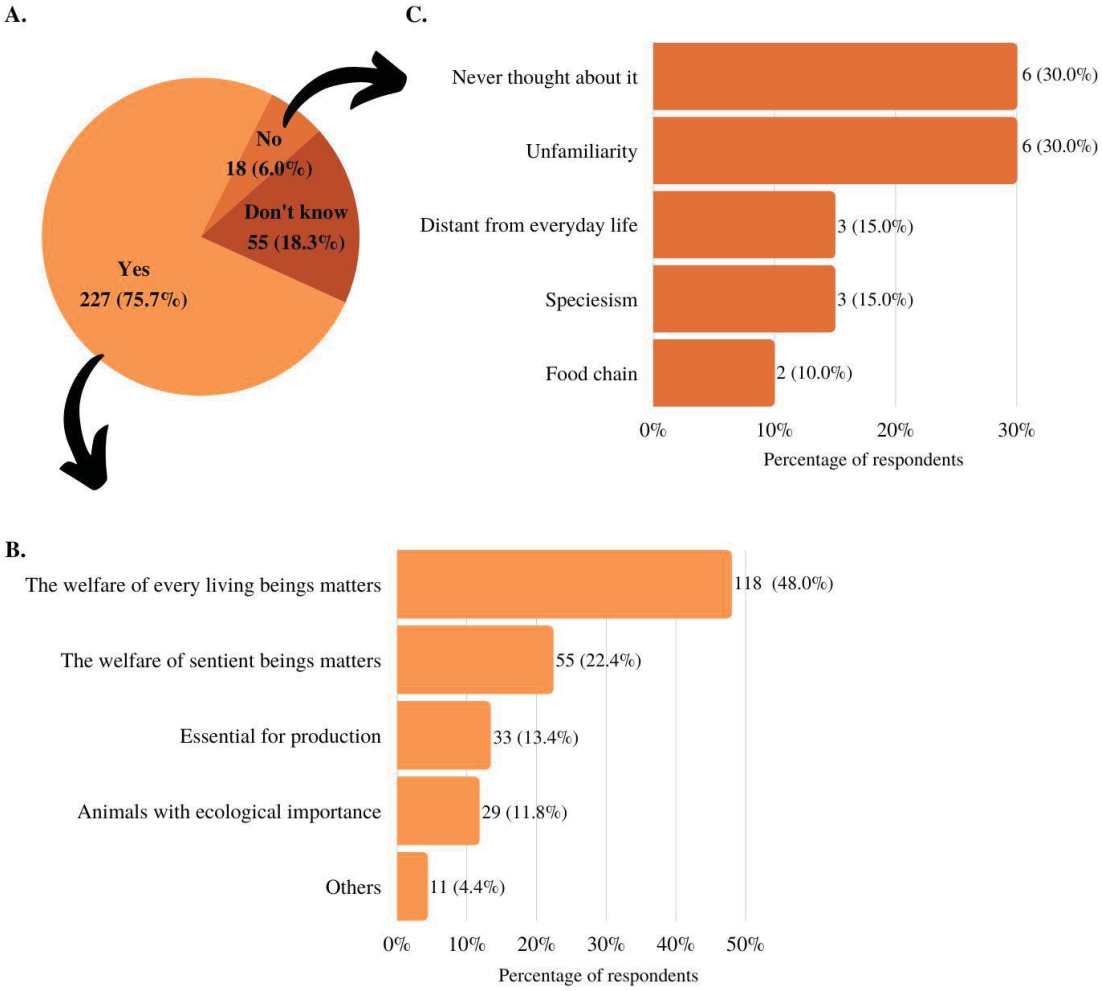

Figure 1 – A. "Does the shrimp welfare matter to you?"; B. percentage of respondents by categories created from the motivation of people who care about the shrimp welfare; C. percentage of respondents by categories created from the motivation of people who said they did not care about the shrimp welfare; responses obtained by 300 respondents residing in Brazil and over 18 years old, from March to December 2022.

It was observed that gender and area of professional activity significantly affected the opinion of respondents about the importance of shrimp welfare (Table 2). With the post hoc analysis, we observed where the main specific differences lay between the categories, and there was significance for both genders for the "don't know" response, as well as for respondents who work in agricultural sciences, for the "yes" response.

Table 2 - "Does the shrimp welfare matter to you?"; 300 respondents residing in Brazil, from March to December 2022; p-values (chi-squared) according to Pearson's chi-squared test.

Variables	Levels	Yes	No	Don't know	P-value (χ^2)
Gender	Female	158 (52.8%)	11 (3.7%)	52 (17.4%)	<0.001 (15.5)*
	Male	68 (22.7%)	7 (2.3%)	3 (1.0%)	
Age	18-24	72 (24.0%)	6 (2.0%)	23 (7.7%)	
	25-34	81 (27.0%)	10 (3.3%)	17 (5.7%)	
	35-44	36 (12.0%)	1 (0.3%)	6 (2.0%)	0.517 (7.19)
	45-54	19 (6.3%)	1 (0.3%)	5 (1.7%)	
	≥55	19 (6.4%)	0 (0.0%)	4 (1.3%)	

Region	South	123 (41.0%)	13 (4.3%)	34 (11.3%)	0.177 (8.94)
	Southeast	60 (20.0%)	5 (1.7%)	17 (5.7%)	
	Northeast	27 (9.0%)	0 (0.0%)	3 (1.0%)	
	North and Midwest	17 (5.7%)	0 (0.0%)	1 (0.3%)	
Level of education	Postgraduate	84 (28.0%)	5 (1.7%)	18 (6.0%)	0.688 (2.26)
	University education	117 (39.0%)	12 (4.0%)	29 (9.7%)	
	Up to High School	26 (8.7%)	1 (0.3%)	8 (2.6%)	
Socioeconomic condition in minimum wages	No income	35 (11.7%)	1 (0.3%)	7 (2.3%)	0.264 (14.6)
	Up to 1	17 (5.7%)	2 (0.7%)	6 (2.0%)	
	From 1 to 2	48 (16.0%)	2 (0.7%)	12 (4.0%)	
	From 2 to 3	26 (8.7%)	4 (1.3%)	5 (1.7%)	
	From 3 to 5	35 (11.7%)	7 (2.3%)	7 (2.3%)	
	From 5 to 10	36 (12.0%)	0 (0.0%)	11 (3.7%)	
	More than 10	29 (9.7%)	2 (0.6%)	8 (2.7%)	
Religion	Catholic	59 (19.7%)	3 (1.0%)	23 (7.7%)	0.330 (15.7)
	Atheism	33 (11.0%)	5 (1.7%)	6 (2.0%)	
	I prefer not to inform	30 (10.0%)	4 (1.3%)	5 (1.7%)	
	Evangelical	25 (8.3%)	3 (1.0%)	8 (2.7%)	
	Spiritism	24 (8.0%)	1 (0.3%)	6 (2.0%)	
	None	19 (6.3%)	1 (0.3%)	1 (0.3%)	
	Spiritualist	16 (5.3%)	0 (0.0%)	2 (0.7%)	
	Others	21 (7.0%)	1 (0.3%)	4 (1.3%)	
Profession (occupation area)	Students	68 (22.7%)	5 (1.7%)	19 (6.3%)	0.038 (24.7)*
	Agricultural Science	40 (13.3%)	0 (0.0%)	1 (0.3%)	
	Human and Applied Social Sci.	24 (8.0%)	3 (1.0%)	11 (3.7%)	
	Teachers/ Professors	19 (6.3%)	0 (0.0%)	6 (2.0%)	
	Exact Sciences and Engineering	15 (5.0%)	2 (0.7%)	2 (0.7%)	
	Biological and Health Sciences	24 (8.0%)	2 (0.7%)	4 (1.4%)	
	Linguistics, Letters and Arts	11 (3.7%)	3 (1.0%)	1 (0.3%)	
	Others	26 (8.7%)	3 (1.0%)	11 (3.7%)	
Consumption frequency	At least 2 times a month	12 (4.0%)	1 (0.3%)	2 (0.7%)	0.054 (18.1)
	At least 1 time a month	23 (7.7%)	1 (0.3%)	4 (1.3%)	
	At least once every 3 months	19 (6.3%)	3 (1.0%)	11 (3.7%)	
	At least once every 6 months	27 (9.0%)	6 (2.0%)	10 (3.3%)	
	At least 1 time a year	46 (15.3%)	2 (0.7%)	14 (4.7%)	
	Never	100 (33.3%)	5 (1.7%)	14 (4.7%)	

*Significant (p<0,05).

In Figure 2A, among the 78 male respondents, 82.2% said they were concerned about the welfare of shrimp, and 8.8% answered “don’t know”. Among the 221 female respondents, 71.5% said they were concerned about the welfare of shrimp, while 23.5% answered “don’t know”. In Figure 2B, 97.6% of the 41 people who work in the areas of agricultural sciences stated that they care about the welfare of shrimp, and 2.4% of them answered “don’t know”. Likewise, 80.0% of the 30 workers in the areas of biological and health sciences said they cared, and 13.3% answered “don’t know”. In exact sciences and engineering, 78.9% of the 19 respondents said they cared and 10.5% answered “don’t know”. In human and applied social sciences, 63.2% of the 38 respondents cared and 28.9% answered “don’t know”. In languages, letters, and arts, 73.3% of the 15 participants cared, and 6.7% answered “don’t know”. Among students without a specified area of activity, 73.9% of the 92 respondents said they cared about welfare, and 20.7% answered “don’t know”. The group of teachers and professors (25 respondents) accounted for 76.0% of responses claiming to care about welfare and 24.0% answered “don’t know”. Finally, in the group “others”, composed of traders, service

providers, military, self-employed, housewives, retirees, and entrepreneurs, 65.0% of the 40 respondents stated that they care about the welfare of shrimp, and 27.5% of them answered “don’t know”.

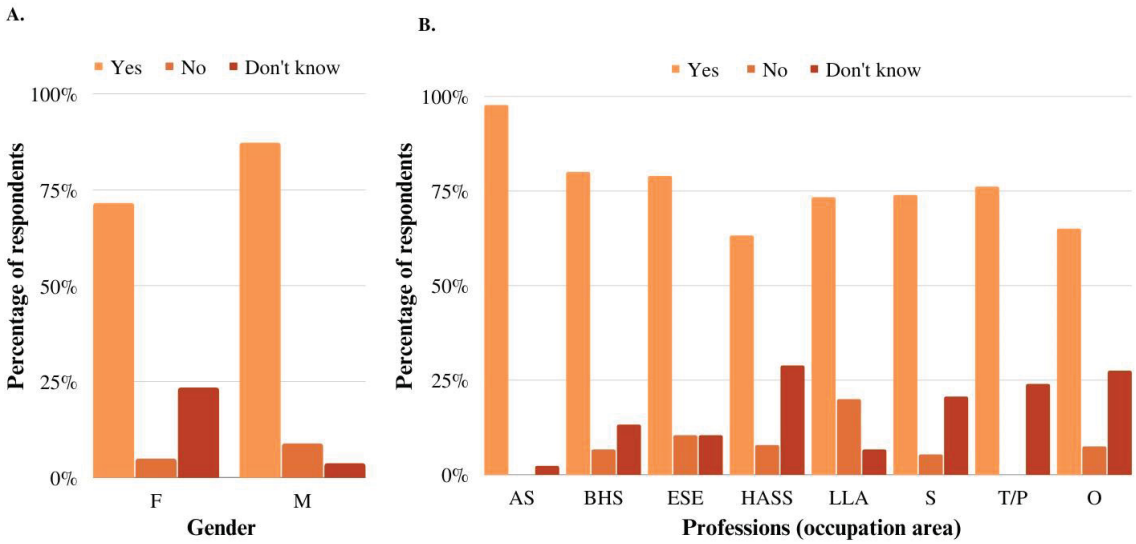

Figure 2 – “Does the shrimp welfare matter to you?”, 300 respondents residing in Brazil and over 18 years old, from March to December 2022; A. graph showing the proportion of men (M - male) and women (F - female) who answered yes, no or don't know; B. graph showing the percentage of yes, no or don't know answers for each area of professional activity (AS - agricultural sciences; BHS - biological and health sciences; ESE - exact sciences and engineering; HASS - human and applied social sciences; LLA - linguistics, letters and arts; S - students; T/P - teachers/professors; O - others); both graphs show results that had significant differences in the Pearson’s chi-squared test.

2.3.3 Perception related to the shrimp’s sentience

To the question “In your perception, are shrimps capable of feeling negative emotions, such as fear?” 63.0% of respondents answered yes, 10.3% no, and 26.7% I don't know. Among the situations reported by 189 respondents who thought that shrimp can feel fear, the most cited were during predation by other animals (28.7%) or during any situation that makes the animal feel threatened (22.8%). Other reported situations were during fishing or harvesting (16.2%), aversive or inadequate environmental conditions (13.2%) such as high stocking densities, non-ideal temperature, salinity and low food availability. Situations of stress and mistreatment (8.1%), including witnessing other individuals of the same species dying and quotes such as “cooked alive”, “death by suffocation” and “death by freezing”, as well as situations of imminent death (3.7%), that is, the water removal until death, were other situations considered to cause fear. In addition, inadequate or invasive management practices (4.4%) and being in an unfamiliar or unnatural environment (2.9%) were cited by people who

believed that no matter how controlled the production environment is, the animal is constantly in fear.

When asked “In your perception, are shrimps capable of feeling positive emotions, such as pleasure?”, 47.7% answered yes, 12.0% no, and 40.3% were unsure. The most cited situations in which the 143 respondents believed that shrimp can feel pleasure were during feeding (29.9%), reproduction (16.8%), being under favorable environmental conditions (16.2%), and during positive social interactions between intra- or interspecific individuals (15.2%). In addition to the mentioned categories, other responses addressed the feeling of pleasure generated by not living in a production environment but in their natural habitat (7.6%), living in a safe and threat-free environment (7.1%), performing natural species-specific behaviors (4.1%), and during positive situations (3.0%), such as with achievements and rewards.

When the question presented to the respondents was “In your perception, can shrimps feel pain?” 84.0% answered yes, 4.0% no, and 12.0% did not know. The most cited response by the 252 respondents was that shrimp can feel pain when they are injured (44.7%), such as when they are crushed, cut, or mutilated. Other cited responses were in situations of stress and mistreatment (11.7%); under aversive or inadequate environmental conditions (9.1%); during death (9.1%), whether caused by humans (such as in slaughter) or not; during fishing or harvesting (8.8%); during predation or hunting by other animals (4.8%); during animal handling (4.3%); in disease situations (2.8%); and in other situations (4.6%), such as when experiencing hunger, during reproduction, in response to potentially painful stimuli, or when used for scientific research.

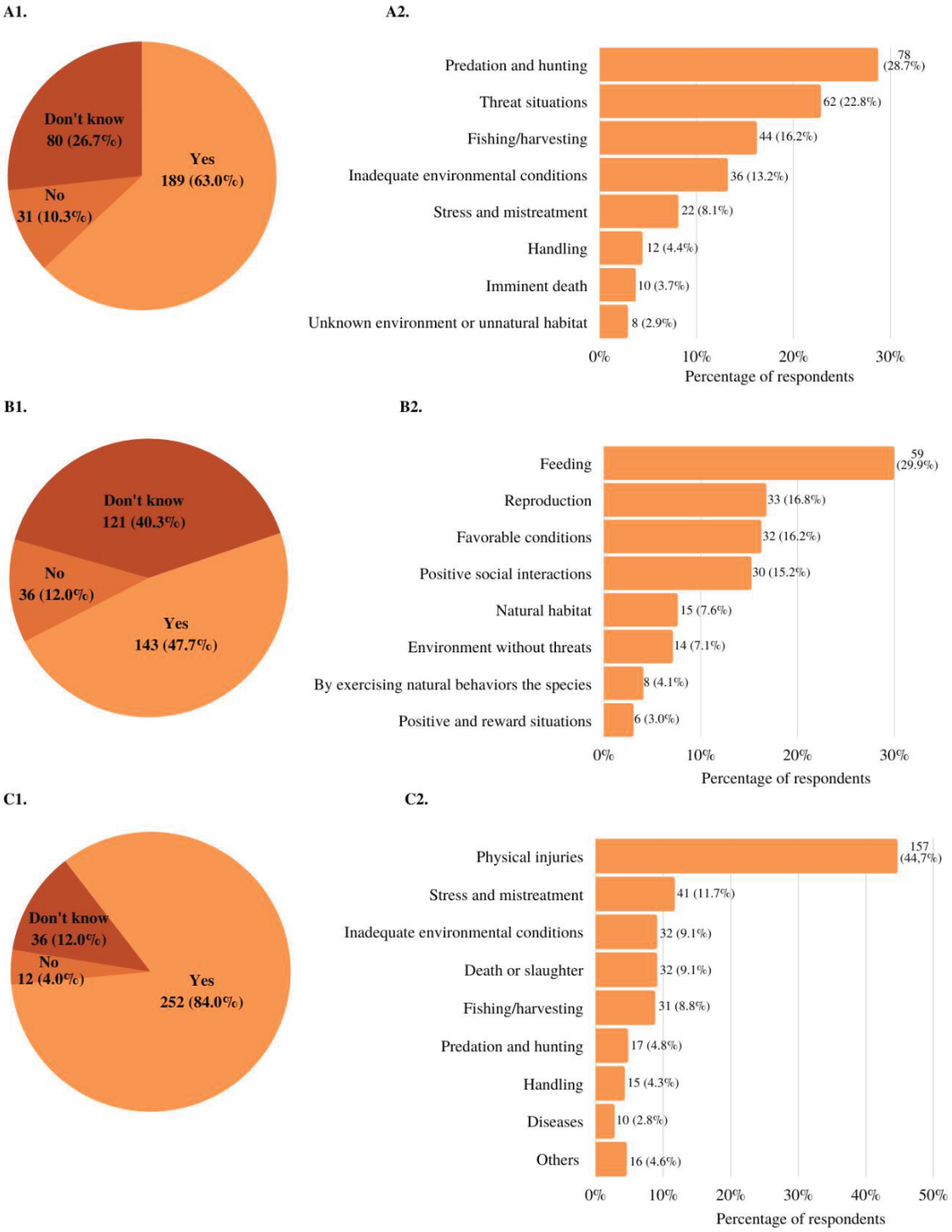

Figure 3 – A1. "In your perception, are shrimp capable of feeling negative emotions, such as fear?"; A2. percentage of respondents by open response categories to question A1; B1. "In your perception, are shrimp capable of feeling positive emotions, such as pleasure?"; B2. percentage of respondents by open response categories to question B1; C1. "In your perception, can shrimp feel pain?"; C2. percentage of respondents by open response categories to question C1; 300 respondents residing in Brazil and over 18 years old, from March to December 2022.

Regarding the possibility of animals feeling the sensation of hunger, 98.3% of respondents answered yes. Only 0.3% marked no and 1.3% marked don't know.

Additionally, education level, socioeconomic status, occupation area and frequency of shrimp consumption significantly affected respondents' perception of the shrimp's ability to feel fear and pleasure (Table 3). No significant association for pain was found. For the fear question, there was a significant association among response variables (yes, no, or don't know) and education level, socioeconomic status, occupation area and frequency of consumption. For the question about the shrimp's ability to feel pleasure, there was a significant association with level of education and frequency of consumption. We observed that despite the overall statistical significance in the chi-squared test for the association between answers regarding shrimp's ability to experience fear and the respondents' socioeconomic status and the respondents' area of occupation, the post hoc analysis did not identify specific differences between the categories. However, for the same answers about fear, significance was observed among individuals in postgraduate programs for the "don't know" response, and among those who consume shrimp at least twice a month for the "no" response. Additionally, no post hoc differences were observed between answers on the ability of shrimp to experience pleasure concerning education level and consumption frequency.

Table 3 - Factors that influenced the perception about the ability of shrimps to feel fear, pleasure and pain; 300 respondents residing in Brazil, from March to December 2022; p-values (chi-squared) according to Pearson's chi-squared test.

Variables	Fear	Pleasure	Pain
Gender	0.822 (0.391)	0.073 (5.23)	0.454 (1.58)
Age	0.905 (3.42)	0.846 (4.12)	0.564 (6.75)
Region	0.450 (5.77)	0.288 (7.38)	0.636 (4.30)
Level of education	0.014 (12.6)*	0.036 (10.3)*	0.144 (6.86)
Socioeconomic condition in minimum wages	0.012 (25.7)*	0.324 (13.6)	0.815 (7.60)
Religion	0.402 (14.7)	0.339 (15.6)	0.194 (18.3)
Profession (occupation area)	0.030 (25.5)*	0.309 (16.1)	0.577 (12.4)
Consumption frequency	0.015 (22.1)*	0.002 (28.4)*	0.068 (17.3)

*Significant ($p<0,05$).

