UNIVERSIDADE FEDERAL DE ALAGOAS – UFAL
INSTITUTO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE
Programa de Pós-Graduação em Diversidade Biológica e Conservação nos Trópicos/PPG-DIBICT

RAFAEL BARROS DE CASTRO

CONECTIVIDADE DO CONHECIMENTO ECOLÓGICO LOCAL ENTRE OS PESCADORES ARTESANAIS DE CAMARÃO: DIRECIONAMENTO E INFLUÊNCIAS NA PRODUTIVIDADE PESQUEIRA

MACEIÓ
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Dissertação apresentada ao Programa de Pós-Graduação em Diversidade Biológica e Conservação nos Trópicos, Instituto de Ciências Biológicas e da Saúde. Universidade Federal de Alagoas, como requisito para obtenção do título de Mestre em CIÊNCIAS BIOLÓGICAS, área de concentração em Conservação da Biodiversidade Tropical.

Orientador(a): Profº. Dr. Vandick da Silva Batista

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RESUMO

A pesca artesanal de camarão tem importância socioeconômica e cultural, principalmente nos países em desenvolvimento. Para viabilizar a explotação sustentável dos recursos, manter o bem-estar social e respeitar cultura e tradição na atividade é necessário que esta pesca tenha uma gestão compatível com seu perfil, o qual na região é artesanal em média e pequena escala. Para embasar o conhecimento e viabilizar politicamente a gestão, o conhecimento ecológico local (CEL) dos pescadores é um instrumento relevante, mas pouco utilizado. O presente estudo tem o objetivo de investigar quais os perfis de pescadores que melhor se conectam por meio do CEL, e se estes pescadores formam grupos com temas do CEL. Para esta avaliação foram realizadas entrevistas por amostragem acidental com pescadores comerciais de camarões marinhos utilizando como instrumento, formulários semiestruturados em três regiões costeiras no nordeste brasileiro. Foi utilizada regressão linear e o programa Gephi para avaliar a conectividade dos pescadores com os aspectos do CEL. Os resultados mostram que o CEL de reprodução e migração são predominantes para os pescadores e existe um refinamento do CEL com a aquisição da experiência. Também foram registrados grupos de pescadores conectados por meio de temas do CEL, sendo os aspectos aspectos reprodutivos e migração das três principais espécies de camarão foram os mais declarados como conhecidos pelos pescadores da frota camaroneira. Conclui-se que o CEL não é homogeneo entre os pescadores, sendo essencial considerar estas diferenças para melhorar o processo de tomada de decisão e gestão da pesca artesanal. Ter no CEL um canal de comunicação, principalmente por meio dos temas de reprodução e migração, pode auxiliar a efetividade do manejo pesqueiro dos camarões marinhos para seu uso produtivo e sustentável, tendo o bem-estar dos pescadores atendido, e atingindo os objetivos das partes interessadas.

Palavras-chave: Pesca artesanal; conhecimento ecológico local; transmissão cultural; produtividade pesqueira; Penaeidae.

ABSTRACT

Artisanal shrimp fishing is of socio-economic and cultural importance, especially in developing countries. To enable the sustainable exploitation of resources, maintain social well-being and respect culture and tradition in the activity, it is necessary that this fishery has a management compatible with its profile, which in the region is artisanal in medium and small scale. To support knowledge and make management politically viable, local ecological knowledge (LEK) of fishermen is a relevant instrument, but rarely used. The present study aims to investigate which profiles of fishermen are best connected through LEK, and whether these fishermen form groups with LEK themes. For this evaluation, interviews were carried out by accidental sampling with artisanal shrimp fishers, using semi-structured forms as instruments in three coastal regions in north-eastern Brazil. Linear regression and the Gephi program were used to assess the fisher's connectivity on LEK. The results show that LEK on reproduction and migration are predominant for fishers and that there is a refinement of the LEK as experience increases. Groups of fishermen connected through LEK themes were also registered. The reproductive aspects and migration of the three main species of shrimp are the most declared to be known by fishers. It is concluded that the LEK is not homogeneous among the fishers, being essential to consider these differences in order to improve the process of decision making and management of artisanal fisheries. A communication channel among stakeholders may be developed taking LEK as a path, mainly through the themes of reproduction and migration, helping the effectiveness of fisheries management of marine shrimps for their productive and sustainable use. The dialogue would improve fishers well-being and achieving the objectives of the interested groups.

Keywords: Artisanal fishing; traditional ecological knowledge; cultural transmission; fisheries yield; Penaeidae.

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1 Apresentação

Com o avanço nos processos de gestão dos recursos pesqueiros em ambientes costeiros, a inclusão dos atores envolvidos na explotação dos recursos nestes processos é altamente válida para melhorar a eficiência da gestão e, ao mesmo tempo, contribuir para o bem-estar e produtividade dos pescadores (BERGMANN et al., 2004; BERKES, 1993; DREW, 2005; SILVANO et al., 2008). A inclusão do conhecimento ecológico local na gestão é um dever para atingir os objetivos de ambas as partes interessadas (BUTLER et al., 2012; CINTI; SHAW; TORRE, 2010). Ainda assim, pouco é conhecido sobre o conhecimento ecológico local (CEL) dos pescadores artesanais, efetuada tipicamente na pesca de arrasto. Além disso, entender quais temas do CEL interferem no sucesso na produção dos pescadores pode aumentar a produtividade da atividade, assim como pode melhorar os canais de comunicação com a gestão, aumentando a sustentabilidade da atividade e dos recursos.

Esta dissertação é dividida em dois capítulos. No primeiro capítulo são abordados os avanços teóricos e desafios relacionados ao CEL, focando principalmente nos conceitos e teorias que tratam de como o CEL se conecta com os pescadores e como este conhecimento potencialmente influencia na gestão dos recursos pesqueiros das comunidades locais. Este capítulo também aborda um tópico sobre as teorias de redes utilizadas na composição das redes locais de conhecimento.

O segundo capítulo é o artigo principal da dissertação, o qual tem como objetivo investigar se existem perfis de pescadores que se conectam com o CEL, e se estes pescadores formam grupos coesos com alguns aspectos do CEL. Nesse capítulo é analisado se temas do CEL dos pescadores formam grupos coesos. Especificamente, este trabalho utiliza de métricas de rede para avaliar as conexões formadas pelos pescadores e o CEL.

2 Revisão da literatura

2.1 Estado da pesca artesanais de camarão

A pesca artesanal tem elevada relevância socioeconômica e cultural em países em desenvolvimento e apoia o bem estar humano das pessoas que vivem nas comunidades envolvidas (BATISTA et al., 2014; BERKES et al., 2001). Porém, muitos problemas atingem as pescarias artesanais, e acabam prejudicando o meio social das comunidades e o ambiente onde vivem e explotam os recursos (CINNER; DAW; MCCLANAHAN, 2009). Embora a sobrepesca e a competição com frotas industriais sejam os principais problemas que afetam a sustentabilidade da pesca artesanal, existem vários outros relevantes de acordo com o perfil e região (BÉNÉ; MACFADYEN; ALLISON, 2005; CINNER et al., 2012; FREIRE; GARCMH, 2000). Além dos fatores ambientais, a inclusão de novas tecnologias de pesca tende a aumentar a captura dos recursos (SIMPSON; WATLING, 2006; WELLS; COWAN; PATTERSON, 2008), assim como problemas de natureza sócio-política estimulam a sobrepesca dos sistemas (CADDY; SEIJO, 2005). Dessa forma, mitigar os conflitos existentes na pesca artesanal torna a explotação de recusos mais sustentável e aumenta o bem-estar dos pescadores.

