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LARISSA DA COSTA PINHEIRO

BIOLOGIA REPRODUTIVA DO PARGO (*Lutjanus purpureus,* Poey, 1866) NA COSTA NORTE DO BRASIL

BELÉM
2022

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Dissertação apresentada ao Programa de Pós-graduação em Aquicultura e Recursos Aquáticos Tropicais do Instituto Socioambiental e dos Recursos Hídricos da Universidade Federal Rural da Amazônia, como requisito para a obtenção do título de Mestre.

Orientadora: Dra. Bianca Bentes
Coorientador: Dr. Eduardo Paes
Área de concentração: Biologia aquática e pesca

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E meus sobrinhos Benjamin e Augusto

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RESUMO

Diante da lacuna de informações biológicas sobre o pargo – *Lutjanus purpureus* – que possam subsidiar estratégias práticas de manejo ao longo da plataforma continental amazônica, o presente estudo objetivou identificar períodos de formações celulares indicativas de desova e, para este fim, foram utilizadas gônadas oriundas de espécimes capturados pela pesca comercial entre 2016 e 2017 e as células reprodutivas foram identificadas e contabilizadas por meio de técnicas histológicas. Os períodos de maior frequência de folículos pós ovulatórios (FPO) foram traduzidos como de intensa desova e teve o pico observado no mês de abril, a julgar pelas limitações de coleta no período de desova da espécie. Além do FPO, ovócitos hidratados e tiveram pico de ocorrência no mês de julho, sugerindo continuidade reprodutiva ou um segundo pico neste período pois forma identificados também folículos atrésicos e tecidos em atresia neste mesmo período. Face às características da pesca que atua preferencialmente sobre indivíduos muito jovens, sugere-se o aumento do período de defeso até o mês de julho de cada ano, como forma de garantir um aumento efetivo da reprodução do estoque desovante.

PALAVRAS-CHAVE: desova, desenvolvimento ovocitário, FPO, pesca artesanal de larga escala,*Lutjanus*, Plataforma continental amazônica, Amazônia, ODS14.

ABSTRACT

Given the lack of biological information on the snapper - *Lutjanus purpureus* - that can support practical management strategies along the Amazon continental shelf, this study aimed to identify periods of cell formations indicative of spawning and, to this end, gonads from specimens captured by commercial fishing between 2016 and 2017 were used and the reproductive cells were identified and counted using histological techniques. The periods of higher frequency of post ovulatory follicles (POF) were translated as of intense spawning and had the peak observed in the month of April, judging by the collection limitations in the spawning period of the species. Besides POF, hydrated oocytes and had a peak occurrence in July, suggesting reproductive continuity or a second peak in this period because atresic follicles and atresia tissues were also identified in this same period. Given the characteristics of the fishery, which preferentially acts on very young individuals, it is suggested that the closed season be extended to July of each year, to ensure an effective increase in reproduction of the spawning stock.

KEY WORDS: spawning, oocytes development, FPO, large-scale artisanal fisheries, *Lutjanus,*Amazon continental shelf, Amazon, SDO 14;

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ESTRUTURA DA DISSERTAÇÃO

O presente trabalho foi elaborado no formato de uma introdução geral e um artigo científico intitulado: **Recent findings of spawning and fishing management recommendations of red snapper, *Lutjanus purpureus* (Poey, 1866) on the Amazon Continental Shelf, Brazil**. O paper está sendo elaborado para ser submetido ao periódico Fisheries Research qualificado como do extrato A1 (fator de impacto 2.8) da CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior).

1. INTRODUÇÃO GERAL

A atividade pesqueira é uma das mais antigas tradicionais praticadas pelos seres humanos, ocorrendo em regiões tanto costeiras quanto continentais. Além disso, tem importância social e econômica, gerando emprego e renda para diversas famílias e, em muitos casos, sendoa sua principal fonte alimentar (BARTHEM; FABRÉ, 2003; CASTELLO, 2010; ISAAC *etal.,* 2006; VIANA, 2013).