In Figure 4 (A1), it is observed that 60.0% of the 15 respondents consumed shrimp at least twice a month believed that shrimps can feel fear and 6.7% did not know. Of the people who consumed at least once a month, 60.7% of the 28 answered yes, and 32.1% did not know. Of the respondents who consumed at least once every three months, 51.5% of the 33 believed that shrimp feel fear, and 27.3% did not know. Among the respondents who consumed at least once every six months, 53.5% of the 43 believed that they feel fear, and 32.6% did not know. Of the 62 people who consumed shrimp at least once a year, 71.0% believed that they feel fear, and 21.0% did not know. Of the 119 respondents who claimed to never consume shrimp, 66.4% of them stated that shrimp feel fear, and 28.6% did not know. In Figure 4 (A2), it can

be noted that 62.9% of the 35 respondents who have up to a high school education, believed that shrimp can feel fear and 37.1% did not know. Of the 158 respondents who completed or did not complete higher education, 58.9% believed that shrimp can feel fear, and 31.0% did not know. Regarding the 107 respondents with postgraduate education, 69.2% claimed to think that shrimp can feel fear, and 16.8% did not know. In Figure 4 (A3), it is possible to observe the variation in the frequency of responses according to the income of the survey participants. Among the 43 respondents with no income, 76.7% claimed that shrimp can feel fear, and 18.6% did not know. Among the 25 people who earned up to one minimum wage, 44.0% thought that shrimp can feel fear, and 44.0% did not know. Of the 62 respondents who earned between one and two minimum wages, 72.6% answered yes, and 24.2% did not know. Among the 35 respondents who earned between two and three minimum wages, 65.7% claimed that shrimp can feel fear, and 25.7% did not know. Of the 49 respondents who earned between three and five minimum wages, 61.2% answered yes, and 32.7% did not know. Of the 47 who earned between five and 10 minimum wages, 59.6% claimed that shrimp can feel fear, and 21.3% did not know. Of the 39 people who earned more than 10 minimum wages, 48.7% answered yes, and 30.8% answered they did not know. In Figure 4 (A4), it is observed that 82.9% of the 41 respondents who work in the areas of agricultural sciences believed that shrimp can feel fear, and 12.2% did not know. In biological and health sciences, 72.3% of the 30 respondents answered yes, and 23.3% did not know. In exact sciences and engineering, 47.4% of the 19 respondents believed that shrimp can feel fear, and 26.3% did not know. In human and applied social sciences, 55.3% of the 38 respondents believed that shrimp can feel fear, and 31.6% answered “don’t know”. In languages, letters, and arts, 60.0% of the 15 participants answered yes, and 40.0% answered “don’t know”. Among students without a specified area of activity, 63.0% of the 92 respondents believed that shrimp can feel fear, and 22.8% answered “don’t know”. The group of teachers and professors (25 respondents) accounted for 60.0% of responses answered yes, and 28.0% answered “don’t know”. In the group “others”, composed of traders, service providers, military, self-employed, housewives, retirees, and entrepreneurs, 52.5% of the 40 respondents believed that shrimp can feel fear, and 42.5% of them answered “don’t know”.

In Figure 4 (B1), it is observed that among the 119 people who never consumed shrimp, 58.0% stated that shrimp feel pleasure, and 36.1% did not know. Of the 62 respondents who consumed shrimp at least once a year, 50.0% indicated that shrimp feel pleasure, and 41.9% did not know. Among the 43 people who consumed shrimp at least once every six months, 34.9% indicated yes, and 46.5% did not know. Of the 33 participants who consumed at least

once every three months, 27.3% believed that shrimp feel pleasure, and 48.5% did not know. Of the 28 respondents who consumed at least once a month, 39.3% affirmed that shrimp can feel pleasure, and 50.0% did not know. And finally, among the 15 who consumed at least twice a month, 53.3% affirmed that shrimp can feel pleasure, and 13.3% did not know. In Figure 4 (B2), it is possible to observe that 40.0% of the 35 respondents who have up to a high school education, believed that shrimp can feel pleasure, and 60.0% did not know. Of the 158 respondents who completed or did not complete higher education, 48.1% believed that shrimp can feel pleasure, and 39.9% did not know. Regarding the 107 respondents with postgraduate education, 49.5% claimed to think that shrimp can feel pleasure, and 34.6% did not know.

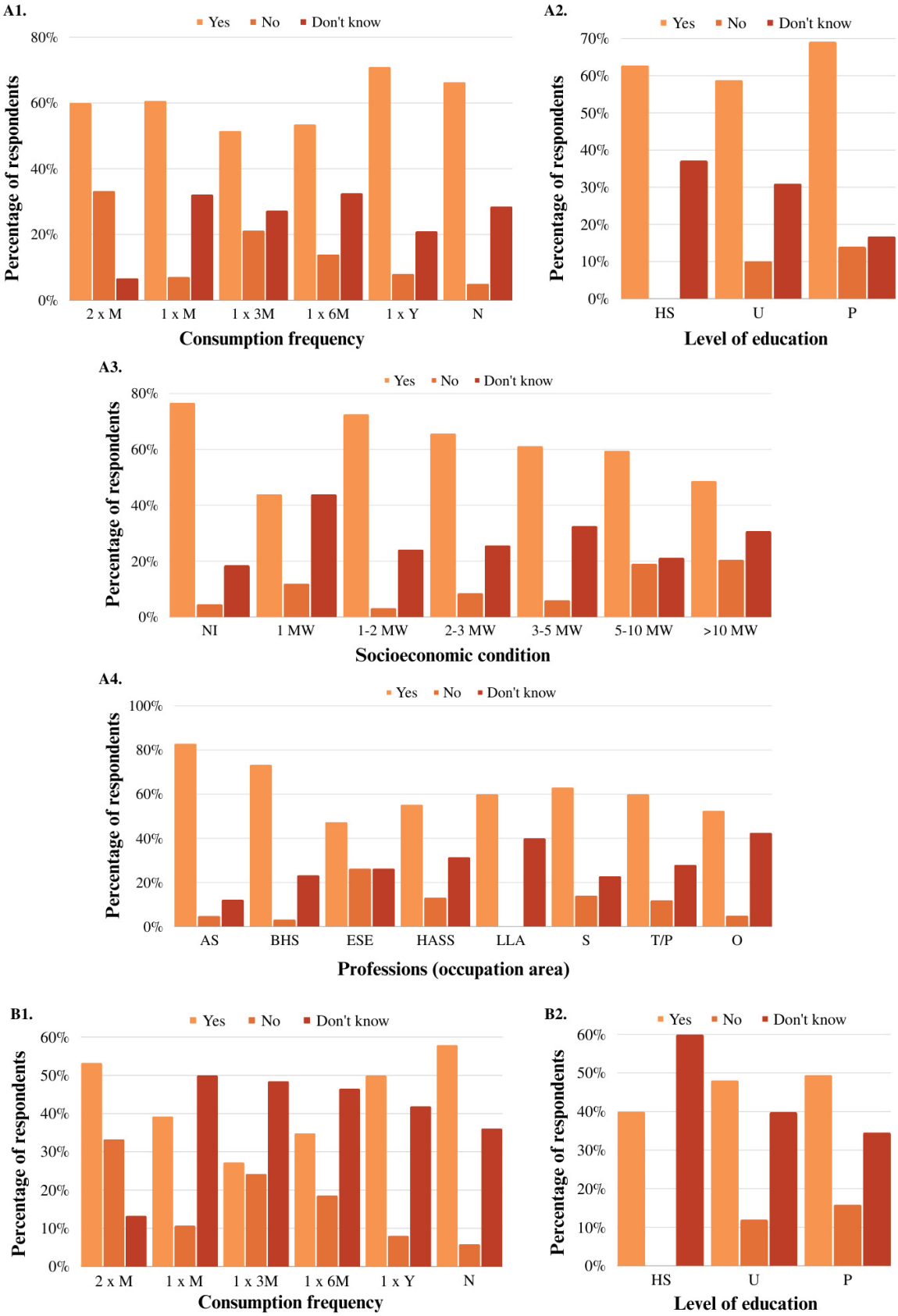

Figure 4 - A1, A2, A3 and A4. "In your perception, are shrimp capable of feeling negative emotions, such as fear?"; B. "In your perception, are shrimp capable of feeling positive emotions, such as pleasure?"; 300 respondents residing in Brazil, from March to December 2022; A1 and B1. by consumption frequency: 2 x M - at least twice a month, 1 x M - at least once a month, 1 x 3M - at least once every three months, 1 x 6M - at least

once every six months, 1 x Y - at least once a year, N - never; A2 and B2. by education level: HS - up to high school, U – university, P – postgraduate; A3. by socioeconomic condition: NI - no income, 1MW - up to one minimum wage, 1 to 2 MW - from one to two minimum wages, 2 to 3 MW - from two to three minimum wages, 3 to 5 MW - from three to five minimum wages, 5 to 10 MW - from five to ten minimum wages, >10 MW - more than ten minimum wages; A4. profession (occupation area): AS- agricultural sciences, BHS- biological and health sciences, ESE- exact sciences and engineering, HASS – human and applied social sciences, LLA- linguistics, letters and arts, S- students, T/P- teachers/professors, O- others; the graphs show results that had significant differences in the Pearson's chi-squared test.

2.3.4 Perception related to eyestalk ablation

After the questions about welfare and sentience, respondents were presented with another question: "Have you ever heard of eyestalk ablation in shrimp?" Among them, 81.7% answered that they had never heard of it. After a brief contextualization and a link that redirected to an informative article, if they were interested, another question was asked: "Do you consider this practice acceptable?" 81.3% answered no and 16.0% answered don't know. The justifications that led people to answer either yes or no were grouped into a word cloud (Figure 6), with the most cited justifications being that the practice is painful, cruel, causes suffering, is mutilator, mercantilist, and disrespectful to animal welfare. The last question asked was "Do you think that shrimp suffer from the production system that performs eyestalk ablation?" and 84.0% answered yes, and 14.0% answered don't know.

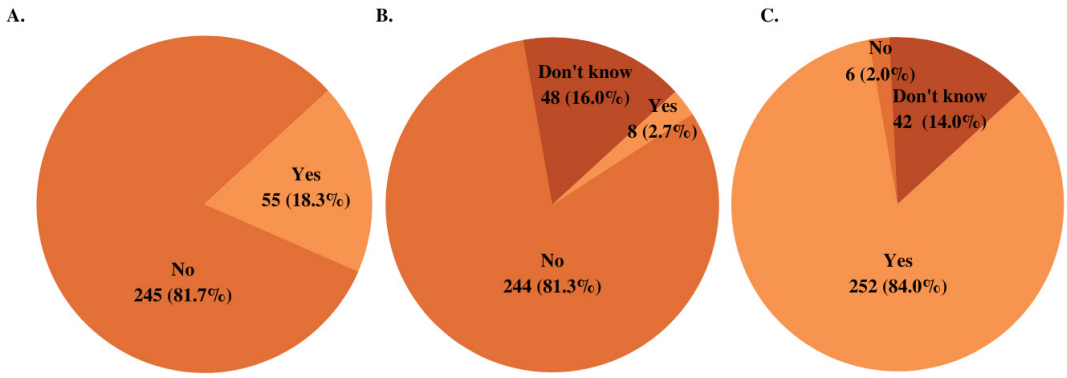

Figure 5 - A. "Have you ever heard of eyestalk ablation in shrimp?"; B. "Do you consider this practice acceptable?"; C. "Do you think shrimp suffer from the production system that carries out eyestalk ablation?" 300 respondents residing in Brazil, from March to December 2022.

Figure 6 - Word cloud generated from categorizing the justifications of the respondents for considering the practice of eyestalk ablation not acceptable (81.3% of respondents) or acceptable (3.7% of respondents); 300 respondents residing in Brazil, from March to December 2022.

For the question about the acceptability of the eyestalk ablation practice, there was a significant association between the response variables (yes, no or don't know) with gender, region, occupation area and consumption frequency. For the question about the possibility of shrimp suffering from the ablation procedure, there was a significant association with age, occupation area and consumption frequency of the respondent (Table 4). The post hoc analysis revealed that the main significant differences related to the answers on whether the practice of eyestalk ablation is acceptable lay in both genders (with both "yes" and "no" answers), northern and central-western regions (with "yes" answers), and in the "others" category on occupational area ("no"). Despite statistical significance in the chi-squared test related to consumption frequency, the post hoc analysis did not identify specific differences between the categories. Regarding the possibility of shrimp suffering from the eyestalk ablation procedure, post hoc statistical significance was observed in the 45-54 age group ("no") and among those who never consume shrimp ("yes"). Despite statistical significance in the chi-squared test related to the occupational area, the post hoc analysis did not identify specific differences between the categories.

Table 4 - Factors that influence perception of the acceptability of the practice of eyestalk ablation and the ability of shrimp to suffer from the procedure; 300 respondents residing in Brazil, from March to December 2022; p-values (chi-squared) according to Pearson's chi-squared test.

Variables	Acceptable	Suffering
Gender	0.001 (13.6)*	0.402 (1.82)
Age	0.796 (4.64)	0.048 (15.6)*
Region	0.008 (17.4)*	0.744 (3.50)
Level of education	0.380 (4.20)	0.149 (6.76)
Socioeconomic condition in minimum wages	0.496 (11.4)	0.656 (9.55)
Religion	0.182 (18.6)	0.449 (14.0)
Profession (occupation area)	0.024 (26.2)*	0.021 (26.7)*
Consumption frequency	0.023 (20.7)*	0.002 (27.4)*

*Significant (p<0,05).

In Figure 7 (A1), out of 221 female respondents, 85.1% considered eyestalk ablation an unacceptable practice and 14.0% did not know; out of 78 male respondents, 70.5% considered it unacceptable, and 21.8% did not know. In Figure 7 (A2), in the North and the Midwest, 61.1% of the 18 respondents considered the practice unacceptable and 22.2% did not know. In the Northeast, 83.3% of the 30 respondents considered it unacceptable, and 13.3% did not know. In the Southeast, 85.4% of the 82 respondents considered it unacceptable and 12.2% did not know. Finally, out of 170 respondents from the South of Brazil, 81.2% considered the practice unacceptable and 17.6% did not know. In Figure 7 (A3), out of 119 respondents who never consumed shrimp, 89.1% considered the practice unacceptable and 10.1% did not know. Out of the 62 who consumed the animal at least once a year, 82.3% considered it unacceptable and 16.1% did not know. When consumption was at least once every six months, 79.1% of the 43 respondents considered it unacceptable and 18.6% answered "don't know". Out of the 33 respondents who consumed shrimp at least once every three months, 78.8% considered it unacceptable and 18.2% did not know. Out of the 28 who consumed it at least once a month, 60.7% considered it unacceptable and 32.1% did not know. For 66.7% of the 15 who consumed it at least twice a month, the practice is unacceptable, and 20.0% did not know. In Figure 7 (A4), out of the 41 respondents who work in the areas of agricultural sciences, 90.2% considered the practice unacceptable and 4.9% did not know. Out of the 30 respondents who work in the areas of biological and health sciences, 93.3% considered it unacceptable and 6.7% answered "don't know". For 63.3% of the 19 respondents from exact sciences and engineering, the practice is unacceptable, while 31.6% of them did not know. In human and applied social sciences, 81.6% of the 38 respondents considered the practice unacceptable, while 15.8% did not know. In languages, letters and arts, 86.7% of the 15 respondents also considered it unacceptable, and 13.3% did not know. Out of the 92 respondents from the student's category, 80.4% found it unacceptable, and 16.3% did not

know. Out of the 25 teachers/professors, 92.0% considered it unacceptable and 4.0¨% answered “don’t know”. Finally, out of the 40 respondents from the “others” category, 65.0% considered the practice unacceptable and 35.0% did not know.

When asked whether shrimp suffer from eyestalk ablation (Figure 7 (B1)), 85.1% of the 101 respondents aged 18-24 answered yes, and 13.9% didn't know. In the 25-34 age group, 82.4% of the 108 respondents answered yes, and 16.7% didn't know. From 35 to 44 years old, 86.0% of the 43 respondents answered that shrimp suffer, and 11.6% didn't know. In the 45-54 age group, 80.0% of the 25 respondents answered yes and 8.0% didn't know. Of the 23 participants aged 55 or older, 87.0% answered that the animals suffer, and 13.0% didn't know. In Figure 7 (B2), of the 41 respondents working in agricultural sciences, 85.4% answered that shrimp suffer in the production system, and 14.6% didn't know. Of the 30 respondents from biological and health sciences, 96.7% answered yes, and 3.3% didn't know. In exact sciences and engineering, 63.2% of the 19 answered yes, and 26.3% didn't know. In human and applied social sciences, 78.9% of the 38 respondents answered yes, and 13.2% didn't know. In linguistics, letters and arts, 100.0% of the 15 participants answered that animals suffer from the production system. Among students without a specific field, 81.5% of the 92 answered yes and 17.4% didn't know. Of the 25 teachers without a specific field, 88.0% answered yes, and 12.0% didn't know. Finally, of the 40 respondents whose professions were classified as "others," 85.0% answered yes, and 15.0% didn't know. In Figure 7 (B3), 80.0% of the 15 respondents who consumed shrimp at least twice a month believed that they suffer from ablation, and 13.3% didn't know. Of the 28 respondents who consumed at least once a month, 71.4% answered yes. Among those who consumed at least once every three months, 75.8% of the 33 believed that they suffer, and 24.2% didn't know. Of the 43 respondents who consumed at least once every six months, 76.7% believed that shrimp suffer from ablation, and 23.3% didn't know. Among the 62 people who consumed shrimp at least once a year, 83.9% affirmed that they suffer, and 9.7% answered “don’t know”. Finally, among the 119 people who never consumed shrimp, 92.4% affirmed that shrimp suffer from ablation, and 6.7% answered don’t know.

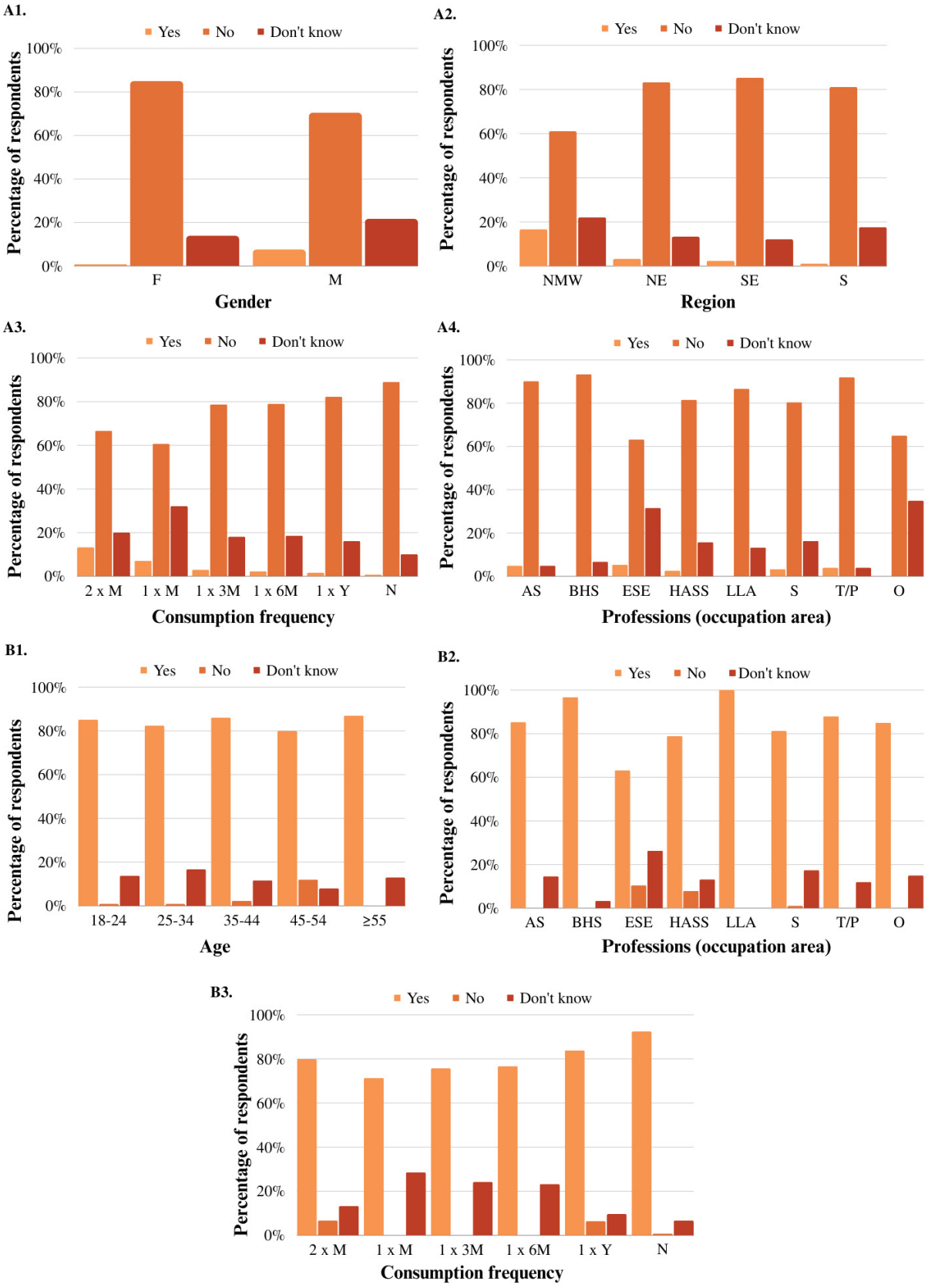

Figure 7. A. "Do you consider the practice of eyestalk ablation in shrimp acceptable?" and B. "Do you believe that shrimp suffer from the production system that carries out the eyestalk ablation procedure?"; 300 respondents residing in Brazil, from March to December 2022; A1. by gender: F - female, M - male; A2. by region of birth: NMW – North and Midwest, NE - Northeast, SE - Southeast, S - South; A3 and B3. by consumption frequency:

2xM - at least twice a month, 1xM - at least once a month, 1x3M - at least once every three months, 1x6M - at least once every six months, 1xY - at least once a year, N - never; B1. by age: 18-24, 25-34, 35-44, 45-54, ≥55; A4 and B2. by professional area of expertise: AS - agricultural sciences, BHS – biological and health sciences, ESE - exact sciences and engineering sciences, HASS – human and applied social sciences, LLA - linguistics, letters, and arts, S - students, T/D - teachers, O – others; the graphs show results that had significant differences in the Pearson's chi-squared test.