A explotação de recursos pesqueiros de interesse comercial que necessita de altas demandas para suprir a necessidade, possuem explotação predominante em redes de arrasto duplo, mas outras estratégias podem ser utilzadas pelos pescadores. Este é o caso da pesca de camarões marinhos nos trópicos, usualmente da família Penaeidae. As pescarias camaroeiras são categorizadas em três tipos (GILLETT, 2008), industrial, semi-industrial e artesanal, sendo que no Nordeste do Brasil predomina a semi-industrial e artesanal (ANDRADE et al., 2016; SANTOS, 2010a). A pesca artesanal, de pesquena ou média escala (sensu BATISTA et al., 2014), é realizada nos estuários, reentrâncias e águas rasas próximas à costa. Os apetrechos de pesca utilizados usualmente são redes de arrasto de pequeno e médio porte, operadas manualmente ou com guincho. As principais espécies capturadas são o camarão-sete-barbas (*Xiphopenaeus kroyeri* Heller, 1862), camarão-rosa (*Penaeus subtilis* Pérez Farfante, 1967), e em menor proporção o camarão-branco (*Penaeus schmitti* Burkenroad, 1936) (ARAGÃO; CINTRA; SILVA, 2015; D'INCAO; VALENTINI; RODRIGUES, 2002; VALENTINI et al., 2012). Nesta variedade de espécies e com uso das diferentes redes e técnicas, as pescarias artesanais de camarão nos tropicos possuem características que estão relacionadas a habilidade dos pescadores usarem apetrechos em acordo com a espécie e o momento bioecológico em que se encontram, o que deve se consolidar no CEL dos pescadores.

A pesca artesanal de média escala de camarões marinhos é considerada semi-industrial sendo uma modalidade da pesca artesanal mais focada no recurso (MACHAVA; MACIA; DE ABREU, 2014; SALAS et al., 2011). Contém embarcações melhor equipadas para a navegação, captura e conservação do pescado do que as demais artesanais, usando técnicas que possibilitam alcançar uma produtividade de pescado mais elevada que a artesanal local de menor escala (SALAS et al., 2011). Sendo assim, é factível que a produção dessas pescarias alcançe a produtividade da pesca industrial, desde que bem manejada.

2.2 Características bioecológicas dos camarões peneídeos explotados

Com relação a pesca na região Nordeste das espécies de Penaeide com importância comercial, as pescarias são de características artesanal em algumas localidades com uma escala semi-industrial (ARAGÃO; CINTRA; SILVA, 2015; SANTOS, 2010a). Os barcos tem um comprimento aproximado de 13 metros (CARMO, K. A.; COELHO-FILHO, P. A.; OLIVEIRA, 2015). A maioria das embarcações utilizam redes de arrasto duplo para capturar as espécies.

Peneídeos são camarões que tem como característica o crescimento rápido e período de vida curta, com longevidade entre um e 2 anos e meio. O ciclo de vida destes camarões é caracterizado por entrada e saída dos estuários, para as espécies *P. schmitti* e *P. subtilis*, a espécie *X. kroyeri* completa seu ciclo de vida exclusivamente em meio marinho (EUTRÓPIO et al., 2013; MUNEHISA SHIMIZU et al., 2014; MUNGA et al., 2013; SILVA et al., 2016b). Os peneídeos tem uma distribuição espacial mundial, principalmente em mares tropicais e subtropicais (COUTO et al., 2013; MUNGA et al., 2013), onde encontram condições apropriadas para o seu desenvolvimento, crescimento e reprodução.

Os camarões peneídeos possuem várias fases ontogenéticas até atingir a fase adulta de maturação e posteriormente reprodução. Essas espécies tem o comportamento de cardume e esses fatores somado a intensa atividade pesqueira têm risco de sobrepesca em muitas regiões, tornando essas áreas prioritárias para o desenvolvimento de planos de manejo de sua explotação (CADRIN; BOUTILLIER; IDOINE, 2004; GARCIA, 1996). Portanto, considerar as características biológicas dos camarões, e a necessidade destas espécies possuírem manejo, tem possibilidade de tornar as pescarias mais sustentáveis e rentáveis.

Com relação ao habitat que as espécies se econtram, existem duas diferenciações.

Os camarões branco (*Penaeus schmitti*) e rosa (*Penaeus subtilis*), quando juvenis se encontram em estuários e baías costeiras, na fase adulta esses camarões se encontram na plataforma continental (D'INCAO; VALENTINI; RODRIGUES, 2002). Os camarões sete barbas (*Xiphopenaeus kroyeri*) vivem na plataforma continental, podendo migrar para áreas costeiras marinhas (HECKLER et al., 2014).

A literatura relata que os camarões branco e rosa estão associados a fundo de areia, areia-lamoso, areia de cascalho, calcário e lama. O camarão sete barbas está associado a locais de silte e argila (D'INCAO; VALENTINI; RODRIGUES, 2002; DALL et al., 1990). A profundidade que os camarões se encontram variam de 20 a 60 metros para os camarões branco e rosa. E o camarão sete barbas tem uma variação de profundidade entre 2 e 30 metros (COSTA et al., 2016).

Com relação a aspectos reprodutivos, os camarões branco tem uma primeira maturação em um período de 12 meses com tamanho de 15 cm de comprimento total (PEIXOTO et al., 2018). Não tem informada a idade de primeira maturação para os camarões rosa. E de acordo com Viana et al., (2015) o camarão rosa tem um tamanho de primeira maturação de 13,5 cm de comprimento total. O camarão branco tem um tipo de reprodução contínua com picos no outono e primavera. O camarão rosa também tem reprodução contínua, com picos em março e outro pico em setembro. O camarão sete barbas tem reprodução contínua e picos de reprodução de dezembro a abril (BOCHINI et al., 2014; DALL et al., 1990; HECKLER et al., 2014; HELOU et al., 2012).

2.3 O ambiente formador do CEL na pesca artesanal de camarão

As espécies de camarões que compõem a Família Penaeidae (Rafinesque, 1815), tem um importante valor comercial agregado (BRANCO et al., 2013; HECKLER et al., 2014; SILVA et al., 2016b). Por esta razão é um dos recursos pesqueiros que mais frequentemente é explotado pela pesca artesanal, semi-industrial e industrial, em regiões costeiras de todo mundo (EUTRÓPIO et al., 2013). Por serem consideradas espécies que possuem valor comercial, podem ser usadas de modelo para estudos que integrem o CEL dos explotadores destes recursos.

A definição de CEL, proposto por Berkes (1993), caracteriza este conhecimento formando uma rede entre crenças, práticas e saberes. O CEL (ou LEK, do inglês Local Ecological Knowledge) tem muitos direcionamentos de estudos, oferecendo e possibilitando através de investigações, uma rica fonte de informações que podem diminuir ou prevenir que os recursos alcancem níveis de sobre-explotação ou colapsem (BERKES; TURNER, 2006; LEITE; GASALLA, 2010; PRADO; MURRIETA, 2015). Nos estudos que envolvem o CEL incluem temáticas sobre sistemas de classificação taxonômica, estratégias de coleta e captura de indivíduos, estudos na área da farmacologia, além de abordar técnicas de uso e manejo de recursos naturais (BERGMANN et al., 2004; GERHARDINGER; GODOY; JONES, 2009; LEITE; GASALLA, 2013; MUSIELLO-FERNANDES; ZAPPES; HOSTIM-SILVA, 2017; POSEY, 1985). Este conjunto de temas representam algumas vertentes que fazem do CEL em uma poderosa fonte que permite interligar sociedades com a dinâmica da natureza para termos a humanidade interagindo com os recursos sem comprometer seus próprios anseios, necessidades e potencialidades.

O caráter difuso e multiespecífico da pesca artesanal gera ambiente social onde o CEL melhor se desenvolve e tem relevância (BUTLER et al., 2012). Por outro lado, nele também é onde há maior dificuldade em rastrear o caminho do conhecimento, justamente devido à grande variedade e dispersão de informações entre espécies e regiões. Estudar as espécies de alto interesse comercial pode ser a chave para encontrar os caminhos do conhecimento no CEL, o que é o caso dos camarões Penaeidae, usualmente de alta relevância social e econômica tanto na pesca artesanal quanto industrial (EUTRÓPIO et al., 2013). Sendo as poucas espécies explotadas nas diversas regiões e culturas, é potencialmente relevante como objeto para avaliar conhecimentos locais e suas origens.

2.4 A incorporação do conhecimento ecológico local na gestão

Aspectos da conservação e manejo de recursos baseada na comunidade surgiram a partir de três grandes mudanças conceituais que ocorreram nos últimos anos na ecologia (BERKES, 2004); a primeira é a mudança do reducionismo para uma visão sistêmica do mundo, a segunda mudança é para incluir humanos no ecossistema e a terceira mudança é de uma abordagem baseada em especialistas para a conservação e gestão participativa (BRADSHAW; BEKOFF, 2001; LUDWIG, 2001). Essas mudanças ecológicas que ocorreram nos últimos anos, possibilitou a inserção mais eficaz da gestão participativa aumentando o envolvimento dos atores sociais envolvidos.