2.4 DISCUSSION

Most respondents said they care about the welfare of shrimp and believe that such animals are capable of feeling hunger, pain, fear, and to a lesser extent, pleasure. In addition, it appeared that most people were unaware of the practices carried out in shrimp farming, such as the ablation of the eyestalk in breeding females. However, after a brief introduction to eyestalk ablation, respondents considered the procedure unacceptable and likely to cause suffering to the shrimp. They labeled the practice painful, cruel, that causes suffering, harmful, mercantilist, aggressive, unnatural, disrespectful, mutilating, unnecessary, among other terms.

The results showed significant differences between genders and areas of professional activity when asked if respondents care about the welfare of shrimp, and between levels of education, socioeconomic status, frequency of consumption and areas of professional activity when asked about the ability of shrimp to feel fear. There were also significant differences between frequency of consumption and levels of education in the answers about the ability of shrimp to feel pleasure. No association was observed between the answers about the ability of shrimp to feel pain and sociodemographic factors. Furthermore, significant differences were also observed between gender, region of birth, frequency of consumption, and profession for the question about the acceptability of the practice of eyestalk ablation in shrimp and between age, profession, and frequency of consumption for the question about the possibility that shrimp suffer in production systems that carry out the procedure. Religion is the only factor that showed no significant differences among respondents in any of the questions.

Gender is an important predictor of concern for animals and the differences between how genders perceive the animal welfare are documented in several scientific articles. Our results demonstrate a gender difference due to the greater engagement of women, with a percentage of female participants higher than the proportion of women in the Brazilian population (Table 1). In general, women are more concerned about animal welfare than men and more often believe that animals intended for consumption should be treated with dignity (MARÍA, 2006; HERZOG, 2007; TOMASEVIC *et al.*, 2020; ALMEIDA; FERNÁNDEZ, 2020). Women are

also more likely to support animal protection movements, question the use of animals in research, and avoid consuming animal products (ELDRIDGE; GLUCK, 1996). Men, in turn, show a greater tendency to emphasize the benefits of using animals in research (ELDRIDGE; GLUCK, 1996), in a manner related to Adams' theory (1990), in his book “The Sexual Politics of Meat”, in which animal exploitation for meat consumption is linked to the idea of masculinity. In our results, the gender differences noted for the question whether shrimp welfare matters differed from those prevalent in the literature. As our response options included three different alternatives (yes, no and don't know), it was observed that females were more careful in expressing an opinion, showing a higher percentage of don't know answers. Consequently, male respondents had higher percentages of yes and no answers. Regarding the results obtained for the question about the acceptability of the practice of ablation, the pattern found in the literature was evident, with higher rates of females considering the practice unacceptable.

Differences in areas of professional practice can also influence the way people view animal welfare (MARÍA, 2006; TAYLOR; SIGNAL, 2006). Our results for the question about whether the welfare of shrimp matters suggested that there are significant differences between answers of respondents of distinct professional areas. Among them, the professionals who showed the most concern for the welfare of the shrimp were those in agricultural sciences, closely followed by professionals in biological and health sciences. These results concur with those of María (2006), who observed that veterinarians and professionals connected with production cared more about animal welfare. Furthermore, the fields of agricultural sciences and of biological and health sciences exhibited a higher proportion of individuals who believed that shrimp are sentient beings capable of experiencing fear and suffering. It is highly likely that this has influenced professionals in these areas to be the most concerned about the well-being of shrimp and, for the most part, opposed to the practice of eyestalk ablation, considering it unacceptable. On the other hand, the opposite was observed among professionals in the fields of exact sciences and engineering, as well as those in the fields of human and applied social sciences. These groups had the highest proportions of individuals who responded that they believe shrimp do not feel fear and suffering. They also had the highest rates of individuals who stated that they do not care about the well-being of shrimp, second only to those in languages, literature, and arts. Nevertheless, many respondents remained uncertain about whether the practice of ablation is acceptable. Meanwhile, professionals in languages, literature, and arts had the highest percentages of individuals who responded that they do not care about the well-being of shrimp. Many of

them had doubts about whether shrimp can experience fear and whether the practice of ablation would be acceptable, but 100.0% of them believe that shrimp can suffer. Thus, our results show dissonances which warrant further studies. With this, we can see that although more respondents from languages, letters and arts believe that shrimp suffer from ablation, they say they do not care about the welfare of these animals. We can associate this neglect with the suffering of certain animals to speciesism (CAVIOLA *et al*., 2019). In a study by Marriott and Cassaday (2022) that listed levels of sympathy for different species, it was observed that companion animals, among other mammals, were more appreciated when compared to animals of other classes. They also showed that certain production animals, such as chickens, attracted greater public sympathy than shrimp, and that species considered pests (pigeons, rats, spiders and wasps) were even more undervalued. The protection of certain species is often influenced by issues of analogy with humans, with more related and similar animals being considered more worthy of protection (BROOM, 2007). In addition, despite people having more positive views toward profitable species, such as shrimp, when compared to species that are considered pests, the attitudes they take regarding the use of profitable species follow a similar pattern to those regarding the use of species considered pests (MARRIOTT; CASSADAY, 2022).

There was no clear pattern between age and people's belief that shrimp can suffer from ablation. Despite no significant differences related to responses about the shrimp's ability to feel pain, 84.0% of respondents believed that they are capable of sensing painful stimuli. With this, we can observe that there seems to be a contradiction in opinions about the ability of shrimp to feel pain and suffer from ablation among a proportion of our respondents. This may have occurred because the participants disassociated the state of pain from the feeling of suffering. As suffering can result from a variety of states including pain, anxiety, and fear (DEGRAZIA; ROWAN, 1991), perhaps hesitation on the part of certain age groups results from difficulty in admitting the likely sentience of invertebrate animals intended for human consumption. This can be explained by the concept of “dementalization” or by the concept of “mind denial”, a form of cognitive dissonance in which animals used for food are intellectually demeaned as an alternative to morally resolving the conflict between hurting sentient beings and enjoying eating meat, so that concerns about their welfare diminish, justifying the procedures performed in the meat production chain (LOUGHANAN *et al*., 2010; BASTIAN *et al*., 2012; MARRIOTT; CASSADAY, 2022). On the other hand, the opposite can perhaps be explained more by a recognition of the suffering caused by the

consequences of the eyestalk ablation procedure for the animal and less by the capacity of the shrimp in experiencing painful stimuli due to the invasiveness of the procedure itself.

One point that was evident in relation to the frequency with which the respondent consumes shrimp is that the category “consumes at least twice a month” was the one that demonstrated less belief in the sentience of shrimp and less concern for their welfare. And conversely, a greater number of people who believed that shrimp are sentient and care about their well-being was observed among individuals who never consume shrimp. In general, greater trends with concern related to the welfare of production animals are observed in people with lower consumption rates (CLONAN *et al*., 2015). In addition, the acceptability of eyestalk ablation decreased as consumption decreased, which coincided with the findings of Clonan *et al*. (2015). Furthermore, although the central regions of the graphs often displayed high rates of people who did not believe these animals can experience fear and pleasure, a significant portion of them considered ablation unacceptable and believed that these animals suffer from the procedure. Thus, there is likely a reluctance to believe that shrimp can experience more complex emotions, probably associating this suffering with pain or the consequences of ablation.

Studies point to contradictory views for the opinions linked to animals by people of different incomes and education. People with lower incomes and people with lower levels of education were more concerned about animals in the survey by Kendall *et al*. (2006). In contrast, other studies have shown greater knowledge and greater concern for animal welfare by people with higher education and from middle or upper economic classes (BURREL; VRIEZE, 2003; VERHUE; VERZEIJDEN, 2003; ANDRADE *et al*., 2019; TOMASEVIC *et al*., 2020). People with greater purchasing power had the highest percentages of responses stating that shrimp are not afraid. This finding may also result from factors such as the theory of “dementalization” (LOUGHNAN *et al*., 2010). Additionally, the lack of proximity to the animal, as reported by Tamioso *et al*. (2018), may influence the attitudes and perception towards shrimps. Regarding education, our results showed a higher rate of respondents with university education or postgraduate degrees who believed that shrimp do not experience fear and pleasure. Therefore, the results are again in line with those observed by Kendall *et al*. (2006), that is, people with higher incomes and higher education levels were those who most doubted the shrimp's ability to feel fear and pleasure, which directly influences the concern for the welfare of this animal.

According to the graph of the Brazilian regions associated with the acceptability of the ablation practice (Figure 7(A2)), respondents from states in the North and Midwest of Brazil

showed less concern for the welfare of shrimp when compared to the Northeast, Southeast and South, which may be related to cultural differences in location (BOAITEY; MINEGISHI, 2020). In fact, our results in this regard are preliminary, requiring further research with a larger number of respondents from the North and Midwest regions.

In our results, we found certain limitations related to the scope of the questionnaire, consistent with convenience sampling, in which factors such as geographic proximity, accessibility, availability and willingness of participants representing the target population influence the final sample (DÖRNYEI, 2007; ETIKAN *et al*., 2016). Furthermore, another factor that may have influenced the observed frequencies is a greater interest by certain groups of the population in subjects related to the science of animal welfare, for example, Kendall *et al*. (2006) observed that women, younger people, with less education and lower income were more concerned with the welfare of animals, while Wrenn (2019) noted a greater concern on the part of atheists and Clonan *et al*. (2015) noticed a greater concern on the part of people who consume meat less frequently. Therefore, we noticed that some proportions among our respondents, such as gender, age, region, education, socioeconomic status and religion, differed from those presented by the IBGE referring to the Brazilian population in general. Thus, we had a greater proportion of female audience (research – 73.7%; IBGE – 51.1%); people between 18 and 24 years old (survey – 33.7%; IBGE – 14.9%) and between 25 and 34 years old (survey – 36.0%; IBGE – 15.9%); of respondents from the Southern Region of Brazil (survey – 56.7%; IBGE - 14.8%); of people with complete or incomplete university (research – 52.7%; IBGE – 17.4%) or with a postgraduate degree (finished or studying – 35.7%). Regarding the socioeconomic status, the average income of the research participants was lower than the Brazilian average, with a higher proportion of people without income (research – 14.3%; IBGE – 4.4%) and who receive from 1 to 2 minimum wages (survey – 20.7%; IBGE – 10.5%) and a smaller proportion of people earning between 2 to 3 (survey – 11.7%; IBGE – 21.5%) and 3 to 5 minimum wages (research – 16.3%; IBGE – 34.3%). The comparison between the religion of the respondents and that obtained by the IBGE in 2010 also followed a different pattern, with a high number of atheists (14.7%), a greater participation of spiritism (survey – 10.3%; IBGE – 2.0 %) and spiritualists (survey – 6.0%; IBGE – 0.03%) and a smaller number of catholics (survey – 28.3%; IBGE – 64.8%) and evangelicals (survey – 12.0%; IBGE – 22.1%).

In addition, some categories had a relatively a low sample, e.g., age groups between 55 and 64 years old (18 respondents) and ≥65 years old (five respondents); the North (11 respondents) and Midwest (seven respondents) regions; education level corresponding to

complete or incomplete primary education (three respondents); people with a socioeconomic status of more than 20 minimum wages (ten respondents); people with spiritualists religion (18 respondents); people from the exact sciences and engineering (19 respondents), biological sciences (16 respondents), linguistics, letters and arts (15 respondents), health sciences (14 respondents), human sciences (six respondents); and related to the frequency of shrimp consumption, those who consumed it one or more times a week (four respondents) and those who consumed it at least twice a month (11 respondents). With this in mind, studies are needed with a larger number of respondents for the categories mentioned above to more effectively characterize the opinions of different strata of the population, since we couldn't observe clear patterns for some continuous variables.

Despite the limitations listed above, most discussions on animal welfare focus on the negative aspect of subjective experiences (BIRCH *et al*., 2021). As we observed in the results, the study population thought that the animals were more likely to experience negative sensations or feelings, such as pain or fear, than positive feelings, such as pleasure. Even people who believed that shrimp were sentient were doubtful about the experience of positive feelings by these animals. This may happen precisely because most studies focus on aversive experiences, with rare mention of pleasurable situations. However, evolutionary principles demonstrate that animals are motivated to seek rewards in the same way that they avoid pain and suffering. In a sentient animal, impulses to gain food, shelter, sexual partners, and social contact are motivated by desire and reinforced by feelings of pleasure and this is reflected during behaviors in the areas of play, feeding, reproduction and touching (BALCOMBE, 2009).

Finally, there is a growing appreciation by the consumer market for buying food from farms that prioritize and care about the animal welfare (ALONSO *et al*., 2020). Furthermore, despite the scarcity of studies on the sentience of shrimp, there is substantial evidence suggesting that they are sentient beings like some other decapod crustaceans. Thus, exposing shrimps to aversive practices, such as eyestalk ablation, is not recommended, as it can cause pain and suffering to individuals (BIRCH *et al*., 2021). This way, the procedures carried out in shrimp farming should be reevaluated to promote a better physical and mental health to the animals.

2.5 CONCLUSION

In the current small sample, there is a predominant perception that shrimp are sentient beings capable of experiencing negative subjective experiences such as pain, fear and suffering, which are critical concern in the science of animal welfare. As a result, the majority sees the practice of eyestalk ablation in shrimp farming as unacceptable because it violates animal welfare principles in exchange for profit and production maximization. Furthermore, factors such as gender, age, region, education, socioeconomic status, profession and frequency of consumption have been shown to influence the perception of shrimp sentience and welfare. The predominant reason people didn't care about the welfare of shrimp was likely the general lack of knowledge about the animals themselves and about the production system to which they are subjected. Therefore, a greater dissemination of knowledge to the population about the evidence of sentience in some decapod crustaceans and about the shrimp farming system can serve as a driving force for the redefinition of practices carried out in production systems with a view to improving shrimp welfare.

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3 COMO ENTENDER A DISTRIBUIÇÃO DA SENCIÊNCIA NO REINO ANIMAL? EVIDÊNCIAS CIENTÍFICAS DE SENCIÊNCIA EM INVERTEBRADOS

RESUMO

A avaliação da senciência animal é um processo complexo que requer a integração do conhecimento científico disponível, de forma que abranja uma ampla gama de informações e considere diversas áreas. Assim, o presente estudo teve como objetivo aprimorar e facilitar a compreensão da avaliação da senciência animal no Brasil e em outros países lusófonos. Desta maneira, buscou-se trazer para o idioma português a mais completa estrutura existente para avaliar a distribuição da senciência nos animais não humanos, incluindo o exemplo de sua aplicação em dois táxons de invertebrados: os moluscos cefalópodes e os crustáceos decápodes, com uma contextualização para o cenário brasileiro e uma atualização com os estudos mais recentes acerca do tema. Tal avaliação científica possibilitou a descoberta de indícios de senciência nesses dois grupos e, por tal motivo, recomenda-se que eles sejam considerados animais sencientes no que tange legislações futuras. Ainda, é notável que, para a maioria das espécies de invertebrados, existe uma lacuna no conhecimento essencial para fundamentar cientificamente essa avaliação. Com base nisso, é imprescindível reconhecer a falta de conhecimento, a fim de evitar injustiças ao classificar certos grupos taxonômicos como não sencientes, quando a limitação não está relacionada a ausência de senciência, mas sim ao entendimento limitado sobre o assunto.

Palavras-chave: bem-estar animal; crustáceos decápodes; ética; moluscos cefalópodes; legislação.

3.1 INTRODUÇÃO

A compreensão acerca da distribuição da senciência no reino animal tem impactos éticos, sociais, econômicos, legislativos e políticos. Tal importância decorre do fato de que a senciência é o critério relevante para se estabelecerem direitos a um indivíduo, para que ele seja entendido como um sujeito, para quem a sua própria condição de vida importa e, consequentemente, seja merecedor de consideração moral relativa à proteção de seus interesses em não sofrer e em vivenciar sentimentos positivos (CUNHA, 2021). Assim, à medida que a ciência reconhece a capacidade de sentir dor, angústia, medo e frustração, entre outros sentimentos negativos, de sentir prazer e alegria, assim como de ter interesses provenientes de tais sentimentos - ou seja, a presença de senciência - em uma espécie animal, há um esforço para que os indivíduos de tal espécie passem a ter consideração moral e proteção legal. O reconhecimento da senciência está em estágio mais avançado no que tange aos animais vertebrados, sendo abordado na literatura científica sobre invertebrados apenas mais recentemente.

Uma metodologia importante para avaliar evidências de senciência em moluscos cefalópodes e crustáceos decápodes foi apresentada recentemente por Birch *et al*. (2021). Eles desenvolveram oito critérios em uma estrutura de deliberação sobre presença de senciência para avaliar de maneira sistematizada os resultados das publicações científicas individuais, as quais em conjunto podem apresentar o quadro informativo mais completo possível. Em tal trabalho, foram estudadas mais de 300 publicações científicas, investigando também potenciais implicações de bem-estar nas práticas comerciais atuais. A estrutura combina e integra a experiência empírica e teórica em comportamento animal, cognição comparativa, ecologia sensorial, neurociência, bem-estar animal e filosofia. Ao revisar as evidências relevantes, surgem desafios. Por exemplo, a justaposição de evidências do campo da cognição comparativa, no qual a ênfase reside em descartar explicações mais simples para um determinado comportamento, resposta ou desempenho em várias tarefas de resolução de problemas, com evidências de bem-estar animal, no qual a questão gira em torno de capacidades potenciais, como a potencial capacidade de sentir dor. Além disso, alguns dos critérios podem ser mais convincentes por si só do que outros. Assim, uma abordagem interessante para entender a senciência é avaliar as evidências em termos de níveis de confiança, variando de nenhuma confiança a confiança muito alta, em relação a critérios pré-estabelecidos. Dessa forma, considerar esses níveis de confiança de maneira conjunta

constitui uma forma de integrar diferentes categorias de evidências, favorecendo uma conclusão embasada na melhor base científica possível.

O objetivo deste trabalho foi trazer para o idioma português a mais completa estrutura existente para avaliar a distribuição de senciência nos animais não humanos. Isso incluiu uma parceria com autores do mais recente relatório sobre senciência em invertebrados, juntamente com a discussão em relação a dois grupos de invertebrados: os moluscos cefalópodes e os crustáceos decápodes, uma atualização e contextualização para o cenário brasileiro, além de também analisar potenciais implicações de bem-estar nas práticas atuais envolvendo tais animais. Os cefalópodes compreendem uma classe que abrange cerca de 750 espécies no filo dos moluscos, incluindo todas as espécies de polvo, lula, choco e náutilo (TANNER *et al*., 2017). Os decápodes constituem uma ordem de animais invertebrados pertencentes ao subfilo crustáceos, contendo cerca de 15.000 espécies, incluindo caranguejos verdadeiros, lagostas, lagostins e camarões verdadeiros (DE GRAVE *et al*., 2009; WOLFE *et al*., 2019). Esses táxons foram selecionados porque tem havido uma quantidade substancial de debate recente em torno de sua possível inclusão nas leis de proteção animal em vários países. Embora sejam apresentadas as questões de senciência nos cefalópodes e nos decápodes, a estrutura desenvolvida pode facilitar futuras avaliações da evidência de senciência em outros grupos taxonômicos.

3.2 UMA ESTRUTURA PARA AVALIAR EVIDÊNCIAS DE SENCIÊNCIA

Senciência é a capacidade de sentir. Sentimentos que podem incluir, por exemplo, dor, distresse, ansiedade, tédio, fome, sede, prazer, calor, alegria, conforto e excitação. Um ser senciente é consciente no sentido mais elementar e básico da palavra. Ele não precisa ser capaz de refletir conscientemente sobre seus sentimentos ou compreender os sentimentos dos outros: ser senciente é simplesmente ter sentimentos. Nas discussões sobre bem-estar animal, a senciência às vezes é definida de forma mais restrita, referindo-se especificamente à capacidade de ter sentimentos negativos e aversivos. O Comitê de Bem-Estar Animal do Reino Unido (anteriormente chamado de Comitê de Bem-Estar de Animais de Fazenda) definiu senciência como a capacidade de sentir dor, distresse ou dano (FAWC, 2018). Uma desvantagem dessa definição mais restrita é que ela deixa de fora o lado positivo da experiência subjetiva, como sentimentos de afeto, alegria, conforto e assim por diante. Uma vantagem é isso chama nossa atenção especificamente para o tipo de sentimentos que suscitam o tipo mais grave de preocupação ética. Neste relatório, senciência é considerada

como a capacidade de sentir, incluindo sentimentos positivos e negativos. No entanto, o aspecto negativo da senciência receberá maior ênfase, devido a importância especial dos sentimentos de dor, distresse ou dano para a legislação de bem-estar animal (como enfatizado, por exemplo, na Lei de Bem-Estar Animal de 2006).

A senciência é distinta da nocicepção. A nocicepção é a detecção pelo sistema nevoso de estímulos efetivamente ou potencialmente nocivos, alcançada por meio de receptores especializados chamados nociceptores. Um nociceptor é "um receptor sensorial de alto limiar do sistema nervoso somatossensorial periférico capaz de traduzir e codificar estímulos nocivos" (ASSOCIAÇÃO INTERNACIONAL PARA O ESTUDO DA DOR, 2017). A detecção de um estímulo nocivo não requer necessariamente senciência. É possível, em princípio, que um estímulo nocivo seja detectado sem qualquer experiência ou sensação por parte do sistema que o detecta. No entanto, a senciência e a nocicepção não são desconexas. Em humanos, sentimentos de dor, distresse ou dano frequentemente fazem parte da resposta a estímulos nocivos, conforme detectados inicialmente por nociceptores. Uma das sutilezas a ter em mente é que outras respostas à ativação de nociceptores, como a retirada reflexa, ainda podem ser independentes da experiência da dor. Nos seres humanos, os sentimentos de dor têm dois aspectos principais: um aspecto sensorial, como a percepção de uma lesão ou potencial lesão, e um aspecto afetivo, como sensações desagradáveis, aversivas e negativas. Esses dois aspectos são amplamente reconhecidos na pesquisa da dor humana (AUVRAY *et al*., 2010). É o aspecto afetivo e de valência negativa da dor que é a principal fonte de preocupação ética. Simplificando, a dor é desagradável, sendo o impulso de fazer algo para aliviá-la tipicamente forte. Tal lado afetivo da dor é o que se busca controlar com analgésicos (PRICE *et al*., 1985; CAPUTI *et al*., 2019).

A dor é apenas um exemplo dentro de uma ampla categoria de estados afetivos de valência negativa, uma categoria que também inclui estados de ansiedade, medo, fome, sede, frio, desconforto e tédio (BURN, 2017). Todos esses estados são ruins e motivam comportamentos destinados a remover suas causas. Todos os sentimentos de valência negativa diminuem o bem-estar de um indivíduo e, portanto, todos eles são fontes legítimas de preocupação ética. Consideramos todos os sentimentos negativos como formas de distresse ou dano, e todos eles são relevantes para questões de senciência.

3.2.1 A questão da senciência dos invertebrados

O progresso da neurociência e da biologia no final do século XX e início do século XXI gradualmente tornou insustentável a sugestão de que a senciência fosse exclusivamente humana, resultando na ampla aceitação dentro da comunidade científica da senciência de mamíferos e aves (BOLY *et al*., 2013). Nos últimos anos, livros de sucesso (MONTGOMERY, 2015; GODFREY-SMITH, 2016) popularizaram a ideia de que os polvos podem ser sencientes. Essa é uma ideia considerada por cientistas há várias décadas. O Reino Unido liderou nessa questão em 1993 ao incluir o polvo comum (*Octopus vulgaris*) para o âmbito da Lei de Animais (Procedimentos Científicos) de 1986 (ASPA). Em 2012, seguindo a diretiva da UE de 2010 sobre o uso de animais para fins científicos, o escopo da lei foi estendido a todos os moluscos cefalópodes.

Em 2012, a Declaração de Cambridge sobre Consciência (LOW *et al*., 2012) cristalizou um consenso científico de que os humanos não são os únicos seres conscientes. Ela acrescentou que "animais não humanos, incluindo todos os mamíferos e aves, e muitas outras criaturas, incluindo polvos" possuem substratos neurológicos suficientemente complexos para viabilizar experiências conscientes. Embora essa afirmação tenha sido formulada em termos de consciência e não de senciência, a capacidade de experiência consciente e a capacidade de senciência estão intimamente ligadas, porque os sentimentos são experiências conscientes no sentido mais básico e elementar do termo. A referência aos polvos destaca o crescente reconhecimento dentro da comunidade científica internacional de que pelo menos alguns invertebrados podem ser sencientes.

3.2.2 Por que essa questão importa?

A questão da senciência dos invertebrados importa tanto do ponto de vista ético quanto legal. Se um ser é senciente, há limites para o que um ser humano pode eticamente fazer com ele. Um ser senciente tem interesses, e não é ético agir de uma maneira que demonstre consideração inadequada ou nenhuma consideração por tais interesses. Essa ideia está no cerne das atuais legislações de proteção animal. Legalmente, no Reino Unido a senciência importa legalmente por várias razões. Primeiro, nenhum invertebrado foi incluído no escopo da Lei de Bem-estar Animal de 2006 (AWA) do Reino Unido, mas a Lei concede ao Secretário de Estado o poder de expandi-la se novas evidências científicas da capacidade de dor e sofrimento em invertebrados surgirem. Como a dor e o sofrimento são componentes

da senciência, avaliar evidências de senciência em invertebrados é crucial para definir o escopo da AWA.

Em segundo lugar, a Ordem de Bem-estar dos Animais (Transporte) (Inglaterra) de 2006 (WATEO) inclui todos os "animais invertebrados de sangue frio" e exige que seu transporte não cause lesões ou sofrimento desnecessário. Como o sofrimento requer senciência, a senciência é relevante para o escopo da WATEO. Terceiro, o Anexo 4 do Regulamento de Bem-estar no Momento do Abate (Inglaterra) de 2015 (WATOK) exige que todos os animais não protegidos de outra forma devem ser abatidos de forma humanitária, ou seja, sem dor, distresse ou sofrimento evitáveis. No entanto, permanece uma grande incerteza sobre quais métodos de abate, se houver, não causam dor, distresse e sofrimento evitáveis aos invertebrados. Novamente, a questão de quais invertebrados são sencientes é crucial para a aplicação adequada de tais regulamentos. Em quarto lugar, legislação diferente se aplica a procedimentos científicos, e o conceito de senciência desempenha um papel crucial nessa legislação. Como mencionado anteriormente, o polvo comum (*O. vulgaris*) foi incluído no escopo da ASPA em 1993. Na União Europeia (UE), todos os cefalópodes (incluindo polvos, lulas, chocos e náutilos) foram incluídos no escopo da Diretiva da UE 2010/63/EU sobre a proteção de animais utilizados para fins científicos, e a ASPA foi emendada em conformidade em 2012. No Brasil, as leis de proteção animal mais fundamentais, i.e., o artigo 225 da Constituição Federal e a Lei Ambiental 9605/1998, abrangem todos os animais sem nenhuma distinção taxonômica. Desta forma, há amplo escopo para sua interpretação a partir da consideração do benefício da dúvida para as espécies cuja possibilidade de senciência ainda é menos conhecida. Entretanto, no cenário legal brasileiro há também leis que excluem os invertebrados de sua proteção, como é o caso da Lei 11.794/2008, sobre uso de animais em pesquisa e conhecida como Lei Arouca, que protege apenas os animais vertebrados.

3.2.3 Quais animais são sencientes?

Existem importantes obstáculos para responder à pergunta sobre a senciência de invertebrados além de qualquer dúvida razoável. Sentimentos, como dor, não podem ser observados diretamente. A melhor evidência que existe da senciência em outros seres humanos é que eles podem relatar suas experiências — podem nos dizer o que estão sentindo. Mesmo em relação a outros mamíferos, não há esse tipo de evidência, pelo menos não na linguagem humana. O que existe para outros mamíferos são as evidências de semelhança substancial com seres humanos em termos de organização cerebral, função cerebral, cognição,

afeto e comportamento. A parte do cérebro mais intimamente ligada às experiências subjetivas em seres humanos é o neocórtex, uma estrutura no córtex cerebral que consiste em seis camadas ricamente organizadas de tecido neural. A presença de um neocórtex em outros mamíferos, com a mesma organização, significa um ponto de consenso científico sobre a senciência de outros mamíferos. Essa estratégia de procurar mecanismos e estruturas neurais que são compartilhadas com o cérebro humano também funciona, mas em menor grau, para aves. As aves têm uma estrutura chamada pálio dorsal que se assemelha ao neocórtex dos mamíferos. Embora a arquitetura seja diferente, os padrões de conectividade são semelhantes (CLAYTON; EMERY, 2015; GÜNTÜRKÜN; BUGNYAR, 2016). Geralmente se considera implausível que as diferenças na organização cerebral entre mamíferos e aves possam fazer uma diferença relevante entre a presença e a ausência de senciência. Portanto, há um amplo consenso de que as aves também são sencientes (BOLY *et al*., 2013).

No entanto, essa estratégia começa a perder eficácia ao analisar vertebrados mais distantes dos seres humanos, como os peixes. Os cérebros dos peixes diferem substancialmente daqueles dos mamíferos. Não há neocórtex ou uma estrutura que se assemelhe ao neocórtex. Como resultado, o ceticismo sobre a senciência de peixes às vezes é expresso (KEY, 2016), embora tais expressões de ceticismo sejam recebidas com resistência vigorosa (por exemplo, SNEDDON *et al*., 2018). O sistema nervoso dos invertebrados difere daquele do ser humano muito mais radicalmente que aquele dos peixes. Invertebrados e seres humanos estão separados por mais de 500 milhões de anos de evolução. A estrutura básica do cérebro dos vertebrados, que consiste em um prosencéfalo, um mesencéfalo e um rombencéfalo, não está presente em invertebrados (FEINBERG; MALLATT, 2016). Contudo, não se pode concluir que a senciência esteja ausente em um invertebrado simplesmente porque seu cérebro é organizado de maneira diferente de um cérebro de vertebrado. Por analogia, o olho de um cefalópode é organizado de maneira muito diferente do olho de um mamífero, mas não podemos concluir com base nisso que os cefalópodes não podem enxergar. Várias vias neurológicas podem existir para o mesmo resultado. Não há motivos para pensar que a senciência não possa ser alcançada por sistemas estruturalmente diferentes dos cérebros de vertebrados (por exemplo, FEINBERG; MALLATT, 2016; GINSBURG; JABLONKA, 2019).

Isso levanta a questão: o que constitui evidência de senciência em uma espécie evolutivamente distante dos seres humanos, para a qual não se pode esperar semelhanças na organização cerebral? A resposta é que devemos confiar, pelo menos em parte, em indicadores comportamentais e cognitivos de senciência. É necessário caracterizar

cuidadosamente os tipos de comportamentos e de habilidades cognitivas que implicam em um risco claro de dor, distresse ou dano ao animal e integrar essas evidências comportamentais e cognitivas com o que é conhecido sobre o sistema nervoso do animal. Há considerável esforço científico para de encontrar os mais relevantes indicadores de senciência (por exemplo, SMITH; BOYD, 1991; BATESON, 1991; AHAW, 2005; VARNER, 2012; SNEDDON et al., 2014; BROOM, 2014).

É concebível, para qualquer conjunto de indicadores comportamentais, cognitivos e neurocientíficos da senciência, que tais indicadores podem ser alcançados sem a presença de senciência. É por isso que não se pode resolver a questão da senciência dos invertebrados com certeza ou colocá-la além de qualquer dúvida. Entretanto, tal nível de prova é demais para se exigir neste contexto. Na presença de graves riscos de bem-estar, às vezes é necessário agir com base em evidências que não fornecem certeza completa. Este é um princípio geralmente aceito no campo da ciência do bem-estar animal (BATESON, 1992; BRADSHAW, 1998; BIRCH, 2017) e foi explicitamente dado como a justificativa para a inclusão do *O. vulgaris* no escopo da ASPA em 1993. O Presidente Comitê de Procedimentos com Animais (atualmente Comitê de Animais na Ciência), escreveu que "as evidências científicas atualmente disponíveis [na época] são insuficientes para concluir com certeza que os cefalópodes podem sentir dor e sofrimento", mas enfatizou a importância de dar o benefício da dúvida ao polvo comum apesar desta incerteza (APC 1992, Seção 3). Ao mesmo tempo, não devemos presumir automaticamente a senciência em animais que foram repetidamente e meticulosamente investigados em busca de evidências de senciência com pouca ou nenhuma evidência convincente encontrada.

3.2.4 Critérios para reconhecimento de senciência

Em 1991, um Grupo de Trabalho do Instituto de Ética Médica do Reino Unido produziu uma lista de sete critérios para a senciência que influenciaram a política subsequente de bem-estar animal (SMITH; BOYD, 1991, Tabela 1). Por exemplo, esses critérios foram aplicados em 2005 pelo Painel de Saúde e Bem-estar Animal da Agência Europeia de Normas Alimentares em um relatório científico que moldou a diretiva da UE de 2010 sobre o uso de animais para fins científicos (AHAW, 2005). Os sete critérios fornecem um bom ponto de partida; no entanto, eles foram concebidos considerando-se a avaliação de animais vertebrados. Assim, eles não são critérios ideais para propósitos de compreensão da senciência em invertebrados.

Tabela 1. Sete critérios de senciência propostos por Smith & Boyd, 1991.

Número	Critério
1	Posse de receptores sensíveis a estímulos nocivos, localizados em posições funcionalmente úteis e conectados por vias nervosas às partes inferiores de um sistema nervoso central.
2	Posse de centros cerebrais mais elevados no sentido de nível de integração do processamento cerebral, especialmente uma estrutura análoga ao córtex cerebral humano.
3	Posse de vias nervosas que conectam o sistema nociceptivo aos centros cerebrais superiores.
4	Receptores de substâncias opioides no sistema nervoso central, especialmente no cérebro.
5	Os analgésicos modificam a resposta de um animal a estímulos que são dolorosos para um ser humano.
6	A resposta de um animal a estímulos que são dolorosos para um ser humano é funcionalmente semelhante à resposta humana, ou seja, o animal responde de forma a evitar ou minimizar danos ao seu corpo.
7	A resposta comportamental do animal persiste, e ele mostra relutância em se submeter novamente a um procedimento doloroso; o animal pode aprender a associar eventos aparentemente não dolorosos com eventos aparentemente dolorosos.

Com o objetivo de avançar na compreensão da senciência em animais invertebrados, os critérios de Smith e Boyd (1991) foram revisados e atualizados por Birch *et al*., 2021, à luz das necessidades mais específicas relativas a este grupo taxonômico. O resultado é uma lista de oito critérios apresentada na Tabela 2.

Tabela 2. Oito critérios de senciência propostos por Birch et al., 2021.

Número	Critério
1	O animal possui receptores sensíveis a estímulos nocivos (nociceptores).
2	O animal possui regiões cerebrais capazes de integrar informações de diferentes fontes sensoriais.
3	O animal possui vias neurais que conectam os nociceptores às regiões integrativas do cérebro.
4	A resposta comportamental do animal a um estímulo nocivo é modulada por compostos químicos que afetam o sistema nervoso em uma ou ambas as seguintes maneiras: (1) sistema de neurotransmissores endógenos que modula (de forma consistente com a experiência de dor, distresse ou dano) suas respostas a estímulos nocivos reais ou potenciais; (2) anestésicos locais, analgésicos (como opioides), ansiolíticos ou antidepressivos modificam as respostas a estímulos nocivos reais ou potenciais de forma consistente com a hipótese de que esses compostos atenuam a experiência de dor, distresse ou dano.
5	O animal usa compensações motivacionais, nas quais o desvalor de um estímulo nocivo ou ameaçador é ponderado em relação ao valor de uma oportunidade de recompensa, levando a uma tomada de decisão flexível; deve ser demonstrada flexibilidade suficiente para indicar o processamento centralizado e integrador de informações envolvendo uma avaliação.
6	O animal apresenta um comportamento autoprotetor flexível (por exemplo, cuidar de feridas, guardar, limpar, esfregar) de um tipo que provavelmente envolve a representação mental da localização corporal de um estímulo nocivo.
7	O animal demonstra aprendizagem associativa em que estímulos nocivos se associam a

	estímulos neutros ou em que novas maneiras de evitar estímulos nocivos são aprendidas por meio de reforço. Nota: habituação e sensibilização não são suficientes para cumprir este critério.
8	O animal demonstra valorizar um analgésico ou anestésico quando ferido de uma ou mais das seguintes maneiras: (1) o animal aprende a autoadministrar analgésicos ou anestésicos potenciais quando ferido; (2) o animal aprende a preferir, quando ferido, um local em que analgésicos ou anestésicos possam ser acessados; (3) o animal prioriza a obtenção desses compostos sobre outras necessidades (como alimentação) quando ferido.

Embora os critérios comportamentais e cognitivos (critérios 5-8) sejam especialmente importantes no caso de invertebrados, critérios neurobiológicos (critérios 1-4) permanecem para que o quadro geral tenha um equilíbrio entre evidências neurobiológicas e cognitivo-comportamentais. Vale ressaltar que nenhum critério único fornece evidência conclusiva de senciência por si só.

3.2.5 Proposta de classificação

Como o reconhecimento da senciência depende de vários critérios, é útil ter um sistema de integração das várias informações para se concluir sobre cada espécie. A proposta de classificação utiliza níveis de confiança para comunicar a força da evidência de que os animais em discussão satisfazem ou falham em cada critério. Os níveis de confiança possíveis são confiança muito alta, confiança alta, confiança média, confiança baixa, confiança muito baixa e nenhuma confiança. Os níveis de confiança levam em conta tanto a quantidade de evidências para uma alegação quanto a confiabilidade e qualidade do trabalho científico. A categoria de “confiança muito alta” é identificada somente quando há uma grande quantidade de evidências confiáveis e de alta qualidade, ou seja, quando o peso da evidência científica não deixa margem para dúvidas razoáveis. A categoria de “alta confiança” refere-se aos casos em que, depois de considerar cuidadosamente todas as evidências, há evidências suficientes para considerar que os animais satisfazem ou reprovam no critério, mesmo que reste algum espaço para dúvidas razoáveis. A categoria de “confiança média” surge nos casos em que há preocupações sobre a confiabilidade das evidências, que impedem uma confiança alta. Para casos em que há pouca evidência de que um animal satisfaça ou falhe no critério denomina-se “baixa confiança”, e “muito baixa” ou “nenhuma confiança” quando a evidência for seriamente inadequada ou inexistente. Assim, quando se tem “baixa confiança” de que um critério é satisfeito, isso não significa que a senciência é improvável ou refutada, mas sim que a evidência é fraca, de baixa qualidade, ou ambas. Um esquema de classificação aproximado é

proposto para passar dos critérios individuais para um julgamento geral. A confiança alta ou muito alta de que um animal satisfaz sete ou mais dos critérios equivale a uma evidência muito forte de senciência. A confiança alta ou muito alta de que um animal satisfaz cinco ou mais critérios equivale a uma forte evidência de senciência, e a confiança alta ou muito alta de que um animal satisfaz três mais critérios equivale a uma evidência substancial de senciência.

3.3 AVALIANDO AS EVIDÊNCIAS DE SENCIÊNCIA EM CEFALÓPODES

Nesta seção, foram revisitadas todas as evidências dos cefalópodes que se relacionam com os oito critérios de senciência (Tebela 3). Revisões relevantes sobre este tópico incluem AHAW (2005), Andrews *et al*. (2013), Sneddon *et al*. (2014), Broom (2014), della Rocca *et al*. (2015), Sneddon (2015) e Fiorito *et al*. (2015). Embora todas essas revisões sejam de alta qualidade, novas evidências surgiram desde que foram escritas. Em vez de depender de revisões passadas, fora revisitadas todas as evidências originais para produzir uma revisão atualizada. Ainda, é importante salientar que nos casos em que não há confiança alta ou muito alta de que um critério é satisfeito, isso ocorre invariavelmente por falta de evidência positiva, e não por evidência clara de que os animais falharam no critério.

3.3.1 Critério 1

Existem condições para uma confiança muito alta de que polvos (ordem Octopoda), lulas miopsídeo (Myopsida) e lulas bobtail (Sepiolida) satisfazem o critério 1. Há alta confiança, com base em considerações evolutivas e evidências de outros moluscos com sistemas nervosos mais simples (CROOK; WALTERS, 2011; WALTERS, 2018), que outros cefalópodes, incluindo outras lulas, chocos (ordem Sepiida) e nautilóides (Nautilida) também satisfazem o critério 1. Há evidências de alta qualidade de que lulas e polvos possuem neurônios sensoriais aferentes que respondem diferencialmente a estímulos nocivos, que sofrem sensibilização e mostram ativação espontânea após exposição a estímulos nocivos (ROWELL, 1963, 1966; ALTMAN, 1971; ROSS, 1971; CROOK *et al*., 2013; HAGUE *et al*., 2013; ALUPAY *et al*., 2014; PEREZ *et al*., 2017; HOWARD *et al*., 2019; BAZARINI; CROOK, 2020; CROOK, 2021). Os polvos também possuem marcadores moleculares de nociceptores em seus tentáculos (DI CRISTINA, 2017). Essa evidência atualmente se baseia principalmente em estudos com polvos (particularmente *O. vulgaris*), com alguns estudos mais recentes em lulas.

3.3.2 Critério 2

Existe uma confiança muito alta de que os cefalópodes coleóides (polvos, lulas e chocos) satisfazem o critério 2. Há evidências fortes de que os cefalópodes coleóides possuem cérebros complexos e centralizados capazes de integrar diferentes tipos de informações, inclusive nociceptivas (YOUNG 1963a, 1979, WELLS, 1978; BUDELMANN, 1995; GUTNICK *et al*., 2001; HOCHNER *et al*., 2006; ZULLO *et al*., 2009; ZULLO; HOCHNER, 2011; HOCHNER, 2012; BROWN; PISCOPO, 2013; ANDREWS *et al*., 2013; DELLA ROCCA *et al*., 2015; FIORITO *et al*., 2015; ZARRELLA *et al*., 2015; SHIGENO *et al*., 2018). Embora não haja uma estrutura identificada como um análogo direto ao córtex cerebral de mamíferos, o lobo vertical é o centro cerebral responsável pela aprendizagem e memória (YOUNG, 1963b, 1991; SHIGENO *et al*., 2018). Tais estruturas não estão presentes em nautilóides (BUDELMANN, 1995; NIXON; YOUNG, 2003)

3.3.3 Critério 3

Há alta confiança de que os cefalópodes coleóides (polvos, lulas e chocos) satisfazem o critério 3. Mais evidências neurofisiológicas são necessárias para gerar uma confiança muito alta. Há evidências indiretas sobre conexões entre os nociceptores e regiões integrativas do cérebro em cefalópodes. Existe uma alta conectividade entre o sistema nervoso periférico e o cérebro central, bem como entre os diferentes lobos do cérebro, e essas vias podem retransmitir sinais nociceptivos para regiões integrativas do cérebro (YOUNG, 1963a, 1979, 1991; BUDELMANN; YOUNG, 1985; NIXON; YOUNG, 2003; HOCHNER, 2012; ANDREWS *et al*., 2013; CROOK *et al*., 2013; ALUPAY *et al*., 2014; FIORITO *et al*., 2015; ZARELLA *et al*., 2015; DI CRISTINA., 2017; LEVY; HOCHNER, 2017; PEREZ *et al*., 2017; BUTLER-STRUBEN *et al*., 2018; BAZARINI; CROOK, 2020; CROOK, 2021), mas isso ainda não foi demonstrado de maneira irrefutável (ANDREWS *et al*., 2013; FIORITO *et al*., 2015; ZARELLA *et al*., 2015).