A incorporação do CEL para elaboração de planos de manejo com base ecológica tem sido reconhecida como um mecanismo de conservação potencialmente poderoso em todo mundo (JOHANNES, 2002). Quando a comunidade apoia os planos de conservação, isto emerge consistentemente como um dos fatores mais importantes para manter a eficácia de longo prazo dos planos (ASWANI, 2019). Os programas que incorporam práticas costumeiras de manejo com base ecológica em sua concepção atraem mais apoio dos povos tradicionais (ASWANI; HAMILTON, 2004; DREW, 2005; EVANS; BIRCHENOUGH, 2001). Nos últimos anos, pesquisas têm demonstrado a importância do conhecimento ecológico local na elaboração e implementação de planos de manejo da pesca (ALLISON; BADJECK, 2004; DREW, 2005; SILVA; OLIVEIRA; JUNIOR, 2013; SILVANO; BEGOSSI, 2012). Assim, o CEL tem demonstrado ser uma forte ferramenta para auxiliar na determinação das políticas públicas apropriadas na gestão participativa da pesca, particularmente nos trópicos, permitindo que os pescadores sejam incluídos nos processos de gestão (BEGOSSI et al., 2011). Com isso, insere as práticas e costumes tradicionais nas políticas de manejo da pesca permitindo com que a gestão participativa alcance aos objetivos determinados.

2.5 A transmissão do conhecimento ecológico

Para que as tradições e conhecimentos locais sejam incorporados e respeitados em planos de gestão e manejo, é importante compreender alguns aspectos deste conhecimento e como ele pode ser transmitido entre indivíduos e também entre gerações. A transmissão de CEL está diretamente conectada com os processos de reprodução social, em que fatores como tecnologias, conhecimentos, comportamentos, a linguagem e as crenças são disseminados e adquiridos (CAVALLI-SFORZA et al., 1982). Três modos de transmissão de conhecimento têm sido reconhecidos: (1) transmissão horizontal: entre indivíduos da mesma geração; (2) transmissão vertical: entre indivíduos de diferentes gerações, mas dentro da genealogia; e (3) transmissão oblíqua: entre linhas genealógicas distintas (GALLOIS et al., 2018; HEWLETT; CAVALLI-SFORZA, 1986). A forma em que um tipo de transmissão de conhecimento é dominante em uma população pode influenciar em diferentes aspectos nos processos de inovação e de gestão em uma localidade (CAVALLI-SFORZA et al., 1982). Investigar os principais determinantes que podem influenciar no processo de transmissão do conhecimento tradicional é crucial no desenvolvimento da gestão, afetando a comunicação entre os tomadores de decisão envolvidos.

Um determinante clássico para o aprendizado do conhecimento é o envolvimento no tema, como conceitualizado pela aprendizagem significativa (AUSUBEL, 1969). Os pescadores, atores sociais das comunidades costeiras, são frequentemente, dependentes diretos dos recursos naturais, por isto sendo esperado que haja o desenvolvimento de conhecimentos a partir das informações obtidas em seu cotidiano na pesca. Daí desenvolvem vasto conhecimento acerca dos ecossistemas, biologia e ecologia dos recursos locais, os quais são transmitidos, culturalmente, entre as gerações de pescadores (CLAUZET; RAMIRES; BEGOSSI, 2005; MICHAEL L. DOMEIER et al., 2012; SILVANO et al., 2008). De acordo com Castellanos-Galindo et al. (2018) as informações fornecidas baseadas no CEL dos pescadores também ajudam a compreender e, consequentemente preencher algumas lacunas de conhecimento sobre os aspectos biológicos básicos, fornecendo percepções sobre os planos de longo prazo. Dessa forma, além do CEL fornecer informações cruciais para tornar a gestão dos recursos pesqueiros mais eficaz e ser um setor mais produtivo para os pescadores, o CEL também possibilita que novas investigações científicas sejam viabilizadas e assim surgir novas descobertas.

O uso produtivo e sustentável dos recursos explotados em pescarias artesanais depende da redução na corrida pelo peixe (GORDON, 1954; GRAFTON, 2005; LAM; PAULY, 2010). O setor artesanal tem diagnóstico mais difícil pela frota artesanal estar usualmente dispersa e nem sempre com sistemas socioeconômicos com articulação social que facilitem uma tomada de decisão produtiva (BATISTA et al., 2014; DAW, 2008; HILBORN, 2007; MCGOODWIN, 2001; RUBIO-CISNEROS et al., 2019). Dessa forma, é necessário melhorar a gestão da pesca artesanal, inclusive a camaroeira, principalmente em países em desenvolvimento, por meio de políticas que conciliem a exploração sustentável dos recursos, o bem-estar social, e o respeito à cultura e tradição na atividade.

2.6 Conceito de conectividade social: redes de saberes e seu contexto na conservação ambiental

2.6.1 Redes de saberes em sistemas socio-culturais

A teoria da análise das redes sociais (ARS), baseia-se nas ciências sociais, e possui uma abordagem estrutural no estudo da interação entre os atores sociais (FREEMAN, 1978, 2004). As relações investigadas nas ARS estudam geralmente aquelas que ligam os seres humanos individuais. No estudo realizado por Sen et al. (2019) investiga o que essas redes sociais podem mudar na estrutura da governança local. De acordo com analistas de redes sociais, frequentemente são examinadas as ligações entre grupos ou organizações. Dessa forma, a abordagem que a análise de redes sociais podem colaborar para solucionar questões que incorporem o ator social até grupos organizacionais.

A abordagem da rede social é baseada na noção intuitiva de que a padronização dos vínculos sociais, nos quais os atores estão inseridos, tem consequências importantes para esses atores sociais envolvidos (FREEMAN, 2004). Os analistas de rede, portanto, procuram descobrir vários tipos de padrões. E tentam determinar as condições sob as quais esses padrões tem efeito, e também para descobrir as suas consequências (COHEN; EVANS; MILLS, 2012; MARTIN et al., 2017; SIH; HANSER; MCHUGH, 2009). Com isso, deve-se relacionar a importância que essas redes tem entre o conhecimento ecológico local e os pescadores, e assim, incorporar essas descobertas em estratégias de políticas públicas de pesca.

Os estudos que abordam a teoria da análise de redes sociais, mostram que algumas pesquisas que abrangem os aspectos sociais dos indivíduos têm se concentrado consistentemente nas relações sociais que ligam os indivíduos e não nos próprios indivíduos (BODIN; CRONA, 2008, 2009). O tipo de pesquisa que examina as ligações entre os objetos de estudo é chamado estrutural. Assim, é importante salientar que este tipo de abordagem estrutural não se limita ao estudo das relações sociais humanas.

O conceito de conectividade é aplicado à quando nos referimos a comunicação e movimento de pessoas, bens, ideias, cultura e conhecimento (KONDOLF; PINTO, 2016). A conectividade de conhecimento possibilita o compartilhamento de informações entre os pescadores e pode ser um componente social fundamental da gestão pesqueira.

2.6.2 Conectividade de saberes para conservação e gestão de recursos pesqueiros

Compreender a dinâmica social do compartilhamento de informações pode ajudar a informar as estratégias de gestão identificando os pescadores centrais nas redes de compartilhamento de informações (FULLER et al., 2017). Esses pescadores centrais podem auxiliar os gestores na coleta de informações sobre a distribuição de oportunidades de pesca, o estado da pesca e recursos, e as maneiras pelas quais os pescadores usam seus conhecimentos para se adaptarem às intervenções de mudança do manejo (TURNER; POLUNIN; STEAD, 2014). Com isso, sem o conhecimento dessas relações de conectividade, a gestão terá dificuldades em prever as respostas adaptativas dos pescadores para ações de manejo.

Desta forma, é essencial a incorporação do conhecimento ecológico local dos pescadores na avaliação, monitoramento e gestão, particularmente nas pescarias tropicais artesanais e semi-industriais, onde há grande dispersão da frota, diversas espécies são explotadas, e o nível de investimento é usualmente baixo (BATISTA et al., 2014). Assim, é importante considerar as características das pescarias artesanais, os potenciais de manejo de recursos e encontrar soluções que possam gerenciar os conflitos e atender os objetivos da gestão e dos pescadores.

3. Local ecological knowledge connections on tropical artisanal shrimp fisheries

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Highlights:

- Fishers knowledge connectivity is high and driven by common exploiting interests.
- Fisher experiences deal better with hard to observe themes, as growth, mortality or feeding. Conversely, reproduction and migration are widely known.
- Regional knowledge similarities favor the implementation of management policies in a regional scale

Abstract

Local ecological knowledge (LEK) in fishing communities is the result from interactions between fishers and the exploited resources. It is transmitted through social networks, interdisciplinary structures that drives the dynamics of socio-ecological systems (SES). The LEK variability is supposed to depends on quality and quantity of ecological information flow among different stakeholders. To assess what is driving the LEK-SES themes, we hypothesized that the formation of LEK clusters among fishers is determined by networks articulation, fisher experience and the commercial value of the exploited species. The study area comprises three fishing communities in the Western South Atlantic at the tropical coast of Brazil where artisanal shrimp fisheries (on Penaeus schmitti, P. subtilis and Xiphopenaeus kroyeri) is a major activity. Data collection took place between March, April, and November 2019. To test our hypothesis, linear regression and bipartite network analyzes were performed to visualize the interactions between fishermen groups and LEK themes. The connectivity, nesting, modularity, and centrality parameters in this social network were calculated to test the hypothesis. Gephi and R software were used on data analysis. Our results indicate that experienced fishers improve LEK in their networks towards the themes of food, mortality, and growth. Furthermore, there are subgroups of fishers with distinct knowledge about the exploited shrimp species. We concluded that there is a spatial similarity in the connectivity of fisher’s knowledge, mainly concerning the reproductive and migratory dynamics of the target species, but also differences permeated by fishers experience and local interests. Managers starting co-management agreements using reproduction and migration referential variables as landmarks will be more successful incorporating LEK on information pool used on decision-making. Regional knowledge similarities favor the implementation of management policies in a regional scale potentially reducing conflicts within fishing communities and increasing efficiency on resource use.

Introduction

The interaction between fishers and resources generates individual ecological knowledge that is redistributed in the system of relationships according societies profile (CRONA; BODIN, 2010; RICO GARCÍA-AMADO et al., 2012). Redistribution influences on social functions, with individual characteristics that determines the quality and quantity of knowledge in a society, affecting the social groups structure (SALPETEUR et al., 2017). Several individual characteristics influence local ecological knowledge (LEK), such as gender (CAMOU-GUERRERO et al., 2008), demography (BEGOSSI; HANAZAKI; TAMASHIRO, 2002; SILVANO; BEGOSSI, 2002), or formal education (ZARGER, 2002). Beyond the individual level, social organization produces strong influence on local knowledge (BRONFENBRENNER, 1977), what is central on fishers need to use natural systems plenty of uncertainties (BERKES; COLDING; FOLKE, 2000; KIMMERER, 2012). Thus, the community's local ecological knowledge profile is expected to be associated with quality and quantity of information on bioecological aspects of their target resources which are useful to improve fisheries yield.

Incorporated into local society, cultural knowledge is transmitted or dispersed through social networks that are interdisciplinary structures essential to the development of the dynamics and structure of socio-ecological systems (LABEYRIE et al., 2019). The social network profile defines social groups most connected by sharing and information flow (GIRVAN; NEWMAN, 2002; SALPETEUR et al., 2016). Social connectivity among fishers influences the processes of artisanal fisheries management, usually involving a large variety of stakeholders (JENTOFT et al., 2010). These agents are inserted in various fishing and interagency institutions at different scales and in heterogeneous ways (SALPETEUR et al., 2017), comprising complex socio-ecological systems. In this context, apart from the relationship between the fisherman and the local ecological knowledge, the quality of the connections among agents from fisheries sector is essential in the dissemination of LEK, as well as in the generation of the world view of those actors involved directly in fishing.

The knowledge network strength is an essential feature too, considering that the ability of social actors to use and spread information is key in structuring an equitable social structure to support participatory deliberative processes (PRELL; HUBACEK; REED, 2009), promoting a qualitatively critical basis for management initiatives (CALVET-MIR et al., 2015; HAUCK; SCHMIDT; WERNER, 2016). Collaborative networks are potential multipliers of information relevant to decision-making by social groups (ISAAC et al., 2014; SALPETEUR et al., 2016), including those related to artisanal fishing (BERKSTRÖM et al., 2019; VELEZ;

ADLERSTEIN; WONDOLLECK, 2014). The potential can be influenced by attributes such as the amount of interactions and the degree of cohesion (BODIN; CRONA, 2009), the position of individuals in the network (TURNER; POLUNIN; STEAD, 2014), the presence of central informants (ABBASI; HOSSAIN; LEYDESDORFF, 2012; FREEMAN, 1978) and subgroups in a community (DORMANN; STRAUSS, 2013, 2014). In this way, the quality and quantity of ecological information circulating in traditional communities can be an indicator of the ability to adapt management in a viable socio-ecological arrangement.

Management arrangements are processes that allows to manage conflicts of interest among stakeholders, where the inclusion of all social actors is an essential feature (KIMMERER, 2012; MUSIELLO-FERNANDES; ZAPPES; HOSTIM-SILVA, 2017). Artisanal fishing is a predominant activity in traditional coastal communities, being small-scale fishing characterized by low investment in external technologies, the use of small vessels that limit the extent of fishing and the extensive use of LEK (see Batista et al., 2014). However, the supposed simplicity of artisanal fishing contains a variety of interests and knowledge that may or may not be dialoguing, generating social maturity or not, processes that may bring conflicts and not solutions (BERKES, 2009; CHRISTIE et al., 2017; DIAS; SEIXAS, 2019; POMEROY et al., 2007). Therefore, the structuring of LEK redistribution through flows between existing relationships, once understood, can generate positive externalities in fisheries management, enhancing its effectiveness.

Artisanal shrimp fisheries in the tropics are environments where LEK is mainly enhanced by the relationships between fishers (BUTLER et al., 2012). In tropical coastal ecosystems of the tropical South Western Atlantic, shrimp fisheries is undergone mostly by artisanal fleets (SANTOS; BRANCO; BARBIERI, 2013) at small and medium scales (BATISTA et al., 2014; SANTOS, 2010b; SANTOS; FREITAS, 2005). Of the marine shrimp species that co-occur in coastal waters there are three mainly targeted by these fisheries, the white shrimp *Penaeus schmitti* – high commercial value, followed by the pink shrimp *Penaeus subtilis* and the seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) – the most abundant, all from the family Penaeidae (SANTOS, 2010a; SANTOS; PEREIRA; IVO, 2006). They are resources of socioeconomic importance, exploited in the region with beam trawls since 1969 (SANTOS; COELHO; PORTO, 2006), with indication that it is close to recruitment overfishing (LOPES et al., 2014; SILVA et al., 2015, 2019). This scenario allows the existence of typical fisheries conflicts at socioeconomic, political (CADDY; SEIJO, 2005), and environmental dimensions (SIMPSON; WATLING, 2006; WELLS; COWAN; PATTERSON, 2008), but also instigate to understand which are the drivers that sustain a poor regulated fishery. Therefore, we have tropical shrimp fisheries as socio-ecological systems that are culturally interrelated by patterns of competitive use of species of high economic interest with low effort regulation, where segments with higher LEK and active perception for environmental changes should be more efficient.

Based on the assumption that there is a relationship between LEK diversity and the local social network in socio-ecological systems (SALPETEUR et al., 2017), we established the objective of evaluating the existence of fisher groups in traditional artisanal fisheries with differentiated capacity for LEK to the main co-occurring target species . We hypothesize that the domain of information on the LEK is affected by fishing experience, by the locally articulated social networks, and by the interest related to the commercial value of the shrimp species, delimiting social network groups of fishers with differentiated knowledge.

The integration of local social networks at regional scales, identified by traditional knowledge in the patterns of use of species of high commercial value, can generate subsidies for integrative and sustainable management as well as co-management tools. Therefore, we have a bridge to fishers' communication with managers, enabling the productive conservation of target species and their associated socio-ecological systems.