3.3.4 Critério 4

Há alta confiança de que os polvos satisfazem o critério 4. Não há evidências suficientes no momento para uma confiança média ou alta de que outros cefalópodes

satisfazem este critério. Um estudo notável de 2021 fornece evidências da modificação das respostas a estímulos nocivos por um anestésico local (lidocaína) em polvos (CROOK, 2021). Atualmente, existem algumas evidências de que o cloreto de magnésio também pode atuar como anestésico local em polvos (BUTLER-STRUBEN *et al*., 2018). Há também evidências da presença de neurotransmissores e receptores endógenos relevantes em cefalópodes (ANDREWS *et al*., 2013; ZARELLA *et al*., 2015; FIORITO *et al*., 2015), incluindo encefalinas (MARTIN *et al*., 1979; CROOK; WALTERS, 2011; SHA *et al*., 2012; DI CRISTINA, 2017), estrogênio (SHOMRAT *et al*., 2010; SHOMRAT *et al*., 2015; BAZARINI; CROOK, 2020) e serotonina (PEREZ *et al*., 2017), mas estes não foram diretamente ligados à atividade nas vias nociceptivas. Novos estudos, principalmente sobre os efeitos de analgésicos e similares, são importantes para fornecer tais informações.

3.3.5 Critério 5

Não há evidências suficientes para termos alta confiança de que qualquer molusco cefalópode satisfaz o critério 5. No entanto, evidências indiretas de cefalópodes coleóides são sugestivas de trocas motivacionais, permitindo um nível médio de confiança. O gargalo parece ser a inexistência de estudos que testem diretamente as compensações motivacionais em cefalópodes. Existem estudos mostrando que uma ameaça ou lesão produz mudanças comportamentais (SUTHERLAND *et al*., 1963; ROSS, 1971; BOAL *et al*., 2000; CROOK *et al*., 2011; CROOK *et al*., 2014; BEDORE *et al*., 2015; OSHIMA *et al*., 2016; WILSON *et al*., 2018; HOWARD *et al*., 2019). Os resultados são compatíveis com a hipótese de que os cefalópodes estão cientes de suas lesões e mudam suas prioridades quando feridos, mas também são compatíveis com a hipótese de que a lesão produz diretamente aumento da sensibilidade à ameaça.

3.3.6 Critério 6

Há uma confiança muito alta de que os polvos satisfazem o critério 6 e uma confiança média de que os chocos o satisfazem. A evidência muito forte de limpeza e proteção de feridas é observada em polvos, pois os indivíduos feridos enrolaram os tentáculos adjacentes em torno do local ferido ou tentaram esfregar a área ferida (POLGLASE *et al*., 1983; ALUPAY *et al*., 2014; FIORITO *et al*., 2015; CROOK, 2021). Há evidências baseadas em observações pessoais de tratamento de feridas em chocos, permitindo confiança média, mas

neste caso não há evidências em artigos revisados por pares (I. GLEADALL, observação pessoal citada em ANDREWS *et al*., 2013; observação pessoal de A.K. SCHNELL e C. JOZET-ALVES comunicada a A.K. SCHNELL). Em lulas, há evidência de sensibilização nociceptiva generalizada após lesão, mas nenhuma evidência de comportamento protetor direcionado especificamente ao local de uma ferida (CROOK *et al*., 2011; CROOK *et al*., 2013; CROOK *et al*., 2014; BAZARINI; CROOK, 2020).

3.3.7 Critério 7

Há uma confiança muito alta de que os polvos (Octopoda) e os chocos (Sepiida) satisfazem o critério 7. Há também uma confiança alta de que as lulas o satisfazem e uma confiança média para os nautilóides. A aprendizagem associativa foi demonstrada de forma convincente em polvos e chocos (MATHER, 1995; DARMAILLACQ *et al*., 2004; AGIN *et al*., 2006; HOCHNER *et al*., 2006; MATHER, 2008; MARINI *et al*., 2017; HANLON; MESSENGER, 2018; SCHNELL *et al*., 2020). Poucos estudos investigaram o aprendizado associativo em lulas (ALLEN *et al*., 1985; ZEPEDA *et al*., 2017), mas o quadro geral de evidências aponta para o aprendizado associativo como uma capacidade compartilhada dos cefalópodes coleóides (HOCHNER *et al*., 2006). Existem também poucos estudos em nautilóides, mas as evidências que existem apontam para uma capacidade de aprendizagem associativa (CROOK; BASIL, 2008; CROOK *et al*., 2009).

3.3.8 Critério 8

Há evidências em um artigo recém-publicado de que os octópodes satisfazem o critério 8. Embora este seja um estudo único, sua alta qualidade permite alta confiança no resultado. O estudo fornece evidências de que um polvo aprende a preferir, quando exposto a um estímulo nocivo (ácido acético), uma câmara na qual um anestésico local pode ser acessado (CROOK, 2021).

Tabela 3. Resumo da evidência de senciência em cefalópodes; as letras representam o nível de confiança de que o critério em questão é atendido pelos grupos taxonômicos de animais; MA indica uma confiança muito alta, A indica alta confiança, M indica confiança média, B representa baixa confiança, e MB representa uma confiança muito baixa.

	Critério 1	Critério 2	Critério 3	Critério 4	Critério 5	Critério 6	Critério 7	Critério 8
Polvos (Octopoda)	MA	MA	A	A	M	MA	MA	A
Choco (Sepiida)	A	MA	A	B*	M	M	MA	B*
Outros coleóides (lulas, de todas as ordens)	A	MA	A	B*	M	B*	A	B*
Nautilóides	A	B*	B*	B*	B*	B*	M	MB*

* É importante destacar que confiança baixa ou muito baixa implica apenas que a evidência científica de um modo ou de outro é fraca, não que o animal falhe ou é provável que falhe no critério.

3.4 AVALIANDO AS EVIDÊNCIAS DE SENCIÊNCIA EM DECÁPODES

Nesta seção, foram revisitadas todas as evidências de decápodes que se relacionam com os oito critérios de senciência (Tabela 4). Revisões relevantes sobre esse tópico desde 2000 incluem as de Sherwin (2001), AHAW (2005), Elwood *et al*. (2009), Gherardi (2009), Broom (2014), Sneddon *et al*. (2014), Sneddon (2015), Burrell (2017), Walters (2018) e Elwood (2019a, b). Embora todas essas revisões sejam de alta qualidade, nova evidências surgiram desde que foram escritas. Em vez de depender de revisões passadas, foram revisitadas todas as evidências originais a fim de produzir uma revisão atualizada.

3.4.1 Critério 1

Evidências genéticas e evidências de outros artrópodes levam a alta confiança de que os nociceptores estão disseminados nos decápodes. Seriam necessárias evidências neurofisiológicas diretas para uma confiança muito alta. Duas linhas principais de evidência apoiam a hipótese de que os nociceptores estão disseminados nos decápodes. Primeiro, os nociceptores estão presentes em outros artrópodes, como os insetos (WALTERS, 2018). Em segundo lugar, as famílias de canais iônicos envolvidas na nocicepção são altamente conservadas evolutivamente, tendo sido caracterizadas em espécies que variam de platelmintos a humanos (ARENAS *et al*., 2017; KÁDKOVÁ *et al*., 2017), e várias proteínas de canais iônicos homólogas foram encontradas expressas em caranguejos e lagostas (TRACEY *et al*., 2003; PURY; FAULKES, 2010; IM; GALKO, 2012; FAULKES, 2015; KOZMA *et al*., 2018; KOZMA *et al*., 2020). Tomadas em conjunto com as evidências

comportamentais consideradas posteriormente, essas linhas de evidências juntas sugerem que os nociceptores estão presentes nos decápodes.

3.4.2 Critério 2

Há uma confiança muito alta de que o critério 2 é satisfeito por caranguejos verdadeiros (infraordem Brachyura), caranguejos anomuros (Anomura), lagostas e lagostins (Astacidea, Achelata) e camarões carídeos (Caridea). Pode ser que esse critério seja satisfeito por outras infraordens de decápodes, mas muitas delas não foram estudados em detalhes. Decápodes possuem cérebros que integram informações de diferentes fontes sensoriais. O complexo central, os corpos hemielipsóides e os lobos acessórios desempenham funções integrativas (UTTING *et al*., 2000; DEFOREST MELLON, 2003; BROWN; WOLFF, 2012; MAZA *et al*., 2016; SAYRE; STRAUSFELD, 2019; STRAUSFELD *et al*., 2020). Os caranguejos verdadeiros (infraordem Brachyura) e os caranguejos anomuros (Anomura) parecem ter os corpos hemielipsóides proporcionalmente maiores e mais desenvolvidos entre os decápodes estudados até agora, seguidos pelos camarões carídeos (Caridea) (KRIEGER *et al*., 2010; MACHON *et al*., 2019; STRAUSFELD *et al*., 2020). Lagostas e lagostins (Astacidea, Achelata) têm corpos hemielipsóides relativamente pequenos, mas integram informações usando lobos acessórios relativamente aumentados (SANDEMAN *et al*., 1995; WACHOWIAK *et al*., 1996; SANDEMAN *et al*., 2014).

3.4.3 Critério 3

Há baixa confiança de que os decápodes satisfazem o critério 3. Isso se deve exclusivamente e à falta de evidências suficientes para que haja confiança média ou alta. As vias neurais conectam outros receptores sensoriais às regiões integrativas do cérebro em decápodes, e é plausível que os nociceptores estejam conectados às mesmas regiões cerebrais, mas não foram encontradas evidências que atendam especificamente o critério 3 (SANDEMAN *et al*., 2014).

3.4.4 Critério 4

Há uma confiança muito alta de que o critério 4 é atendido por caranguejos verdadeiros (infraordem Brachyura) e por lagostas/lagostins de água doce (Astacidea). Há

confiança média de que o critério 4 é atendido por camarões carídeos (Caridea) e camarões peneídeos (família Penaeidae). Para outros táxons, não existem evidências suficientes para permitir ter confiança média, alta ou muito alta. Os crustáceos decápodes possuem sistemas endógenos de neurotransmissores, incluindo sistemas endógenos de opioides, serotoninérgicos, dopaminérgicos e octopaminérgicos (HARLIOĞLU *et al*., 2020). Em caranguejos verdadeiros (infraordem Brachyura), os opioides medeiam a resposta a estímulos ameaçadores e potencialmente dolorosos (LOZADA *et al*., 1988; MALDONADO *et al*., 1989; VALEGGIA *et al*., 1989; ROMANO *et al*., 1990; TOMSIC; MALDONADO, 1990; TOMSIC *et al*., 1991; TOMSIC *et el*., 1993; GODOY; MALDONADO, 1995; BARR; ELWOOD 2011). Esse efeito é consistente com a hipótese de que os opioides atenuam experiências aversivas, ao mesmo tempo em que é consistente com a hipótese de que os opioides produzem uma redução geral na responsividade. Há também evidências de um papel da dopamina (KLAPPENBACH *et al*., 2012) e da octopamina (KACZER; MALDONADO, 2009; KACZER *et al*., 2011) na mediação da aprendizagem de estímulos aversivos e atrativos. Tanto em caranguejos verdadeiros quanto em astacídeos, há evidências de que a serotonina medeia as respostas ao estresse (AGGIO *et al*., 1996) e evidências de que drogas antidepressivas ou ansiolíticas podem ser usadas para modular a resposta (FOSSAT *et al*., 2014; FOSSAT *et al*., 2015; HAMILTON *et al*., 2016; BACQUÉ-CAZENAVE *et al*., 2017; PERROT-MINNOT *et al*., 2017). Há também evidências de que o anestésico tópico lidocaína modula as respostas à lesão em camarões carídeos e peneídeos (TAYLOR *et al*., 2004; DIARTE-PLATA *et al*., 2012).

3.4.5 Critério 5

Há uma confiança média de que as compensações motivacionais estão presentes em caranguejos anomuros (infraordem Anomura). Há evidências de alta qualidade de que as respostas ao choque elétrico em caranguejos eremitas (infraordem Anomura) são moduladas pelo odor (MAGEE; ELWOOD, 2016a). Há também evidências de que as respostas dos caranguejos eremitas ao choque elétrico também são moduladas pela qualidade da concha (ELWOOD *et al*., 1979; ELWOOD, 1995; APPEL; ELWOOD, 2009a), mas essa evidência é menos confiável, devido a potenciais fatores de confusão, e os principais resultados são apenas marginalmente estatisticamente significativos. Há evidências de alta qualidade de que a tolerância à ameaça em lagostins depende do estresse fisiológico (FOSSAT *et al*., 2014; FOSSAT *et al*., 2015; BACQUÉ-CAZENAVE *et al*., 2017), mas esse tipo de sensibilidade

não é evidência de um sistema de tomada de decisão centralizado que pondera as diferentes necessidades entre si.

3.4.6 Critério 6

Existe uma confiança muito alta de que os caranguejos verdadeiros (infraordem Brachyura) satisfazem o critério 6. Há uma alta confiança de que os caranguejos anomuros (Anomura) satisfazem o critério 6. Também há uma confiança média de que os camarões carídeos (Caridea) satisfazem o critério 6. Linhas de evidência de diferentes estudos sustentam a hipótese de que espécies de caranguejos verdadeiros (infraordem Brachyura) são capazes de direcionar comportamentos de autoproteção para o local de um estímulo nocivo (por exemplo, garra, boca, abdômen) (KOTSYUBA *et al*., 2010; DYUIZEN *et al*., 2012; MCCAMBRIDGE *et al*., 2016; ELWOOD *et al*., 2017). Embora nenhum estudo isolado seja totalmente convincente, eles fornecem boas evidências quando considerados em conjunto. Há também relatos credíveis de comportamento de limpeza direcionado em caranguejos eremitas (Anomura) (APPEL; ELWOOD, 2009b). A evidência de comportamento autoprotetor direcionado às antenas em camarões (BARR *et al*., 2008; DIARTE-PLATA *et al*., 2012) tem sido contestada (PURI; FAULKES, 2010).

3.4.7 Critério 7

Há uma alta confiança de que caranguejos verdadeiros (infraordem Brachyura) satisfazem o critério 7 e uma confiança média de que lagostas/lagostins (infraordem Astacidea e Achelata) satisfazem o critério 7. Estudos fornecem evidências convincentes de aprendizagem associativa em caranguejos verdadeiros (infraordem Brachyura) (DENTI *et al*., 1988; DIMANT; MALDONADO, 1992; FERNANDEZ-DUQUE *et al*., 1992; MAGEE; ELWOOD, 2013; MAGEE; ELWOOD, 2016b), embora existam também alguns estudos pouco convincentes e um notável resultado nulo. O estudo da aprendizagem associativa em outros táxons de decápodes (como lagostins e lagostas) (FINE-LEVY *et al*., 1988; KAWAI *et al*., 2004; TOMINA; TAKAHATA, 2010; BHIMANI; HUBER, 2016; DATTA *et al*., 2018) está em um estágio comparativamente inicial e ainda não produziu resultados convincentes. A literatura destaca os desafios do desenvolvimento de desenhos experimentais que distinguem rigorosamente a aprendizagem associativa da habituação e da sensibilização.

3.4.8 Critério 8

Em relação ao critério 8, o nível de confiança é muito baixo para todas as infraordens, pois não há evidências a favor ou contra a afirmação de que qualquer decápode satisfaz esse critério.

Tabela 4. Resumo da evidência de senciência em decápodes; as letras representam o nível de confiança de que o critério em questão é atendido pelos grupos taxonômicos de animais; MA indica uma confiança muito alta, A indica alta confiança, M indica confiança média, B representa baixa confiança, e MB representa uma confiança muito baixa.

	Critério 1	Critério 2	Critério 3	Critério 4	Critério 5	Critério 6	Critério 7	Critério 8
Caranguejos verdadeiros (Brachyura)	A	MA	B*	MA	B*	MA	A	MB*
Caranguejos anomuros (Anomura)	A	MA	B*	B*	M	A	B*	MB*
Lagostas e lagostins (Astacidea)	A	MA	B*	MA	B*	B*	M	MB*
Lagostas espinhosas (Achelata)	A	MA	B*	B*	B*	B*	M	MB*
Camarões carídeos (Caridea)	A	MA	B*	M	B*	M	B*	MB*
Camarões peneídeos (Penaeidae)	A	B*	B*	M	B*	B*	B*	MB*

* É importante destacar que confiança baixa ou muito baixa implica apenas que a evidência científica de um modo ou de outro é fraca, não que o animal falhe ou é provável que falhe no critério.

3.5 RISCOS DE BEM-ESTAR NAS PRÁTICAS COMERCIAIS COM CEFALÓPODES E DECÁPODES

O objetivo desta seção não é fornecer um guia completo de boas práticas para garantir o bem-estar de cefalópodes e decápodes, mas descrever práticas específicas que estão atreladas a um risco de bem-estar muito baixo.

Cefalópodes capturados na natureza, durante a pesca marítima, quando não morrem durante o processo de captura, geralmente morrem após serem retirados da água, com riscos significativos para o bem-estar devido a traumas físicos e asfixia (PIERCE *et al.*, 2010; FLORINI *et al.*, 2011; PEREIRA; LOURENÇO, 2014). Não há uma maneira fácil de mitigar tais riscos, mas códigos de boas práticas devem ser desenvolvidos para os casos em que os cefalópodes são capturados vivos.

Embora não haja cultivo de cefalópodes no Reino Unido e no Brasil, há algum interesse em outras partes do mundo. Globalmente, a aquicultura de cefalópodes é atualmente de pequena escala e envolve poucas espécies (O'BRIEN *et al*., 2018). No entanto, fazendas podem ser encontradas na Europa, Austrália, América Latina e Ásia (JACQUET *et al*., 2019). Os cefalópodes são às vezes sugeridos como candidatos atraentes para a aquicultura comercial em larga escala, devido à crescente demanda pelo consumo de cefalópodes, seu alto valor, rápido crescimento, alta taxa de conversão alimentar, alto teor de proteínas e alta fecundidade (PIERCE *et al*., 2010). *S. officinalis* e *O. vulgaris* foram descritos como candidatos promissores para a aquicultura comercial na Europa, e certos progressos já foram feitos para a criação de *O. vulgaris* na Espanha. Entretanto, tal progresso tem sido alvo de críticas relacionadas principalmente ao bem-estar dos animais (BBC NEWS, 2023). Com exceção de algumas espécies, os polvos e as lulas são animais relativamente solitários. Assim, quando confinados, podem ocorrer brigas entre indivíduos, além de comportamentos como autofagia/automutilação e tendências canibais (AGUADO-GIMÉMENZ; GARCÍA GARCÍA, 2002; BUDELMANN, 2010; HAYTER, 2005; IBÁÑEZ; KEYL, 2010; JACQUET *et al*., 2019; MOLTSCHANIWSKYJ *et al*., 2007; PIERCE *et al*., 2010). Adicionalmente, não existe um método de abate humanitário que possa ser realizado comercialmente em larga escala (ANDREWS *et al*., 2013; BOYLE, 2010; FIORITO *et al*., 2015). Portanto, há uma confiança muito alta de que a criação comercial de cefalópodes de alto bem-estar é atualmente impossível.

No que tange à captura, transporte e venda de decápodes, há alta confiança de que a remoção das garras (arrancar uma ou ambas as garras de um caranguejo antes de devolvê-lo à água) causa sofrimento aos caranguejos (MCCAMBRIDGE *et al*., 2016; DUERMIT *et al*., 2015; PATTERSON *et al*., 2007; PATTERSON *et al*., 2009). Também há alta confiança de que a prática de cortar o tendão da garra de um caranguejo (conhecida como “nicking”) causa sofrimento e representa um risco para a saúde do animal (WELSH *et al*., 2013; JOHNSON *et al*., 2016). Existe uma confiança muito alta de que um bom grau de bem-estar durante o transporte e armazenamento de decápodes requer uma densidade de lotação adequada, acesso a abrigos escuros e temperaturas frias (para armazenamento úmido, não mais que 8°C) (JACKLIN; COMBES, 2005; BARR; ELWOOD, 2011; BARRENTO *et al*., 2011; BARRENTO *et al*., 2012; FOSSAT *et al*., 2014; FOSSAT *et al*., 2015; HAMILTON *et al*., 2016; CARDER, 2017). Decápodes vivos podem ser encomendados de varejistas online, existindo uma confiança muito alta de que tal prática inerentemente cria um risco de manuseio inadequado e métodos de abate inapropriados. Existe uma confiança média de que o

atordoamento elétrico é eficaz em tornar os decápodes inconscientes (ALKIRE *et al*., 2008; ROTH; ØINES, 2010; WEINECK *et al*., 2018). Há evidências de que tal atordoamento produz um estado semelhante a uma convulsão em que o animal não responde e permanece provavelmente inconsciente (FREGIN; BICKMEYER, 2016). O atordoamento farmacológico é eficaz na imobilização de animais, mas sua eficácia em deixá-los inconscientes não é clara (ANDERSON *et al*., 1997; KEENE *et al*., 1998; SOTO, 1995). Não há confiança de que o resfriamento torne os decápodes inconscientes (TANI; KURAMOTO, 1998; GARDNER; 2004; ROTH; ØINES, 2010; PURI; FAULKES, 2015).