Material and Methods

Study area

This study was conducted in three fishing communities in Northeast Brazil: (1) Pontal do Peba (10 ° 21'14.92''S 36 ° 17'53.76''W); (2) Barra de Sirinhaem (8 ° 36'50.99''S 35 ° 03'10.94''W); (3) Baía Formosa (6 ° 22'05.52''S 35 ° 00'14.56''W). Artisanal shrimp fishing is one of the main local fishing activities (ANDRADE et al., 2016; SANTOS; PEREIRA; IVO, 2006) (Figure 1). The main fishery is located in Pontal do Peba associated with the São Francisco River discharge enriching coastal waters (KNOPPERS et al., 2005). There are 65 motorized wooden boats, with a length between 8 and 12 meters (SANTOS; FREITAS, 2006). The trawls are usually in mud bottoms between 10 and 20 meters deep (SANTOS; FREITAS, 2006). Further north, there is the most traditional shrimp fishery in Pernambuco at Barra de Sirinhaém associated with the Sirinhaém river. Local fishing fleet is smaller in size than that of Peba, 12 vessels (LOPES et al., 2014), the average length of the boats is 9 meters that exploits mud fisheries at depths between 10 and 20 meters. Baía Formosa is the third fishing ground located at the north end of the northeast Brazilian coast, mainly associated to the flow of small rivers, mainly rivers Guaju and Curimataú. The exploitation of marine shrimp in Baía Formosa occurs with large beach seines, following the levels of seasonal productivity, with 12 vessels operating locally, with an average length of 9 meters (SANTOS; PEREIRA; IVO, 2006). These vessels are equipped with a net (single drag), or two nets (double drag) which are paired and act simultaneously trawling at an average depth of 20 meters (SANTOS, 2010a; SANTOS; BRANCO; BARBIERI, 2013). Most fishers fish daily, what they call come-and-go. Each vessel usually support two or three fishers, including the skipper (SANTOS; SILVA; CINTRA, 2016).

Data collections were carried out in three fishing grounds off the coast of northeastern Brazil, in coastal cities at different States (Alagoas, Pernambuco and Rio Grande do Norte).

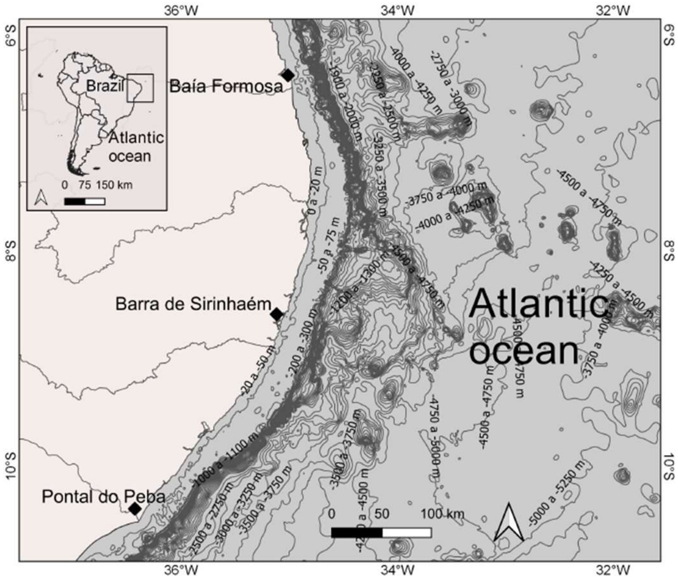

Figure 1. Fishing communities in the Northeast region of Brazil where interviews were performed

Data collection

Field interviews were carried out in March, April, and November 2019. Random sampling was carried out in blocks (the three fishing communities) according to opportunistic meetings with artisanal shrimp fishers at each location (ZAPPES et al., 2016), seeking to interview the maximum number of fishers during the time on field, covering at least 30% of the total number of fishers per fishing community (BERNARD; BERNARD, 2013; MORSE, 2000). In each community, the number of shrimp fishers who uses bottom-trawls was estimated based on the testimonies of the most experienced fishers indicated by communitarians at each location. Only shrimp fishers resident of the locality and that fishes the three main commercial valued Penaeidae species (white, pink and seabob shrimps) were interviewed in each location (following SILVANO; BEGOSSI, 2010). To avoid pseudoreplication, We do not interviewed more than one fisher per boat (GOTELLI;

ELLISON, 2011).

Consequently, in Pontal do Peba, 42 interviews were conducted, representing 59 of fishers, 19 interviews in Barra de Sirinhaém (27%) and 10 interviews in Baía Formosa (14%). All interviews took place after a meeting held with the president of the colony and fishers in the region to present the objective of the study. This research was registered in the Brazilian System of Genetic Resource Management and Associated Traditional Knowledge (SisGen) and approved by the Research Ethics Committee (CEP) at UFAL, on the Plataforma Brasil under number 2.970.521.

A semi-structured questionnaire was prepared containing questions that referred to five topics on the LEK related to the bioecology of the shrimp species: I- feeding, II- reproduction, III- predation, IV- migration and V- growth (Table 1) (questionnaire structure in supplementary material). To all questionnaires applied, the themes with more answers by fishers were recorded.

Table 1. Relationship between LEK themes and shrimp bioecological knowledge

LEK topics	Questionnaire themes
Reproduction	Breeding month
	Seasonal breeding period
	Breeding location
Migration	What migration do shrimps perform
	Purpose of migration
Food items	Feeding in the dry season
	Feeding in the rainy season
Predation	What are the shrimp predators
	What location predation occurs
Growth	Size that shrimps are ripe
	Age that shrimps are ripe
	Longevity

Data analysis

Considering that the age of the fisherman and the time working in the fishery are collinear ($r > 0.7$; $p > 0.001$), the age of the fishers was considered as a proxy for their experience in the activity. In order to verify if the domain of the LEK of shrimp fishers by bioecological theme are explained by the experience in fishing, a model was adjusted between the proportion of fishers by age group to those declared knowledge about the themes asked.

The fisher local ecological knowledge network was represented on two worksheets, one defining the “Nodes” and the other the “Edges”. Fishers and their local ecological knowledge are the nodes, meanwhile Edges are the connections between fisherman and LEK. The nodes' spreadsheet is characterized by two columns, one with the ID and the other label. In this spreadsheet, the ID is classified into an ordinal number, defined by the number of nodes. The "Label" column is designated by the names that will determine each node in the network. The edges worksheet is described by four columns, "Origin", "Destination", "Connection type" and "Weight". The first column contains the source ID, followed by the "Destination" column with the record of the occurrence of responses for each knowledge. The "Connection type" column defines the connection type of the interaction, whether directed or not directed. The "Weight" is defined in Gephi (BASTIAN; HEYMANN, 2009) for each ID. Gephi is an open source program that is used for graph analysis that provides easy and wide access to network data and allows to spatialize, filter, navigate, manipulate and group. The nodes (fisherman and LEK) of the graphs can be generalists, with many interactions, or they can be considered specialists, with few interactions (BASCOMPTE; JORDANO; OLESEN, 2006).

To test our hypothesis, the modularity metric was applied. This metric is characterized by identifying cohesive groups, in this case between fishers and LEK who are highly connected, and thus, interact more with each other than with other nodes in the network (DORMANN; STRAUSS, 2013, 2014; LAMBIOTTE; DELVENNE; BARAHONA, 2014).

$$Q = \frac{\mathbf{1}}{\mathbf{2}\boldsymbol{m}} \sum_{\boldsymbol{C} \in \boldsymbol{P}} \sum_{\boldsymbol{i},\boldsymbol{j} \in \boldsymbol{C}} \left[\boldsymbol{A}_{\boldsymbol{ij}} - \frac{\boldsymbol{K}_{\boldsymbol{i}} \boldsymbol{K}_{\boldsymbol{j}}}{\mathbf{2}\boldsymbol{m}} \right]$$

The analysis is developed using an adjacent matrix A, where A_{ij} is equal to 1 if there is a connection between node i and node j, and zero otherwise; the degree of node i is defined as $k_i \equiv j\ A_{ij}$; and $m \equiv i, j\ A_{ij} / 2$ is the total number of connections on the network. The sum is performed on all pairs of nodes belonging to the same C community of partition P (LAMBIOTTE; DELVENNE; BARAHONA, 2009). The null model $A_{ij} = k_i k_j / 2m$ is usually preferred because it captures the degree of network heterogeneity (GIRVAN; NEWMAN, 2002).

Intermediate centrality is a global measure of network centrality to analyze which LEK themes are central to a network (FREEMAN, 1978). The measure considers the number of times that a specific node is among the various other nodes in the network. The intermediate centrality of a node is defined as the number of shortest paths (among all pairs of nodes) that pass through the specified node divided by the number of the shortest path between any pair of nodes (regardless of passing through the given node) (BORGATTI, 1995). It is calculated by the formula:

$$C_B(V) = \sum_{s \neq v \neq t \in V} \frac{\sigma_{st}(V)}{\sigma_{st}}$$

Where V represents nodes, representing fishers and ecological information. A path from s € V to t € V is defined as an alternating sequence of nodes and edges, starting with s and ending with t, so that each edge connects its anterior node with its posterior node (BRANDES, 2001). Here, edges are understood as the links between fishers and bioecological information.

In addition to these metrics, (i) degree of nesting (nesting) and (ii) degree of network connection, that is, the fraction of all possible connections between nodes that are made in the network, were calculated (Dunne 2006). The connection metric of a network is to check the complexity of the network, being given by:

$$C = \frac{2L}{S(S-1)}$$

Where C is the connection; L, total number of observed interactions; S, number of possible interactions.

The degree of nesting was calculated using the nesting metric based on overlap and decreasing fill (NODF). Nesting can vary on a scale from 0 to 100, with 100 being perfect nesting, that is, when 50% of columns are filled from left to right and top to bottom in the rows (ALMEIDA-NETO et al., 2008). To test the significance of the NODF, random matrices (n = 1000) were generated from the original binary matrix, in which the probability of interactions between fishers and CEL was proportional to the total number of interactions (GUIMARÃES; GUIMARÃES, 2006). The proportion of random matrices with NODF values equal to or greater than the observed values indicated a degree (significantly) greater than the expected nested pattern (ZAPELINI et al., 2019). Observed and null NODF values the matrices were calculated using the software Aninhado v.3.0 (GUIMARÃES; GUIMARÃES, 2006).

The visualizations of the bipartite networks and the analysis of modularity and intermediate centrality were performed in the Gephi program (BASTIAN; HEYMANN, 2009). The connection and nesting dimension metrics were analyzed in the R program (R Development Core Team, 2017) with the Bipartite package (DEVOTO et al., 2020) which has the purpose of visualizing bipartite networks and calculate metrics.

Results

The knowledge about reproduction and migration of the three shrimp species are the most dominant among fishers, regardless of the age of the fisherman. The LEK on breeding is related to the season and month of breeding, indicated by fishers as the time when shrimp reproductive activity is most intense. However, spawning is less known among fishers. The second theme of fishers' domain is about migration and is related to the migration route and the purpose of migration (Figure 2). The remaining themes of the LEK (food, mortality and growth) have less knowledge records among younger fishers (20-30 and 31-40 age classes). The results indicate that the more detailed the aspects of the shrimp life cycle (food, mortality and growth) the greater the effect of the fisherman's experience, as evidenced by the increasing declines between knowledge and age (Figure 2).

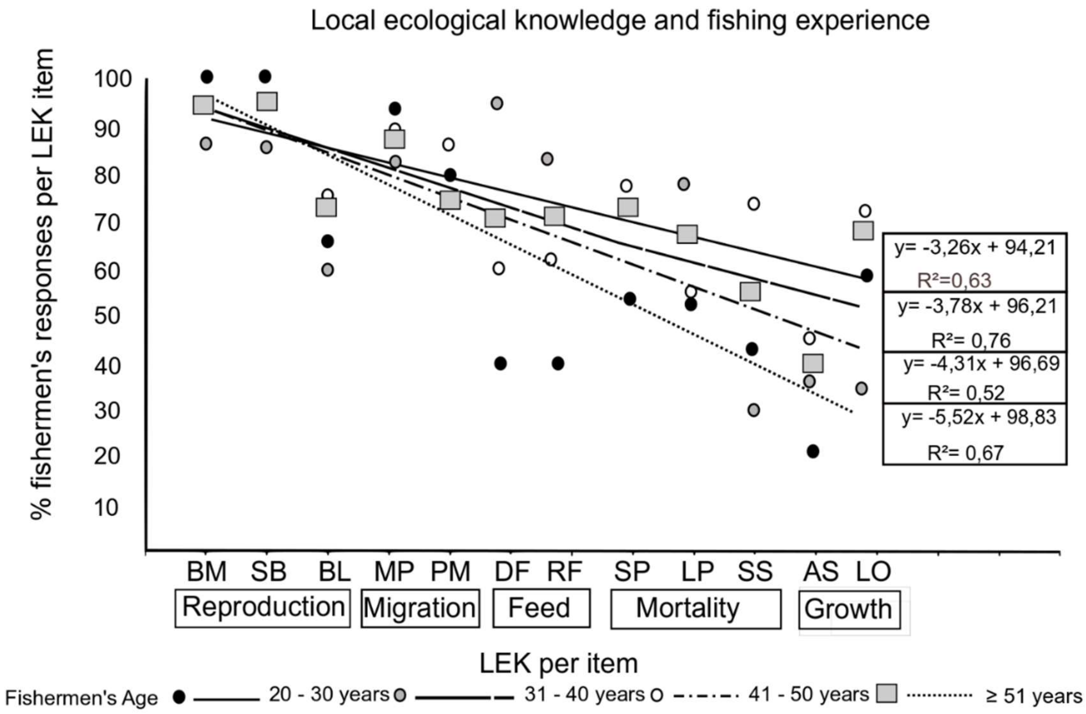

Figure 2. Local ecological knowledge and fishing experience. (BM: Breeding month, SB: Seasonal breeding period, BL: Breeding location, MP: What migration do shrimps perform, PM: Purpose of migration, DF: Dry feeding, RF: Rainy feeding, SP: What are the shrimp predators, LP: What location predation occurs, SS: Size that shrimps are ripe, AS: Age that shrimps are ripe, LO: Longevity).

Local ecological knowledge and knowledge connectivity

The conformation of the associative networks for *P. schmitti* (Figure 3), *P. subtilis* (Figure 4) and *X. kroyeri* (Figure 5), shows different modularity classes of social groups with specific knowledge by location. The differentiated distribution on the number of modularity classes is related to the LEKs of greater dominance among fishers, such as reproduction and migration, as indicated by the centrality metric that varied between 0.054 and 0.126. However, only in Baía Formosa the knowledge networks differ with a smaller number of modularity classes for white shrimp.

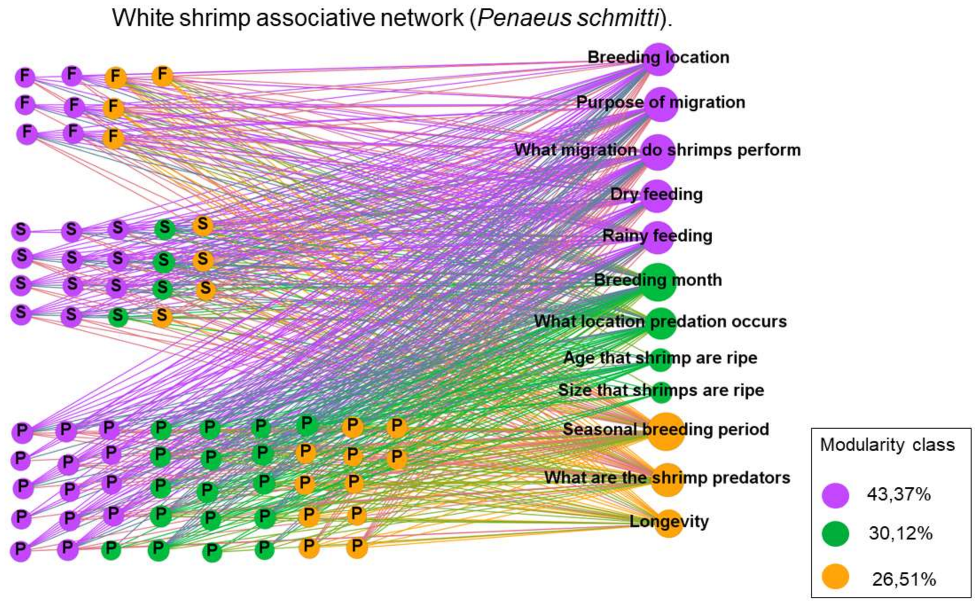

Figure 3. Ecological information network shared about *Penaeus schmitti* (white shrimp) for fishers from Pontal do Peba (P), Barra de Sirinhaém (S) and Baía Formosa (F).