O empalamento duplo (doublespiking) em caranguejos e divisão do corpo inteiro (whole-body splitting) para lagostas são considerados métodos de abate razoáveis, dadas as evidências atuais (BAKER, 1955). Existem maiores riscos de bem-estar associados ao processamento de empalamento único (single-spiking), à divisão apenas de cabeça (head-only splitting), à separação entre o abdômen e o tórax, ou separação entre a cabeça e o tórax (tailing) e ao processamento em alta pressão (high-pressure processing) (ROTH & ØINES, 2010; WATOK, 2015). Há uma confiança alta de que o resfriamento em um congelador doméstico é um método de abate desumano, pois leva mais de uma hora para os animais morrerem (ROTH; ØINES, 2010). Também há alta confiança de que a fervura do animal sem atordoamento prévio é um método de abate desumano para decápodes relativamente grandes, que podem levar mais de 2 min para morrer (BAKER, 1955; ROTH; ØINES, 2010; FREGIN; BICKMEYER, 2016). Há pouca confiança de que aumentar gradualmente a temperatura da água pode ser um processo mais humanitário de abate de decápodes (BARKER, 1955; GUNTER, 1961; FREGIN; BICKMEYER, 2016; ADAMS *et al*., 2019). Adicionalmente, há alta confiança de que a imersão em água doce é um método desumano de abate. Tal procedimento pode levar a um sofrimento mais prolongado que métodos considerados desumanos, como a fervura (BAKER, 1995; GARDNER, 1997).

A ablação do pedúnculo ocular é uma prática comum internacionalmente na aquicultura de camarões, mas que representa um ponto crítico de bem-estar se os animais forem sencientes (TAYLOR *et al*., 2004; DIARTE-PLATA *et al*., 2012; ZACARIAS *et al*., 2019; ZACARIAS *et al*., 2021). No Brasil, a prática ainda é realizada em algumas propriedades, inclusive, a Empresa Brasileira de Pesquisa Agropecuária (Embrapa) criou um comunicado técnico que ensina como realizar a ablação ocular (LIMA *et al*., 2015).

3.6 CONSIDERAÇÕES FINAIS E RECOMENDAÇÕES

Esta revisão apresenta um quadro probatório complexo. A evidência de senciência é muito forte para os polvos (ordem Octopoda) e forte para caranguejos verdadeiros (infraordem Brachyura). Há evidências substanciais para outros cefalópodes coleóides (lulas e chocos) e para alguns outros táxons de decápodes (caranguejos anomuros, astacídeos e camarões carídeos). Em relação à complexidade, três observações gerais merecem destaque. Primeiro, a quantidade de evidências para um dado táxon biológico depende em grande parte da atenção científica que esse táxon recebeu em relação à senciência. Polvos e caranguejos verdadeiros receberam atenção científica constante, enquanto nautilóides e camarões peneídeos, por exemplo, foram pouco estudados. Outros táxons como lulas, chocos e anomuros receberam um nível intermediário de atenção focada na senciência, resultando em uma quantidade intermediária de evidências. Dessa forma, a quantidade de investimento em pesquisas explica boa parte do nível de confiança nas evidências de senciência.

Em segundo lugar, não há casos em que exista uma confiança muito alta ou alta de que um táxon falhe em um critério, ou seja, evidências de que o critério esteja ausente. Embora isso possa parecer surpreendente, deve-se notar que cefalópodes e decápodes foram selecionados para escrutínio precisamente porque parecem candidatos plausíveis à senciência. Se tivesse sido revisado evidências de outros animais invertebrados (por exemplo, águas-vivas), talvez fossem observadas evidências de ausência dos critérios, ou seja, uma confiança muito alta de que os animais não apresentam alguns dos oito critérios.

Terceiro, não há diferenças drásticas na qualidade ou volume de evidências em relação aos cefalópodes quando comparados aos decápodes. Há mais evidências de senciência em polvos que em caranguejos verdadeiros, mas a diferença não é grande, e a evidência de senciência em caranguejos verdadeiros é na verdade um pouco mais substancial do que a evidência de senciência em outros cefalópodes menos estudados. Isso leva a recomendação de que, se os cefalópodes devem ser incluídos no escopo das leis de bem-estar animal, os decápodes também devem ser incluídos.

Como os formuladores de políticas e legisladores devem responder a esse complicado quadro probatório? É recomendado que todos os moluscos cefalópodes e crustáceos decápodes sejam considerados animais sencientes para efeitos de leis e normas de bem-estar e de proteção animal. Eles devem ser contados como animais para fins do Animal Welfare Act 2006, na Lei Arouca brasileira e nas normas de boas práticas de bem-estar para animais utilizados como alimento, na regulamentação de abate humanitário e demais normas do

Ministério da Agricultura, Pecuária e Abastecimento, assim como devem ser incluídos no escopo de qualquer legislação futura relacionada à senciência animal.

Por que fazer estas recomendações? Há evidências muito fortes de senciência em polvos (ordem Octopoda) e fortes evidências em caranguejos verdadeiros (infraordem Brachyura). Em outros casos, algumas evidências eram substanciais, mas não fortes. É provável que isso reflita as disparidades na quantidade de atenção científica que os diferentes táxons receberam. A atenção científica se concentrou em torno de alguns táxons em detrimento de outros por razões de conveniência prática (por exemplo, quais animais podem ser mantidos bem em laboratórios) e geografia (por exemplo, quais espécies estão disponíveis onde um laboratório está localizado). Devido a esta situação, parece inadequado limitar a proteção a ordens específicas de cefalópodes, ou a infraordens específicas de decápodes. Tal abordagem nunca foi adotada com vertebrados. Por exemplo, não protegemos ratos de laboratório (*R. norvegicus*) enquanto excluímos outras espécies de mamíferos menos estudadas, embora muitas evidências sobre a senciência em mamíferos venham de ratos de laboratório. No caso dos vertebrados, os legisladores estão dispostos a generalizar a partir de animais de laboratório bem estudados para outras espécies relevantemente semelhantes. Assim, parece consistente adotar a mesma abordagem em relação aos táxons de invertebrados.

Uma opção alternativa é considerar apenas os polvos como sencientes, com base no fato de que a evidência é mais forte para eles que para qualquer outro táxon estudado de invertebrados. No entanto, como as evidências também são fortes em caranguejos verdadeiros, tal abordagem excluiria os decápodes com base em uma diferença pequena na quantidade de evidências de senciência. Uma outra opção alternativa seria considerar apenas os polvos e caranguejos verdadeiros como animais sencientes. No entanto, essa abordagem também enfrentaria problemas de coerência. Embora as evidências de senciência sejam mais fortes para caranguejos verdadeiros que para caranguejos anomuros (infraordem Anomura) e lagostas (infraordem Astacidea), a diferença não é vasta e pode ser resultante de disparidades em como os cientistas alocaram sua atenção. Adicionalmente, uma lei que protegesse os caranguejos verdadeiros, mas não os caranguejos anomuros e lagostas, seria altamente confusa, porque as várias infraordens de decápodes não são amplamente conhecidas e, de fato, transformaria em lei um fato contingente sobre quais espécies os cientistas escolheram estudar mais intensamente. Se os astácidos fossem incluídos, a exclusão de outros táxons decápodes (como as lagostas espinhosas e os camarões carídeos) estaria sujeita às mesmas críticas: seria ao mesmo tempo confuso e reflexo de disparidades na atenção científica.

Foi observado que há pouca evidência de senciência atualmente em camarões peneídeos. No entanto, se os camarões carídeos fossem incluídos, mas excluídos os camarões peneídeos, o potencial de confusão seria novamente alto. Portanto, no final das contas, é rejeitada a sugestão de que a proteção deva ser estendida apenas a infraordens específicas de decápodes. E isso é um ponto de concordância com o relatório anterior da AHAW (2005).

3.6.1 Atualizações

As evidências científicas encontradas por Birch *et al*. (2021) e apresentadas neste artigo concentraram esforços na avaliação da distribuição de senciência em animais não humanos, com recomendações para a inclusão de todos os crustáceos decápodes e moluscos cefalópodes no escopo das leis de bem-estar animal, enquanto também foram propostas regulamentações aplicáveis às melhores práticas para espécies de importância comercial. Assim, uma das recomendações centrais do relatório foi implementada na recente Lei de Bem-Estar Animal (Senciência) de 2022, que explicitamente reconheceu todos os moluscos cefalópodes e crustáceos decápodes como sencientes, impondo aos formuladores de políticas o dever e responsabilidade para com o bem-estar desses animais (CRUMP et al., 2022a; CRUMP *et al*., 2022b). Apesar do reconhecimento da senciência nesses animais poder não levar a mudanças significativas imediatas ao seu bem-estar, sendo incerto se ela os protegerá de práticas prejudiciais, esse é um importante passo na ciência do bem-estar de invertebrados (CRUMP *et al*., 2022a; COOPER *et al*., 2022). Ainda, espera-se que países que carecem de regulamentações claras, como o Brasil, busquem aprimorar suas abordagens regulatórias em relação ao reconhecimento da senciência animal, seguindo o exemplo de outras nações que já tomaram alguma medida nesse sentido. Isso contribuiria para promover padrões mais elevados de bem-estar animal e alinhar as políticas com avanços científicos na compreensão da senciência em diferentes espécies.

Também houve avanços relacionados a análise de senciência em outros grupos de invertebrados. Um exemplo foi o estudo conduzido por Gibbons *et al*. (2022), que se fundamentou nos oito critérios propostos por Birch *et al*. (2021) para analisar evidências de dor em seis ordens de insetos (Blattodea, Coleoptera, Diptera, Hymenoptera, Lepidoptera e Orthoptera) em pelo menos dois estágios de vida. Os resultados indicaram que adultos de Diptera (moscas e mosquitos) e Blattodea (baratas e cupins) satisfazem seis critérios, representando uma evidência forte de que eles sentem dor. Adultos das demais ordens (com exceção de Coleoptera, besouros) e alguns estágios juvenis (Blattodea e Diptera, assim como

o último instar de Lepidoptera [borboletas e mariposas]) atendem a 3–4 critérios, caracterizando uma "evidência substancial de dor". Não sendo observadas evidências de descumprimento de nenhum critério por parte dos insetos.

Além disso, houve uma alteração na proposta do Critério 7, que reflete as críticas de comentaristas, que questionaram a inclusão de todas as formas de aprendizagem associativa. A possível emenda reiterada por Crump *et al*. (2022c) foi a seguinte:

> Critério 7 (alterado): Aprendizagem Associativa. O animal apresenta formas de aprendizagem associativa nas quais estímulos nocivos se tornam associados a estímulos neutros, ou nas quais novas maneiras de evitar estímulos nocivos são aprendidas por meio de reforço. Essas formas de aprendizagem associativa vão além do condicionamento clássico, no qual um único estímulo condicionado se sobrepõe temporalmente a um estímulo incondicionado. Observação: Formas de aprendizagem associativa que estão, pelo menos tentativamente, relacionadas à senciência em humanos (como aprendizagem instrumental, aprendizagem por reversão e condicionamento por rastreamento) fornecem evidências mais robustas do que outras formas.

Embora a emenda torne o critério mais complexo, ela sinaliza de maneira mais clara o engajamento contínuo no debate sobre quais formas de aprendizagem associativa estão relacionadas à senciência e por quê. Apesar disso, dada a forte evidência de condicionamento operante em crustáceos decápodes e cefalópodes, a avaliação das evidências não seria substancialmente afetada por essa mudança.

3.7 CONCLUSÃO

É possível ponderar sobre a senciência animal por meio da integração do conhecimento científico disponível. Para a maioria das espécies animais ainda há uma escassez de conhecimentos essenciais para uma consideração de senciência de maneira cientificamente embasada. A falta de conhecimento deve ser reconhecida, para prevenir injustiças ao se assumir determinados grupos taxonômicos como não sencientes quando de fato a limitação ainda é o conhecimento humano sobre a questão. Espera-se com esta revisão favorecer vários aspectos do entendimento da senciência animal no Brasil e em outros países lusófonos, envolvendo um refinamento da sua compreensão que é relevante para atividades de pesquisa e ensino, com consequências positivas para a melhoria das discussões éticas, sociais, econômicas, legislativas e políticas relacionadas.

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4 ADDRESSING CRITICAL WELFARE CONCERNS FOR WHITE-LEG SHRIMP (*Penaeus vannamei):* CURRENT CHALLENGES AND FUTURE PERSPECTIVES

ABSTRACT

The growth of shrimp farming, coupled with the lack of regulations in the scientific and production environment, and recent studies on sentience in decapod crustaceans, open the door to important ethical discussions. Billions of shrimps are killed annually during farming. Furthermore, shrimp are often subjected to practices which conflict with basic principles of animal welfare. Thus, this study aimed to outline the priority points of concern for the welfare of *Penaeus vannamei*, the most widely used shrimp species in shrimp farming globally. To achieve this, we conducted bibliographic research and visited four grow-out farms and three larviculture laboratories in northeastern Brazil. Our analysis identified 12 points of concern for shrimp welfare, including illnesses, high stocking density, salinity stress test, health analysis of animals (larvae, juveniles and adults), culling, eyestalk ablation, transport, inadequate control of water parameters in grow-out ponds, biometrics, research, capture, stunning and slaughter. Additionally, the domains affected by each point of concern were identified, as well as the level of concern. We also specified the main issues observed in each critical welfare point, potential negative effects, and recommendations to mitigate the harm that each of them may cause to shrimp. To conclude, we propose a new scenario that integrates common shrimp farming practices, but with greater attention to animal welfare, with a new cell-based production method which eliminates animal suffering and slaughter, thus representing a superior future perspective in terms of protecting shrimp welfare.

Keywords: aquaculture; critical points; penaeid; shrimp farming; well-being

4.1 INTRODUCTION

Shrimp farming is the sector within aquaculture primarily dedicated to the cultivation of saltwater or freshwater shrimp (SEBRAE, 2018). According to FAO, between the years 2016 and 2020 there has been a significant growth in the global shrimp production, with a yearly decrease of 1.8% in shrimp caught from fishing, with a simultaneously yearly increase of 9.0% in the production of farmed shrimp (XIMENES; VIDAL, 2023; FAO, 2022a). Thus, in 2020, shrimp farming accounted for approximately 70.0% of the total global shrimp production (XIMENES; VIDAL, 2023), surpassing extractive fishing. In 2022, shrimp production achieved a new record of 9.4 million tonnes (FAO, 2023) and, according to the 2022 edition of the SOFIA Report (The State of World Fisheries and Aquaculture), the *Penaeus vannamei* was the most produced species, equivalent to 51.7% of the total crustaceans produced in aquaculture in 2020. It is estimated that over 167 billion shrimps of this species are produced annually, but the total number of shrimps and prawns farmed annually is likely bigger, reaching about 440 billion (ALBALAT *et al*., 2022; WALDHORN; AUTRIC, 2022; PEDRAZZANI *et al*., 2023). In this way, there is a crucial need for concern regarding the welfare of shrimps, given the large number of individuals involved in shrimp farming.

Animal welfare can be measured, being dynamic and related to the animal's experience while trying to adapt to its environment. Therefore, it is a temporary state linked to individual experiences, varying from very good to very poor (BROOM, 1986; BROOM, 2011). The pre-requisite for animal welfare concerns is the existence of sentience in non-human animals. In this way, the recognition of sentience in animals can guide the specifics of legislation and policy, thus maximizing protection for these animals (DAWKINS, 2022; JONES, 2022). Sentience is characterized by the experience of feelings of positive or negative valence and the presence of some level of consciousness, even in the most basic form possible (MELLOR, 2019; BIRCH *et al*., 2021). Since 1965, with the Brambell Committee, there was already an understanding that recognizing sentience is an essential part of animal welfare assessment (BRAMBELL, 1965). Despite this, it is worthwhile to think beyond the scientific issues related to proving sentience for the regulation of welfare measures, as the difficulties in sentience measurement can harm potentially sentient animals. Therefore, an ethical approach, as can be observed through the precautionary principle, can be seen as a good alternative to mitigate negative impacts on animal welfare (BIRCH, 2017; DAWKINS, 2022).

Based on this, the Cambridge Declaration on Consciousness (2012) marked a significant turning point by acknowledging that consciousness extends not only to humans but also encompasses a considerable array of non-human animals, spanning vertebrates and even certain invertebrates like octopuses. Expanding on this perspective, Birch *et al*. (2021) undertook a comprehensive inquiry into existing scientific literature concerning sentience of cephalopod mollusks and decapod crustaceans. The study revealed that there is substantial evidence that these animals are sentient beings, and thus potentially aversive and painful practices are not recommended. As a result, it was recommended that they be considered sentient animals for the purposes of the United Kingdom's animal welfare law and be included within the scope of legislation related to animal sentience.

In fact the demand for protection of some invertebrates from suffering has been present beyond the academic conceptual discussions. For example, the *P. vannamei* farming industry is frequently subject to criticism concerning environmental and welfare factors (PRIMAVERA, 1998; PÁEZ-OSUNA, 2001; IBER; KASAN, 2021; LEWIT-MENDES *et al*., 2022; ALBALAT *et al*., 2022; TAHER *et al*., 2023; PEDRAZZANI *et al*., 2023). With a focus on welfare concerns, the most commonly mentioned issues typically involve invasive and handling procedures, such as eyestalk ablation in breeding females, unregulated and non-standardized stunning and slaughter practices, the transport conditions leading to physical injury and stress, inadequate raising environment, stocking density and biological conditions that may lead to diseases and increase mortality rates (LEWIT-MENDES *et al*., 2022; ALBALAT *et al*., 2022; PEDRAZZANI *et al*., 2023).

Considering the likely welfare problems faced by farmed shrimp, it becomes essential to understand the key factors that may lead to a decrease in their welfare, primarily due to the significant adverse impact on a large number of sentient individuals. Thus, the present study aimed to identify these factors, describe the scenario of the production of *P. vannamei,* and propose strategies to mitigate the primary impacts observed.

4.2 MATERIALS AND METHODS

4.2.1 Identification of Critical Welfare Points

The main concerning aspects related to the farming of *P. vannamei* shrimp in the larviculture, maturation, and grow-out stages were observed in routine practices at

laboratories for larviculture and grow-out farms in northeastern Brazil. Specifically, we visited four farms and three larval rearing laboratories. The laboratories/farms visited were of medium and large scale, being of utmost relevance in terms of the national production of *L. vannamei* in Brazil. We prefer not to disclose the locations of the properties for anonymity reasons. All the companies included in this research were pre-selected based on their expressed interest in improving the welfare of farmed shrimp.

4.2.2 Determination of the level of concern

According to the Five Domains model, good welfare refers to the state in which an animal has its physical and mental needs met. This model provides an approach for assessing the animal's general state based on four functional domains (nutrition, environment, health and behavior interactions) and a mental domain that reflects the animal's overall welfare state understood in terms of its affective experiences (MELLOR; REID, 1994; MELLOR; BEAUSOLEIL, 2015; MELLOR *et al*., 2020).

In this way, to determine the level of concern for each critical point, the works of Blokhuis *et al*. (2010), Pedrazzani *et al*. (2020), and Pedrazzani *et al*. (2023) were used as inspiration. First, we marked which of the four domains (behavior, nutrition, health, and environment) were affected by each pre-established critical welfare point. The Mental domain was not evaluated as it is related to all the other four. Second, we expanded the four domains to encompass the intentional killing of shrimp by human action, meaning procedures in which death occurs as part of the process, excluding circumstances that could lead to the animals' death in a "non-intentional" manner. From this, the levels of concern were constructed, according to the marking of the four domains (Very High Concern), three domains (High Concern), or two domains (Medium Concern). Furthermore, as death is the more stressful and determining event in the animal's life, the procedures involving the killing of animals were directly listed as a Very High level of concern. Third, we know that all the listed critical points can affect the five domains; however, for this study, the nutritional domain was considered affected only when there is deprivation or alteration in food supply. We also listed in which phases each critical point generates concern, differentiating them between larviculture, maturation, and grow-out.

4.2.3 Determination of main issues, effects and mitigation strategies

For the compilation of the main issues, effects, and mitigation strategies for each critical welfare point, an adaptation was made from a table created by FAO (2007), which addresses the "factors that affect shrimp larval health and possible control measures for *Penaeus monodon*". Thus, after determining the primary critical welfare points, we listed the main welfare problems associated with each one, the negative effects these issues can generate for the shrimp, and, finally, possible improvement alternatives. The required information was compiled based on field observations combined with data available in the literature.

4.3 RESULTS

4.3.1 Critical welfare points

Our analysis, based on visits to Brazilian *P. vannamei* farms, identified several areas of concern regarding farmed shrimp welfare. These include handling procedures such as the salinity stress test, high stocking density, health analysis of animals (larvae, juveniles and adults), culling of high numbers of healthy animals, the performance of eyestalk ablation in breeding females, live animal transport, adverse conditions during biometrics and others practices that require exposure to air, conducting research without regulations that protect the physical and mental integrity of the animals, capture, stunning, and slaughter, along with the poor control of environmental parameters during the grow-out stage and susceptibility to disease contraction, ultimately results in high mortality rates (Figures 1 and 2).

4.3.1.1 Illnesses and high stocking density

During discussion with the producers, concerns were raised regarding the prevention of diseases that had previously caused significant mortality and losses in production. Some of the mentioned diseases included White Spot Syndrome (WSS), Vibriosis, Gregarine, Necrotizing Hepatopancreatitis (NHP), Infectious Hypodermal and Hematopoietic Necrosis (IHHN), Infectious Myonecrosis (IMN), Taura syndrome (TS) and Yellow Head Disease (YHV). The main factor related to the increase in disease transmission as described by the producers was stocking density. Accordingly, we observed that some properties, especially

those for the grow-out stage, were operating with low densities in order to reduce the risk of infection and transmission of pathogens. These densities are in line with recommendations of Pedrazzani *et al*. (2023). Nevertheless, stocking density remains a critical point of concern in shrimp farming, not only because it is a factor that can influence the health, behavior, environment, and nutrition of the animals, but also because its intrinsic and direct negative impact on welfare. Even stocking densities considered low in the context of farming may represent an important welfare problem, as they are higher than the densities the animals would choose to live and, therefore, they cannot be overlooked. Furthermore, we observed that the water discarded by one property in grow-out farms is recaptured by an adjacent property that shares the same river flow, further contributing to the spread of diseases.