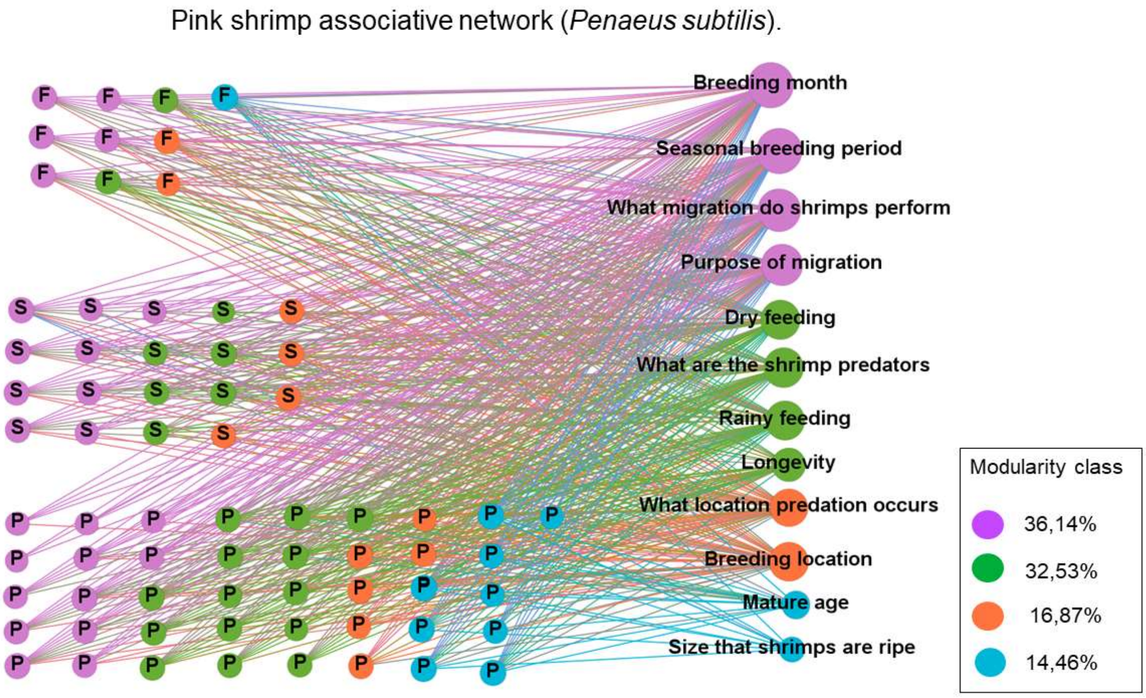

Figure 4. Ecological information network shared about *Penaeus subtilis* (pink shrimp) for fishers from Pontal do Peba (P), Barra de Sirinhaém (S) and Baía Formosa (F).

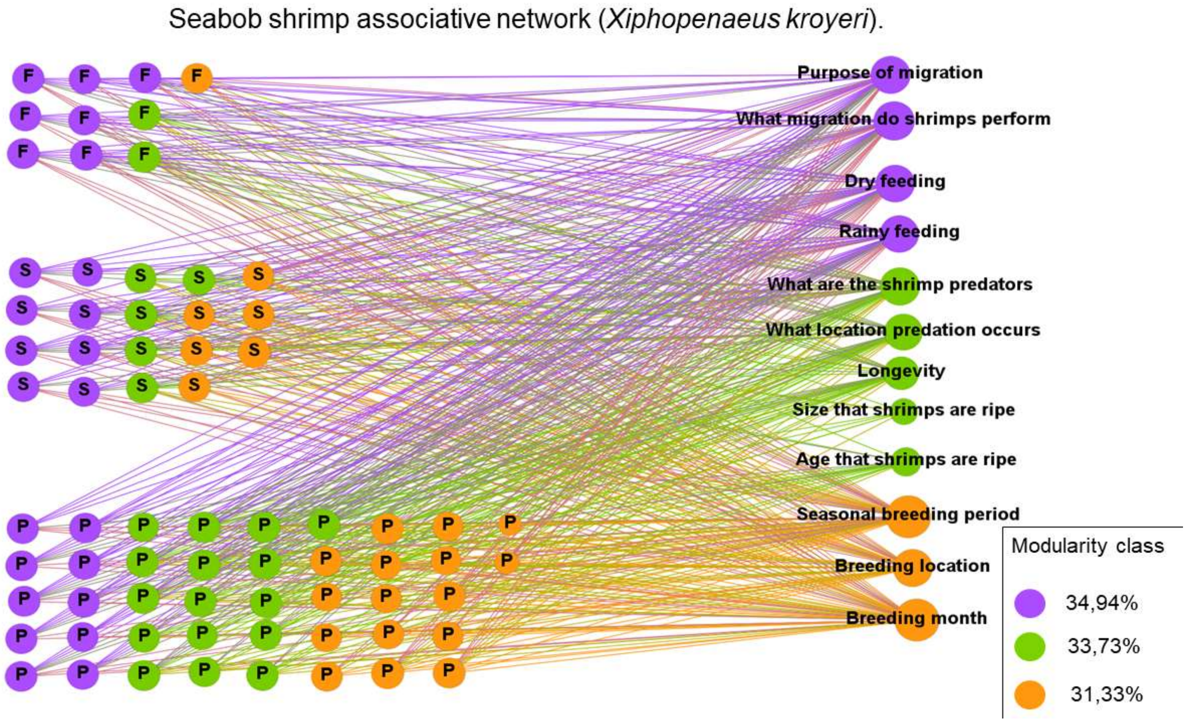

Figure 5. Ecological information network shared about *Xiphopenaeus kroyeri* (seabob shrimp) for fishers from Pontal do Peba (P), Barra de Sirinhaém (S) and Baía Formosa (F).

It should be noted that the metrics of connectivity and nesting networks are similar between species and locations. The degree of nesting, greater than 70, indicates interaction of knowledge between groups of fishers generated by local knowledge of other topics, such as food, mortality and growth (Table 2).

Table 2. Metrics of the fisherman-information interaction networks of the three species

Species	Connectivity	Nesting	Modularity
White shrimp	0.542	77.09	0.109
Pink shrimp	0.531	78.09	0.098
Seabob shrimp	0.557	79.01	0.102

Discussion

Shrimp artisanal fishers' local ecological knowledge are social constructs with strong social ties, what reinforces that public policies for efficient and socially equitable fisheries management. This calls for the incorporation of LEK as an important supporting information for conservation and sustainable use of socio-ecological systems (BERKES, 2003; LEITE; GASALLA, 2013). Our results also show that artisanal prawn fishers increase to more experienced fishers whose LEK on target species bioecology is spread over directly applied themes as reproduction and migration, and refine on side themes as feeding, growth and mortality for more experienced ones. Another important consideration is the aggregating power of fishers' specific local knowledge, generating connectivity linked to the sharing of similar bioecological knowledge about the exploited species.

LEK is known to be influenced by several factors, including fishers age (SILVANO; BEGOSSI, 2002). However, on the context of small-scale artisanal shrimp fisheries, fishers declare knowledge on various topics on the themes reproduction and migration, regardless how old they are. The fact that these species have a continuous reproductive cycle allow fishers to follow the species reproductive cycles during the year, mainly for white and pink shrimps that migrate into estuarine environments to reproduce (BOCHINI et al., 2014; DALL et al., 1990; SANTOS et al., 2020). The acquisition and evolution of LEK is expected to progress through passive adaptive processes according to the cumulative experiences in the environment (GALLOIS et al., 2018; HEWLETT; CAVALLI-SFORZA, 1986), but it just include lower rated topic themes (feeding, mortality and growth) for older fishers (≥41 years). Therefore, the experience acquired over the years by older fishers, allows knowledge absorption of information on most refined and difficult to observe topics.