4.3.1.2 Transport and culling

We were also able to observe the impact of live shrimp transportation. After new breeders arrived at the laboratory, they underwent a bath in a solution containing PVPI for subsequent transfer to the tanks, where the effects of transportation were more noticeable. Changes in coloration in the exoskeleton and musculature were visible, in addition to a high mortality rate, which was estimated at 10%. Dead or moribund animals were removed from the tanks and submerged in a chlorine solution, with no analysis conducted to identify the main causes of death. Thus, there was no initiative to understand the problems and to mitigate the impacts on the integrity of the animals during transportation.

The culling of animals, for the most part, was also carried out by submerging the still-live animal in a solution containing chlorine or by exposure to air. We observed a high rate of culling, mainly in the larviculture sector and mostly related to "leftovers" during the preparation of animals for transport to grow-out farms. The "culling" related to breeding animals were different. Due to the large body size of these shrimp, they were marketed after their use in the maturation sectors. For this reason, the slaughter was carried out with ice to avoid compromising the quality of the meat.

4.3.1.3 Capture, stunning and slaughter

Firstly, the use of the word 'harvest' has been replaced by 'capture,' as also used by Pedrazzani *et al*. (2020) to refer to the mass capture of fish. Given the evidence of sentience in shrimps, the word 'capture' becomes more appropriate.

Thus, the different methods of capture have varied potential to reduce the well-being of the shrimp, although they are all significantly negative. Thus, nighttime captures, with milder weather, were considered to be less stressful when compared to capture procedures during the day, under sunlight exposure and high temperatures. Another notable comparison was between the capture carried out with the assistance of an automated suction device and that done manually. The machine contributes to increase the speed of the process, which is beneficial and reduces the duration of the suffering shrimp experiences during the period between capture and slaughter.

After capture, the animals were promptly placed in tanks filled with an aqueous solution containing ice, water, and sodium metabisulfite, with temperatures ranging between -1°C and 0°C. In this way, no effective stunning method was utilized, and the method of slaughter employed was ice-based.

4.3.1.4 Biometry and health analysis of animals

During biometric assessments, in addition to monitoring growth, were also analyzed various health-related indicators in the animals. These included the observation of changes in exoskeleton coloration, musculature, visible internal structures, deformities, gastrointestinal tract filling and appendages, among others. As a result, it was common for the animals to be exposed to air and light during these biometric procedures, which were conducted either weekly or daily, depending on the growth stage and sector. In both larviculture and grow-out phases, it was observed that animals collected for weighing were often not returned to the tank or pond and subsequently died due to air exposure. Moreover, the microscopic health assessment of the animals was found to be highly invasive and aggressive. In larviculture, for the health analysis, the animals were collected, placed on microscope slides for observation, and were then usually discarded, or they were vivisected with no pain control to view internal structures.

During the grow-out phase, the assessments also included vivisection procedures. After capture, a syringe was inserted into the shrimp's abdomen, effectively rupturing their ventral nerve cord, with the aim of minimize the potentially significant suffering resulting from this procedure. Subsequently, the collection of gills, heart, hepatopancreas, intestinal contents, hemolymph, among other tissues and structures was conducted.

4.3.1.5 Eyestalk ablation and research

We observed that the ablation of the eyestalk in breeding females was still carried out in some laboratories, while others had abandoned the practice. During the fieldwork, we did not observe any ablation being performed; however, we were informed that the procedure involved the cut or maceration of the eyestalk and eyecup of the animal with one's own hands, followed by a bath in a solution containing PVPI, an uncommon procedure in the literature.

Other invasive practices reported were related to research practices. In shrimp farming, numerous studies are conducted to create genetic variants that are resistant to diseases and adverse environmental conditions, which lead to the use of many animals as test subjects. We were unable to directly observe how these studies were conducted and the conditions that the animals were subjected to, and our results are based on oral reports by our hosts during the visits.

4.3.1.6 Poor environmental control in grow-out farms and salinity stress test

We observed a variety of problems with the control of environmental parameters in grow-out farms, which is in stark contrast with the high level of control observed in laboratories during larviculture and maturation stages. Some properties lacked the necessary infrastructure and equipment for daily measurements of water quality parameters, while in others, the significance of such measurements was underestimated due to the shrimp's high adaptability to survive within a broad range of environmental variations. Greater emphasis was set on measuring dissolved oxygen. Other chemophysical parameters such as salinity, temperature, pH, transparency, alkalinity, nitrite levels and non-ionized ammonia were measured less frequently, with the schedule varying among properties. More complete measurements were only conducted after significant environmental adversity or when animals exhibited morphological alterations and increased mortality. Additionally, there was no effective protection against terrestrial predators on any of the farms. The ease and amount of predation, primarily carried out by birds, were used as indicators of pond quality. Protection against aquatic predators was commonly achieved through screens placed at the water inlet and outlet areas of the pond.

Another critical welfare point highlighted in this study was the salinity stress test. This test is often required by grow-out producers as a way to assess the resistance and adaptability of postlarvae that they intend to purchase. The test aims to expose the animals to drastic

salinity variations, thereby assessing survival and consequently mortality rate. As it is a common practice in shrimp farming and as it leads to the mortality of some individuals, this test warrants attention concerning its necessity, applicability, and functionality.

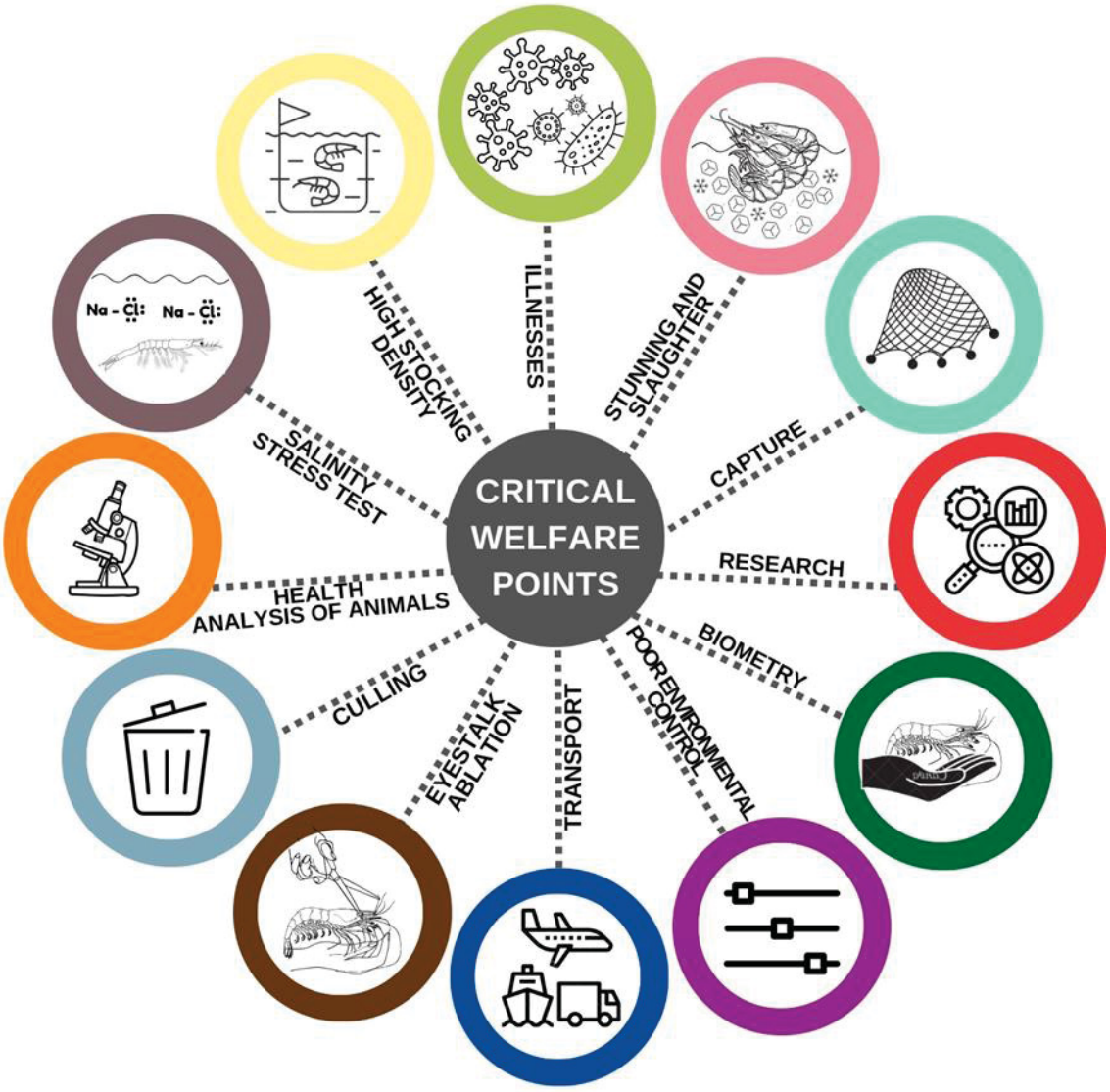

Figure 1 – Critical welfare points observed during visits to Brazilian *P. vannamei* farms, in May 2022, and in November-December 2022.

Figure 2 – Some critical welfare points observed during field visits: A. Culling of postlarvae in chlorine-containing solution; B. Breeding shrimp affected by transport to the laboratory; C. Death of breeders after transport from the farm to the laboratory; D. Animals in tanks containing ice and sodium metabisulphite to slaughter them and preserve their meat; E. Casks where the shrimp were dumped and weighed; F. and G. Shrimp capture and exposure to air during biometrics procedure in grow-out farms; H. Dissection of live juveniles and preparation of slides for microscopic evaluation of organs; I. Microscopic analysis of live postlarvae; J. Culling of animals affected by transport in chlorine solution. K. Counting of postlarvae for biometric analysis. L. Adults handling for health analysis during biometrics.

4.3.2 Level of concern

Upon observation and analysis, we have identified that critical welfare points, such as high stocking density, health analysis of animals, culling, transport, biometry, research activities, capture, stunning, and slaughter, pose a very high level of concern regarding the welfare of *P. vannamei* in the current shrimp farming system in Brazil (Figure 3). Salinity stress tests, eyestalk ablation, and poor water quality control in grow-out farms were classified

as a high level of concern, while illnesses were considered a medium level of concern (Figure 3).

We noticed that illnesses, animal health analysis, culling, biometric analyses, and research activities have the potential to pose risks to the well-being of shrimp at all observed rearing stages (larviculture, maturation, and grow-out). Although stocking density also has the potential to generate risks at all life stages of the animals, it tends to be higher and cause greater concern in larviculture and grow-out. The salinity stress test, conducted with post-larvae, is an issue exclusive to larviculture, while eyestalk ablation in females is specific to the sexual maturation process. Concerns related to the transport of live animals are more common during larviculture and maturation. Points related to poor control of environmental parameters, animal capture, stunning, and slaughter are inherent concerns during the grow-out phase.

Shrimp Welfare		DOMAINS				KILLING BY HUMANS*	LEVEL OF CONCERN
		Behavior	Nutrition	Health	Environment		
CRITICAL POINTS	Illnesses[1, 2, 3]	X		X			MEDIUM
	High stocking density[1, 3]	X	X	X	X		VERY HIGH
	Salinity stress test[1]	X		X	X		HIGH
	Health analysis of animals[1, 2, 3]	X		X	X	X	VERY HIGH
	Culling[1, 2, 3]	X		X	X	X	VERY HIGH
	Eyestalk ablation[2]	X		X	X		HIGH
	Transport[1, 2]	X	X	X	X		VERY HIGH
	Biometry[1, 2, 3]	X		X	X	X	VERY HIGH
	Poor environmental control[3]	X		X	X		HIGH
	Research[1,2,3]	X	X	X	X	X	VERY HIGH
	Capture[3]	X	X	X	X		VERY HIGH
	Stunning and Slaughter[3]	X		X	X	X	VERY HIGH

* Handling practices in which intentional killing of shrimp by humans occurs.

[1] Greater concern during larviculture.

[2] Greater concern during the maturation stage.

[3] Greater concern during the grow-out stage.

Figure 3 – Relationship between four domains and death of animals with the level of concern related to critical welfare points in *P. vannamei* shrimp farming. ≥4X or death: Very High Concern; 3X: High Concern; ≤2X: Medium Concern.

4.3.3 Main issues, negative effects and mitigation strategies

In Table 1 additional information to Figure 3 is provided, with more detail regarding each of the critical welfare points, the main concerns, potential negative effects on shrimp welfare, and strategies to their mitigation. The main concerns of each of the 12 critical welfare points were the frequency of illness, the severity, and morbidity (illnesses or diseases); the quantity of animals per tank or pond, the conditions in which these animals are kept, the maintenance of the environment and mortality (high stocking density); how it is conducted, frequency, the number of animals used and mortality (salinity stress test); method and number of animals (culling); method, endocrine abnormalities and unilateral or complete blindness (eyestalk ablation); method, duration of the entire journey, the conditions in which the animals are kept and mortality (transport); low measurement frequency and consequent lack of intervention for proper maintenance (poor environmental control in grow-out farms); method, frequency, duration and mortality (biometrics); method, quantity, and necessity (research); method, period, and duration (capture); and method and duration (stunning and slaughter).

Table 1 – The main issues related to critical welfare points for farmed *P. vannamei* shrimp, the negative welfare effects that may arise, and mitigation strategies.

Critical welfare points	Main issues	Potential negative welfare effects	Mitigation strategies	References
Illnesses	Frequency, severity and morbidity	Morphophysiological changes and unattended death	Good nutrition, low stocking density, control of environmental parameters and avoid distressful conditions overall	Raja *et al.* (2015); Venkateswarlu; Venkatrayulu (2019); Albalat *et al.* (2022); Wuertz *et al.* (2023)
High stocking density	Amount, condition and maintenance	Stress, poor water quality, cannibalism, illnesses, competition and unattended death	Lower stocking densities, preferably ≤150 g/m^2 for breeders, ≤250 larvae/L, ≤100 postlarvae/L, ≤750 postlarvae/L for postlarvae transport and ≤40 shrimp/m^2 for juveniles and adults	Arnold *et al.* (2006); FAO (2007); Gao *et al.* (2017); Romano; Zeng, (2017); Pedrazzani *et al.* (2023); Wuertz *et al.* (2023)
Salinity stress test	Method, quantity, frequency and mortality	Stress and unattended death	Avoidance of the test and substitution by other assessment options or preventive measures to improve production results for each batch	Tackaert *et al.* (1989); Gallardo *et al.* (1995); Palacios *et al.* (2004); Palacios; Racotta (2007)
Health analysis of animals	Method, quantity, frequency and mortality	Physiological and metabolic changes, stress and unattended death	Anesthesia or stunning and slaughtering before the analysis	Wang *et al.* (2020a); Wang *et al.* (2022); Valente (2022); Ulaje *et al.* (2023)
Culling	Method and quantity	Stress and unattended death	No cull of healthy shrimps and, in other situations, the use of humane culling procedures	Weineck *et al.* (2018); Birch *et al.* (2021); Crustacean Compassion, (2021a); Lewit-Mendes *et al.* (2022);
Eyestalk ablation	Method, endocrine abnormalities, unilateral or complete blindness	Physiological, metabolic, hormonal and immunological changes, blindness, mutilation and unattended death	Abandonment of the procedure	Palacios *et al.* (1999a); Racotta *et al.* (2003); Taylor *et al.* (2004); Sainz-Hernández *et al.* (2008); Lima *et al.* (2015); Zacarias *et al.* (2019); Birch *et al.* (2021); Albalat *et al.* (2022)

Table 1. Continuation. The main issues related to critical welfare points for farmed *P. vannamei* shrimp, the negative welfare effects that may arise, and mitigation strategies.

Critical welfare points	Main issues	Potential negative welfare effects	Mitigation strategies	References
Transport	Method, duration, environmental quality, mortality	Stress, injuries, poor water quality, cannibalism, competition, illnesses and unattended death	Use of the fastest method, provide adequate environmental and nutritional conditions, and identify the causes of death to prevent them. In some cases, the use of sedation may be indicated	ABCC (2005); Lorsingkum *et al.* (2011); Lu *et al.*, (2015); SENAR (2017); Ostrensky; Silva (2017b); Gao; He (2017); Furtado *et al*. (2017); Soares, *et al*. (2021); Crustacean Compassion (2021b); Valente (2022)
Poor environmental control in ponds (grow-out farms)	Low measurement frequency and consequent lack of intervention for proper maintenance	Poor water conditions, stress, low growth, lowered immune response, illnesses and unattended death	Daily water control activities	Ponce-Palafox *et al.* (1997); Li *et al*. (2015); Ostrensky; Silva (2017a); Wang *et al*., (2020b); Millard *et al.* (2021)
Biometry	Frequency, duration, method and mortality	Physiological and metabolic changes, stress, suffering and unattended death	Careful capturing, avoidance of long periods of air exposure, and stunning followed by killing of shrimps that will not return to the pond or tank	Aparicio-Simón *et al.* (2010); Liu *et al*. (2015); Duan *et al*. (2016); Wang *et al.* (2020a); Wang *et al.* (2022); Ulaje *et al*. (2023)
Research	Method, quantity of animals involved and need	Stress, suffering and killing	Application of the 3 Rs of humane animal experimentation; training of research staff, law compliance with regards to obligatory approval by an Animal Ethics Committee	Russell; Burch (1959)
Capture	Method, period and duration	Stress, pain, injuries and suffering	Automated suction device, handling at night	Ostrensky; Silva (2017c); Pedrazzani *et al*. (2023)

Table 1. Continuation. The main issues related to critical welfare points for farmed *P. vannamei* shrimp, the negative welfare effects that may arise, and mitigation strategies.

Critical welfare points	**Main issues**	**Potential negative welfare effects**	**Mitigation strategies**	**References**
Stunning and slaughter	Method and duration	Stress, pain and suffering and agony of death	Electronarcosis or another method with proven effectiveness, prevention of death by suffocation or osmotic shock	Weineck *et al*. (2018); Birch *et al*. (2021); Crustacean Compassion (2021a); Lewit-Mendes *et al*. (2022); Pedrazzani *et al*. (2023)

4.4 DISCUSSION

4.4.1 Animal welfare problems in shrimp farming

The increase in the global population and the high demand for animal proteins has led to a growing concentration and control of production, resulting in the expanded breeding of animals exploited in confinement systems. This increased focus on the economy and income led to the neglect of animal welfare (KOKNAROGLU; AKUNAL, 2013). In 1964, Ruth Harrison exposed the deplorable conditions and mistreatment to which animals were subjected in production. Shifting the focus to aquaculture, issues related to animal welfare also exist (SEGNER *et al*., 2019; BIRCH *et al*., 2021; FRANKS *et al*., 2021; LEWIT-MENDES *et al*., 2022). At the same time, the increase in public awareness puts pressure on producers to seek improvements in the welfare of animals in confinement (KOKNAROGLU; AKUNAL, 2013). With the visits and observations on properties that produce *P. vannamei*, we identified 12 critical welfare points related to animal welfare. Some of them have been discussed in the literature, while others have not been as prominently addressed.

Mortality and losses in production related to diseases were concerns raised by the producers. The growth in the large-scale *P. vannamei* in intensive production systems has brought a series of welfare challenges, many of them related to the acquisition of diseases (ALBALAT *et al*., 2022). Thus, diseases as acute hepatopancreatic necrosis disease (AHPND), hepatopancreatic haplosporidiosis (HPH), hepatopancreatic microsporidiosis (HPM), aggregated transformed microvilli (ATM), covert mortality disease (CMD), white spot disease (WSD), yellow head disease (YHD), infectious myonecrosis (IMN), Taura syndrome virus (TSV) and infectious hypodermal and hematopoietic necrosis virus (IHHNV) (THITAMADEE *et al*., 2016) resulted in major crises that directly affected the welfare of many shrimps.

Within the production environment, stressful situations can lead to reduced health conditions, which can have serious consequences such as the loss of all animals or deformities and atrophies in survivors (ALBALAT *et al*., 2022; WUERTZ *et al*., 2023). The final consequence of disease outbreaks may be connected to financial losses to producers. Stress is a physiological response that helps restore homeostasis after the interference of an adverse external stimulus. However, when an animal is exposed to a more permanent stressor, such as sustained poor water quality or nutritional deficiency, the stress response can lose its adaptive function and become dysfunctional, i.e., distress (RAJA *et al*., 2015; VENKATESWARLU;

VENKATRAYULU, 2019; WUERTZ *et al*., 2023). Consequently, a physical (e.g., transportation), chemical (e.g., O2 and CO2), or social (e.g., high stocking density) stressor can trigger a primary neuroendocrine response, which evokes secondary physiological and behavioral responses to restore homeostasis. If the stressful situation persists, systemic alterations can occur, impairing processes such as molting, growth, reproduction, vigor, feed conversion, and disease resistance (WUERTZ *et al*., 2023). Considering this, acute, subacute, prolonged, and chronic disturbances can influence the susceptibility of decapods to diseases. Acute stress, as observed in biometry or in the drastic changes in water parameters as seen in the salinity stress test (SST), can stimulate the immune system and lead to transient impacts on the host. On the other hand, prolonged stress, such as that observed in the poor control of water quality in grow-out tanks or due to high stocking density, can lead to metabolic changes, immune dysfunction, and consequently, a decline in health (ALBALAT *et al*., 2022). Our results indicated important stress-inducing situations that remain in practice in some of the visited shrimp farms, from points related to environmental stressors and invasive practices, to the final steps of shrimp farming, i.e., capture, stunning, and slaughter.

As for environmental stressors, a severe practice observed was the SST. Perhaps the most critical welfare problem related to SST, in addition to the potential transient impacts on surviving animals, concerns animal deaths. This is so because animals die without any intervention to control their suffering, which epitomizes the severe negative impact of the salinity imposed to all animals during the test. The SST is commonly used in shrimp farming to assess the quality of postlarvae and predict their performance during animal growth or tank stocking (TACKAERT *et al*., 1989; AQUACOP *et al*., 1991; DHERT *et al*., 1992; FEGAN, 1992; REES *et al*., 1994; PALACIOS; RACOTTA, 2007; SENAR, 2016). Therefore, postlarvae with higher survival rates in an SST are considered healthier or of better quality. In theory, the SST helps determine whether the shrimp, previously cultivated in controlled environments resembling seawater conditions, are ready to tolerate salinity changes similar to those found in estuaries, which may be encountered during growth in ponds (PALACIOS; RACOTTA, 2007). However, Álvarez *et al*. (2004) observed that a higher survival rate in the SST was only correlated with greater postlarvae survival during tank stocking, with no such correlation over a longer period. Therefore, Álvarez *et al*. (2004) showed that the SST was not a predictive criterion for good performance throughout the entire growth phase. Hence, investing in research, as well as in proper nutrition (GALLARDO *et al*., 1995; PALACIOS *et al*., 2004; PALACIOS; RACOTTA, 2007; LUO *et al*., 2022), may help reduce the frequency and number of animals that die and the need for the SST.

The CONAMA Resolution 312/2002 (CONAMA, 2002), which deals with the environmental licensing for shrimp farming in coastal areas, establishes that parameters such as suspended material, transparency, temperature, salinity, dissolved oxygen (OD), biochemical oxygen demand (DBO), pH, ammonia, nitrite, nitrate, phosphate, silicate, chlorophyll a, and total coliforms must be monitored at least quarterly. However, according to Ostrensky and Silva (2017a), the flaws in the resolution are that it does not establish limits or criteria to be followed, and some of the listed parameters require daily measurement, while others are not significant in shrimp farming. Furthermore, frequent measurement of relevant environmental parameters can benefit the producer, as fluctuations in abiotic conditions, mainly caused by periods of extreme weather conditions, can affect growth rates, survival, immune response, energy demand, susceptibility to pathogens, and thus eventually lead to disease outbreaks (PONCE-PALAFOX *et al*., 1997; LI *et al*., 2015; WANG *et al*., 2020b; MILLARD *et al*., 2021). Therefore, it is beneficial to both shrimp welfare and production results that the measurement of important parameters be conducted more frequently. In addition, Pedrazzani *et al*. (2023) have established limits for relevant environmental parameters in shrimp farming, which can be helpful for on-field practices and for a revision of the CONAMA Resolution 312/2002.

Spatial limitation for the animals caused by high stocking densities can decrease oxygen levels, lead to water quality degradation, increase the stress induced by crowding, promote adverse behaviors such as cannibalism, slowdown growth, and increase mortality (NGA *et al*., 2005; ARNOLD *et al*., 2006; FAO, 2007; BALAKRISHNAN *et al*., 2011; GAO *et al*., 2017; ROMANO; ZENG, 2017; KRING *et al*., 2023). Therefore, according to Pedrazzani *et al*. (2023), considering animal welfare and other damages, the ideal stocking density for shrimp is ≤150 g/m2 for breeders, ≤250 larvae/L, ≤100 postlarvae/L, ≤750 postlarvae/L for transport, and ≤40 shrimp/m2 for juveniles and adults.

The adverse effects of biometrics and of the health analysis of animals, primarily relate to the injuries caused by capture, handling, and exposure to air, light, and temperature variations. Many animals are not returned to the pond and die without a humane method of killing, often due to exposure to air. In addition to asphyxiation caused by exposure to air, the microscope's brightness can affect the larvae due to the increased temperature caused by the lamp. The removal of decapods from water can impair their gill function and disrupt oxygen consumption, which, in turn, can lead to physiological and metabolic alterations (CRUSTACEAN COMPASSION, 2023). Liu *et al*. (2015) showed that the duration of air exposure significantly influences the survival of shrimp and can cause oxidative damage.

They observed that shrimp remained alive for a maximum of 30 minutes of air exposure, but if the exposure period was relatively shorter (10 minutes), the damage caused could be reversed after re-submersion. Additionally, exposure to air can cause oxidative stress, apoptosis in the hepatopancreas and gills, as well as changes in heart rate and lactate content (DUAN *et al*., 2016; WANG *et al*., 2020a; WANG *et al*., 2022). Manipulation can also increase glucose levels (RACOTTA; PALACIOS, 1998; APARICIO-SIMÓN *et al*., 2010) and hemolymph lactate (APARICIO-SIMÓN *et al*., 2010). However, Aparicio-Simón *et al*. (2010) reported that an increase in lactate levels before hyperglycemia suggests a possible activation of gluconeogenesis as the main lactate clearance pathway. Furthermore, hypoxia can reduce thermotolerance in postlarvae to hyperthermia (ULAJE *et al*., 2023), which can further worsen stress in postlarvae analyzed under a microscope. Also, despite studies like Baloi *et al*. (2013) showing that exposure to artificial light can be beneficial for production, it can have negative effects on decapods, such as damage to photoreceptors (MEYER-ROCHOW, 2001). For longer analyses, such as health assessments, it is recommended that after removing the animals from the tanks or ponds, they should be relocated to a container with water and a source of oxygen. The observation of live animals under the microscope should be avoided, as well as vivisection techniques as described with juveniles and adults, and under no circumstances should they be killed without effective and humane stunning and slaughter methods.

The transport of live animals requires a comprehensive consideration of various crucial factors to ensure the survival and well-being of the animals, as multiple stressors are involved in the process, such as animal handling, exposure to air, vibration, light, noise, inadequate or fluctuating temperatures, overcrowding, and deterioration of water parameters (LU *et al*., 2015; GAO; HE, 2017; FURTADO *et al*., 2017; CRUSTACEAN COMPASSION, 2021b; XU *et al*., 2022; WUERTZ *et al*., 2023). The logistics related to transportation, whether by land or air, should vary according to the duration of the journey. Ostrensky and Silva (2017b) recommend that journeys of less than 8 h be done by land in tanks or transport boxes equipped with aeration or oxygenation devices. For journeys exceeding 12 h, air transportation with double plastic bags protected by cardboard and filled with pure oxygen is recommended (OSTRENSKY; SILVA, 2017b). Other recommendations include not exceeding a transportation period of 24 hours, pre-sanitizing the transport box and truck with hyper chlorinated water to prevent contamination, conducting transportation preferably during cooler temperature hours while protecting animals from direct sunlight, ensuring that the supply of oxygen is sufficient to meet the animals' needs, adhering to appropriate stocking

densities, which may vary depending on the season, type of transport, and age of the animals, adjusting the temperature according to the duration of the transport (cooling the water if the transport exceeds 3 hours to reduce metabolic rate, waste production, and pH fluctuations), considering the use of activated carbon, microalgae, and other substances to mitigate the effects of water degradation, and carefully calculating the frequency and quantity of feeding to avoid cannibalism without compromising water quality (SENAR, 2016; SENAR, 2017; OSTRENSKY; SILVA, 2017b; SOARES *et al*., 2021). Temperature is a critical stressor for shrimp during transport and can affect their survival. Even small temperature fluctuations can significantly impact the mortality rates of transported prawns (COYLE *et al*., 2005) and slowly decreasing the temperature is beneficial to the animals (APEC, 1999; COYLE *et al*., 2005). In addition, changes in physiological indicators of hypoxic and metabolic stress have been observed in shrimp exposed to reduced oxygen levels (CHENG *et al*., 2003). Therefore, developing strategies to ensure and maintain oxygenation, temperature, salinity, pH, and control of nitrogenous waste elimination, among other factors, is crucial for the well-being and survival of transported shrimps (CRUSTACEAN COMPASSION, 2023). Duration of the transport is highly relevant, as the longer the transportation duration, the greater the risks and severity of impacts on animal welfare. Therefore, extra attention and care in planning and preparation are essential to ensure that transportation is carried out as quickly as possible with minimal negative effects on the animals. Finally, conducting necropsies to identify the causes of death is an important initiative, as the diagnosis is the basis to prevent death in future transportations.

Issues related to experimentation on invertebrate animals are a cause for concern. For example, in Brazil, the Arouca Law (Nº 11.794, of October 8, 2008), regulating the use of animals for scientific procedures, applies only to animals in the phylum Chordata, subphylum Vertebrata. Therefore, there are no regulations for approval by an ethics committee for research involving invertebrates. As a result, they are subjected to a diversity of research procedures without any protection, which represents a major threat to their well-being. In industries like shrimp farming, many genetic research studies are conducted to select animals that are more disease-resistant, adaptable to environmental variations, and show rapid growth (ZHANG *et al*., 2013; LYU *et al*., 2021; SHIN *et al*., 2023; LU *et al*., 2023; SRIPHUTTHA *et al*., 2023). Given the latest research on the sentience of invertebrate animals, there is a need for the review of animal protection laws, to include invertebrate taxonomic groups which science indicated as sentient. However, until effective changes occur in laws, institutional animal ethics committees can review invertebrate research proposals and scientists can adhere

to the Russell and Burch (1959)'s 3Rs Principle (1959): Reduction, Replacement, and Refinement. Also related to the 3Rs, Russel and Burch (1959) established the use of anesthesia and analgesia as an undisputed refinement in experimentation. Therefore, vivisection, as observed on some farms for health analysis and research is not acceptable, and animals must be either anesthetized for sample collection or humanely euthanized.

One of the most frequently mentioned procedures related to shrimp farming is eyestalk ablation in female breeders. Ablation is performed with the aim of inducing gonadal maturation, resulting in an advancement of the ovigerous state and an increase in the frequency of spawns. The technique involves the removal of one or both eyestalks of the shrimp using different methods (LIMA *et al*., 2015). Despite being developed and used to improve the reproductive performance of shrimps, the procedure has several consequences due to the fact that the eyestalk region houses an important neuroendocrine center. As a result, eyestalk ablation can cause physical trauma and behaviors indicative of pain (TAYLOR *et al*., 2004; DIARTE-PLATA *et al*., 2012; BAE *et al*., 2013). A study conducted by Albalat *et al*. (2022) compiled some of the major negative impacts already described. Thus, in addition to trauma and pain, ablation can also affect the survival rate, leading to increased mortality of the breeders (ZACARIAS *et al*., 2019), trigger hormonal imbalances that activate/reduce genes related to the immune system (SAINZ-HERNÁNDEZ *et al*., 2008; BAE *et al*., 2013; TREERATTRAKOOL *et al*., 2014), interfere with the pattern of epidermal pigmentation and the Feeding Inhibitor Factor (LIMA *et al*., 2015), induce stress (TAYLOR *et al*., 2004; BAE *et al*., 2013; TREERATTRAKOOL *et al*., 2014), disrupt physiological balance (PALACIOS *et al*., 1999b; DAS *et al*., 2015), lead to reproductive exhaustion (PALACIOS *et al*., 1999b; DAS *et al*., 2015), weight loss (PALACIOS *et al*., 1999b), compromise offspring quality (PALACIOS *et al*., 1999a; ZACARIAS *et al*., 2021), decrease hyperglycemic and molting inhibiting hormones in shrimp (SAINZ-HERNÁNDEZ *et al*., 2008), result in high energy demands (RACOTTA *et al*., 2003), influence macronutrient metabolism (RACOTTA *et al*., 2003; SAINZ-HERNÁNDEZ *et al*., 2008), alter biochemical pathways (RACOTTA *et al*., 2003; SAINZ-HERNÁNDEZ *et al*., 2008), and decrease hemocyanin and glucose levels in the hepatopancreas (PALACIOS *et al*., 1999b). In light of these concerns, scientists do not recommend performing eyestalk ablation (BIRCH *et al*., 2021). Furthermore, Zacharias *et al*. (2019), indicate that it is possible to achieve similar production levels under commercial conditions without resorting to eyestalk ablation.

Anesthesia and analgesia are recommended to protect animal welfare and alleviate nociception, pain, and suffering in potentially painful and distressing practices for decapods,

including long-term restrain, invasive and surgical procedures, sampling, transportation, and euthanasia. The type and depth of analgesia can vary from mild sedation to analgesia and immobility, and anesthesia is characterized by unconsciousness. There are effective methods for administering analgesia and anesthesia to decapods, including baths, intracardiac injections, local anesthetics, or inhalation (VALENTE, 2022). Pain control can also be used during handling and transportation to minimize the impacts on animal welfare (AKBARI *et al*., 2010; LORSINGKUM *et al*., 2011; VALENTE, 2022). However, there is insufficient scientific evidence to conclude that surgical staging levels as per traditional signs provide adequate analgesia and anesthesia, with the necessary unconsciousness for performing more invasive procedures (VALENTE, 2022; PEDRAZZANI *et al*., 2023).

The capture process requires precautions and preparations. Ostrensky and Silva (2017c) recommend that before capture, a biometry should be performed for morphological and health assessments, which includes an additional negative welfare impact. The nutrition of the animals can also be affected, as it is recommended to stop feeding for about two days before capture, to prevent water quality deterioration. Additionally, the emptying of the pond starts about two days before and must be carried out with care to avoid the resuspension of organic matter from the bottom and the reduction in dissolved oxygen concentrations, which must be constantly monitored. Capture is best during periods when the temperature is milder, preferably at night, as high daytime temperatures can influence the behavior of the animals, causing them to bury themselves in the mud, which reduces the efficiency of capture and can prolong its duration. The capture itself begins when the water level in the pond is below 30% (OSTRENSKY; SILVA, 2017c). A measure of the negative effects of the capture on the welfare of the shrimp is the frequency and intensity of the jumping behavior of the animals (PEDRAZZANI *et al*., 2023). In this regard, it is observed that automated suction devices can provide agility and speed to the process as compared to manual capture.

A critical shrimp welfare point that is currently gaining more attention from researchers and producers is the absence or inadequacy of a stunning method before slaughter. Exposure to air and immersion of animals in ice, the most widely used method for shrimp slaughter worldwide, are not stunning procedures (WEINECK *et al*., 2018; PEDRAZZANI *et al*., 2023). The induction time for electric stunning is shorter, quickly paralyzing the animal, with longer recovery compared to chilling (WEINECK *et al*., 2018; ATANASOFF *et al*., 2022). In addition, there is no confidence that chilling renders decapods unconscious (BIRCH *et al*., 2021). However, issues related to total anaesthesia during electric stunning remain uncertain in invertebrates (BIRCH *et al*., 2021). The welfare benefits associated with

electrostunning may depend on the quality of equipment and its settings (WEINECK *et al*., 2018; BIRCH *et al*., 2021; LEWIT-MENDES, 2022). Additionally, the slaughter of crustaceans using ice slurry or asphyxiation is considered inhumane (LEWIT-MENDES, 2022). The use of ice for slaughter can cause death by asphyxiation if there is insufficient contact with the animals or by osmotic shock due to the difference in salinity caused by the melting ice (AHAW, 2005; LEWIT-MENDES, 2022). There is also the possibility of stunning using anesthetic methods, but this needs further study (BIRCH *et al*., 2021; VALENTE, 2022; LEWIT-MENDES, 2022). Finally, it is noted that ice-based slaughter prioritizes the quality of the meat over the well-being of the shrimp (SIDQY *et al*., 2020). The same considerations apply for animals killed during culling.

It is worth noting that the points highlighted here were based on visits to laboratories and shrimp farms in the Northeast of Brazil. Since there are no specific regulations to be followed in shrimp farming, practices can vary significantly among individual laboratories and farms. Therefore, what has been presented here is a first glimpse of the reality on four farms and three laboratories, and further studies are needed before a complete picture of the range of practices in the country. Additionally, we have noticed that some producers acknowledge that shrimp are sentient beings and are committed to exploring new alternatives to improve their welfare.

4.4.2 Exploring alternative approaches: the rise of cultivated seafoods

A new and disruptive production practice promises to deliver the same final product but without the use, and thus the suffering and killing of shrimp.

Cellular agriculture or cellular animal science is an emerging branch of biotechnology that aims to produce meats and other animal food proteins uncoupled from animal raising and slaughtering procedures (HEIDEMANN *et al.,* 2020), addressing issues associated with the environmental impact, sustainability challenges and animal welfare (POST *et al*., 2020; BISCARRA-BELLIO *et al*., 2023). In terms of animal welfare, the case of shrimp seems critical, as together with other invertebrate animals, they are typically not covered under animal welfare legislation. This means that there is no legal basis demanding care for the avoidance of shrimp suffering, for instance, no humane slaughter methods are obligatorily prescribed or enforced. According to Broom (2000), priorities for animal welfare can be set in terms of the severity of suffering and the number of individuals involved. Using this rationale,

the transition from conventional shrimp farming to alternative shrimp production chains can be considered a priority.

Alternative seafood doesn't rely on wild population productivity or geographical considerations (FRANKS *et al*., 2021; ALBALAT *et al*., 2022; BROWNING, 2023). In addition, supply chains and raw materials for alternative proteins are significantly less constrained than conventional seafood supply chains (GFI, 2023). Thus, manufacturing facilities for plant-based and cultivated shrimp don't need to be located near coastal areas. These benefits create an opportunity for plant-based and cultivated seafood to provide a healthier, ocean-friendly, and ultimately less expensive alternative to conventional seafood (JOUET, 2021; GFI, 2023).

Accelerating the development, commercialization, and widespread availability of plant-based and cultivated seafood seems to be a core pillar of the strategic plan of all entities whose vision includes responsible stewardship of both land and sea while ensuring human prosperity (MARWAHA *et al*., 2020). In 2018, the startup Shiok Meats in Singapore announced a scientific breakthrough: the ability to produce shrimp from stem cells (WIRED, 2023). Already on its way to regulatory approval, Shiok Meats is in the final phases of research and development and launched its shrimp commercially in restaurants in 2023 costing US$400 a pound (SEALPAC, 2023). CellMEAT is a South Korea-based food tech company that has been aiming to create cell-cultured shrimp meat to provide a sustainable alternative to the market. The company has since created a safe-to-consume prototype that replicates both the taste and texture of shrimp without the need for shrimp farming. The product recently entered public testing through the 'Sigolo' restaurant in South Korea (SMITH, 2022). S'pore startup is growing shrimp meat from cells in a lab and states that in 10 years is going to be possible to grow it at home (THIAGARAJAN, 2020).

Even though the expansion of alternative protein production may not be a complete replacement to current shrimp farming practices in the near future, it is a promising strategy to decrease critical shrimp welfare points.

4.5 CONCLUSION

Despite progress in animal welfare awareness and legislation in some regions, the global shrimp farming industry still faces significant challenges related to the welfare of these animals. Many countries, particularly major shrimp producers, lack comprehensive regulations and standards for the treatment of decapods, and practices such as eyestalk

ablation and slaughter with ice slurry continue to raise ethical concerns. Efforts to address these issues include recommendations for better management practices in shrimp farming, such as monitoring and improving environmental conditions, stocking densities, and transportation procedures. Anesthesia, analgesia and humane stunning methods are also being explored to minimize pain and suffering during handling and slaughter. Furthermore, the emergence of alternative seafood production methods, such as cellular agriculture, presents a promising venue to produce seafood with fewer ethical dilemmas associated with traditional farming practices, since production is decoupled from animals' suffering and slaughter. While there remains much work to be done to promote the welfare of shrimp farming, growing awareness and evolving technologies offer hope for a more compassionate and sustainable future for both these animals and the seafood industry. It is essential for stakeholders, including governments, producers, and consumers, to strive for the adoption of best practices, including the fostering of radical innovation, to achieve significant improvements in shrimp welfare.

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5 CONSIDERAÇÕES FINAIS

A compreensão de que os camarões são seres sencientes com suas próprias necessidades e capacidades nos leva a questionar a exploração e o tratamento a que eles são submetidos na indústria. Tornar-se consciente do bem-estar desses animais significa avaliar e possivelmente reformar as práticas de criação que frequentemente os submetem a condições de vida inadequadas e sofrimento.

É imperativo que a comunidade científica, autoridades regulatórias e a sociedade como um todo se envolvam em discussões informadas e deliberadas sobre o tratamento e a criação de invertebrados explorados por humanos, como é o caso dos camarões e outros crustáceos decápodes. Devemos estabelecer diretrizes que reflitam nosso entendimento crescente da senciência desses animais e nos esforçar para garantir que sua existência na aquicultura seja digna e livre de sofrimento.

Este trabalho representa um passo na direção de uma atitude mais compassiva em relação aos camarões e, ao mesmo tempo, um apelo a uma abordagem ética e baseada em evidências no que diz respeito a esses animais. O respeito à senciência e ao bem-estar dos camarões deve ser uma parte essencial de nossa busca por uma relação mais ética com os animais.

Por último, acredito ser interessante mencionar que, além de realizar o presente trabalho durante o período de mestrado, eu participei como coautora na publicação do artigo “Demand changes meat as changing meat reshapes demand: The great meat Revolution”, na revista Meat Science, conforme apresentado no Apêndice A.

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APÊNDICE A

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Demand changes meat as changing meat reshapes demand: The great meat revolution

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