The similarity in the quality of ecological information on exploited species indicates that there is information sharing or homology of interests. The themes most often cited as part of LEK were similar across species, contrary to expectations due to known interspecific bioecological differences (e.g., DALL et al. 1990) and attention bias toward higher revenues (LE PELLEY et al., 2016), here the high priced shrimp species. The main bioecological difference between species, discriminated by hypothetical-deductive knowledge, is related to migration. White shrimp (*P. schmitti*) and pink shrimp (*P. subtilis*) need the estuary to complete the life cycle (PEIXOTO et al., 2018; SILVA et al., 2016a, 2015, 2019) while the seabob shrimp (*X. kroyeri*) has the life cycle exclusively at sea (GRABOWSKI; NEGREIROS-FRANSOZO; CASTILHO, 2016; LOPES et al., 2014; SCHIAVETTI et al., 2013). Another difference between species is the age at first maturation. Pink shrimps matures in 2 to 3 months (ARAGÃO; CINTRA; SILVA, 2015); white shrimp from 6 to 7 months (SANTOS; PEREIRA; IVO, 2006), and the seabob shrimp in 12 months (RODRIGUES; BOOS; BRANCO, 2015; SANTOS; COELHO; PORTO, 2006). Even facing the bioecological differences, thematic knowledge was similar to all species as shrimp fisheries are multispecific allowing similar connection of fishers to all species cycles. So, neither abundance nor sales value. What is counting is fishers interest and the frequency and constancy of observation.

The similarity recorded between informants from different locations and consolidated in information networks on bioecological themes, indicates that similar environmental conditions and experiences lived by fishers imprint the acquisition, retention and sharing of knowledge (INGLIS et al., 1993; RUDDLE, 1994). Social actors involved in sharing ecological information interact at different scales (SALPETEUR et al., 2017), what occurs locally mainly at fishing harbors and fishers centers – called colonies or “Colônias” in local language (SILVA; CARDOSO, 2015). The intragroup similarity of fishers on bioecological information on species is consequently determined by the operational fisheries affinity. The fishing gear with greater fishing power to catch shrimp is regionally similar, usually single or double bottom trawls (SANTOS, 2010a; SANTOS; PEREIRA; IVO, 2006), not differing by species. The similarity shows that the connection of knowledge between fishers is anchored in bioecological issues relevant to independent social groups, generating similarity of knowledge even though there is social and cultural heterogeneity between communities. Moreover, the fact that the seabob shrimp life cycle is specific, involving movements between estuaries and the open sea, do not affected LEK on the species related to others. This inability was perceived to be related to the less interest and attention for this species due to its lower economic value.

It is also noteworthy that these species are close to the limits of overfishing (LOPES et al., 2014; SILVA et al., 2015, 2019), thus needing to be effectively monitored. According to our findings, current TEK of artisanal fishers’ key points are on themes on reproduction and migration from experience independent fishers. However, to information on growth and mortality, more experienced fishers felt more able to provide knowledge. Those fishers are not those usually more active, but they are those more listened, providing inputs to other fishers and becoming an important node on the networks locally built.

Information sharing is essential in natural resource management processes that contain a wide variety of social actors, such as artisanal fishers. This sector is essential for coastal food security, having a profile of using common resources that requires participatory fisheries management (JENTOFT et al., 2010), whose planning involves local, and even regional efforts (BERKES; HENLEY, 1997; RUIZ-MALLÉN; CORBERA, 2013; SILVANO; BEGOSSI, 2012). Possible blockages in the flow of ecological information results in limited groups of fishers and local ecological knowledge (GIRVAN; NEWMAN, 2002; SALPETEUR et al., 2016), which generate subgroups caused by spatial distance, such as Baía Formosa to Pontal do Peba (around 480 km distant).

Therefore, social networks are fed by common needs that affects productivity and even their social survival showing high dissemination among the nodes of the networks.

Such items can be considered essential in promoting intercommunity dialogue and with other decision makers aiming at participatory and effective fisheries management.

On the main themes covered by the social networks, the intermediate centrality metric is indicated to monitoring further information exchange in networks (ABBASI; HOSSAIN; LEYDESDORFF, 2012; FREEMAN, 1978), essential for success in natural resources management planning and execution. The most relevant intermediate centrality metrics were on the themes of reproduction and species migration that can be themes to leverage collaboration among stakeholders. Networks must consider all existing knowledge, no matter coming from hypothetical-deductive methods or from LEK, either to improve fisher communities well-being, attending yield targets but also to conserve coastal biodiversity (GALLOIS et al., 2018) that is essential to biological production. Therefore, for an efficient management, the themes of reproduction and migration are bridges for dialogue and decision, reconciling the conservation and earnings for the fishing community.

The bioecological similarity in the LEK of the species evaluated in different areas is a cue suggestive to the development of a regional planning resource management to change actual fragmented profile. Current legal determinations indicates different no-take reproductive periods on the Northeast coast during the last 20 years (e.g., DIAS-NETO, 2011; SANTOS; BRANCO; BARBIERI, 2013) must be concluded, reducing conflict due to the displacement of fleets between fishing grounds. An fisheries agreement validated by government authorities based mainly on experienced fishers LEK and supplemented by scientific advice will reduce conflicts and increase business and social security to fisheries communities. In addition, scientific research on topics where there were weaknesses in the LEK information (*e.g.*, growth and mortality), with participative dissemination of results to all stakeholders may improve management efficiency and the communication quality among networkers.

Thus, ecological information provided by the fishers can be gathered with that generated by experimental science to better support assessment of fisheries stock status (NEIS, 1992) and even to predict changes in the spatial distribution of species (LOPES et al., 2019) with positive social, economic and environmental outputs.

In this way, an expected and effective co-production research (POLK, 2015) can improves the dialogue and the effectiveness of fisheries management. Following common-pool resources principles, mainly collective choice arrangements monitoring methods and eventual sanctions to illegal actions (OSTROM, 1994) are facilitated when managers valuing the knowledge of fishers (FIGUS; CAROTHERS; BEAUDREAU, 2017; MUSIELLO-

FERNANDES; ZAPPES; HOSTIM-SILVA, 2017). As a product, researchers-manager-fishers cooperation can be expected to make this citizen science a basis for social and environmental sustainability, and even to respond to the challenges of climate change and other anthropogenic impacts.

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Conclusão geral

Atualmente, a gestão dos recursos pesqueiros têm iniciativas para o compartilhamento da gestão, englobando as partes interessadas no processo de tomada de decisão. O conhecimento ecológico local é uma importante ferramenta que pode ser incorporada na tomada de decisão. Dessa forma, os temas de reprodução e migração são tópicos predominantes entre os pescadores de camarão, independente da idade dos pescadores. A aquisição da experiência com a atividade pesqueira existe um refinamento desse conhecimento nos temas de crescimento, alimentação e predação dos camarões. Para tanto, sabe-se que integrar fontes alternativas de informação possibilita decisões mais justas com resolução ajustada para a realidade da pesca artesanal, e consequentemente pode minimizar conflitos entre as partes interessadas (BERKES, 2003; BERKSTRÖM et al., 2019; LEITE; GASALLA, 2013). E assim, para a gestão local, o CEL dos pescadores deve ser utilizado como fonte de informação, sempre observando os interesses das partes envolvidas (LIMA et al., 2017) o que apoia a gestão local à atender os objetivos na pesca artesanal.

A existência de grupos de pescadores que tem maior espeficidade com alguns temas do CEL possibilita que esses agrupamentos favoreçam iniciativas de gestão local e regional. A similaridade bioecológica do CEL podem indicar uma gestão a nível regional para locais geograficamente mais próximos, como Alagoas e Pernambuco. A pesca artesanal de arrasto é um tipo de pesca que necessita de medidas regulamentares para minimizar os danos ambientais, sociais e econômicos que causa, assim, a gestão regional pode reforçar no monitoramento da pesca. Com isso, os pescadores devem ser consultados para englobar seus conhecimentos e percepções nas iniciativas de descentralizar da gestão e aumentar a participação social dos pescadores nas tomadas de decisões.

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