Os recursos pesqueiros correspondem as espécies exploradas economicamente pela pesca, os quais tem múltipla importância, que não se resume ao enfoque tradicional que é o ecológico e econômico, estes também geram impacto nos âmbitos culturais e sociais no meio onde são explotados (BATISTA; ISAAC; VIANA, 2003). Para a obtenção de um manejo adequado, se faz necessária a compreensão dos fatores controladores da produção dos estoques pesqueiros, agregando dados biológicos, ecológicos, tecnológicos, econômicos, sociais e institucionais (ISAAC *et al.,* 2006; VIANA, 2013).

O Brasil apresenta uma grande diversidade de ambientes em seu extenso litoral, e a atividade pesqueira se adequa a essas características para otimizar a captura (ISAAC *et al.*, 2006). A plataforma continental brasileira é caracterizada pela baixa produtividade decorrente da sua localização; por um lado em decorrência da circulação oceânica, em grande parte insuficiente na indução de efeitos de afloramento e de outro, em relação a uma rede hidrográfica que, apesar de importante, deságua quase em sua totalidade nas extremidades Norte e Sul (MUEHE; GARCEZ, 2005). Nesse contexto, a região amazônica se destaca na atividade pesqueira, tanto em regiões costeiras quanto em pescarias continentais, e isto ocorre pela riqueza de espécies da região, e pela forte ligação histórica da população tradicional à atividade (BARTHEM; FABRÉ, 2003).

Dentro deste cenário, temos a plataforma Norte do Brasil, grande ecossistema marinho com extensão desde o mar do Caribe até o rio Parnaíba, no Brasil. Este local tem como característica, a recepção dos produtos oriundos do escoamento de grandes rios, como o rio Amazonas por exemplo e com isso, esta região possui elevada produtividade biológica (ISAAC; FERRARI, 2017). O litoral paraense detém elevada importância nas práticas de pesca, e isto ocorre principalmente pela numerosa

quantidade de rios e estuários que se conectam ao Oceano Atlântico, conformando um ambiente aquático de alta complexidade e elevada produtividade biológica (SILVA *et al.,* 2011; FURTADO JÚNIOR; TAVARES; BRITO*,* 2006).

Apesar de não haver dados atualizados de volumes da produção de pescado, Os dados mais recentes que são os do IBAMA (2007) e as parciais publicadas pelo MPA (2011) e OCEANA (2020) indicam que a região Norte possui valores expressivos em relação à volumes explotados.

Há uma grande variedade de espécies capturadas pela pesca comercial na costa Norte, e algumas de alto valor comercial como lagostas (*Panulirus meripurpuratus, Panulirus laevicauda*), camarões (*Penaeidae*) e peixes de considerável valor econômico como a gurijuba (*Sciades parkeri)*, pescada amarela (*Cynoscion acoupa*) entre outras (FURTADO JÚNIOR; TAVARES; BRITO*,* 2006;PEIXOTO *et al.,* 2020; SILVA *et al.,* 2011).

Entre os táxons de alto valor comercial, destaca-se a família Lutjanidae, especificamente a espécie *Lutjanus purpureus*, cuja explotação pesqueira teve início em meados dos anos 60 e 70 na região Norte/Nordeste do País (FONTELES-FILHO,1972). Neste período, houve a introdução das chamadas linhas pargueiras (espinhéis), com o intuito de diversificar as pescarias de atuns e lagostas, espécies que já se encontravam em declínio (IVO; SOUSA, 1988; REZENDE; FERREIRA; FREDOU, 2003). *Lutjanus purpureus*, popularmente conhecido como Pargo ou *red snapper*, é uma espécie que ocorre sobre fundo rochoso em profundidades de 30 a 160 m, encontradas mais comumente entre 70 e 120 m (CERVIGÓN, 1992).

Na região Norte, a produção pesqueira do pargo é quase que exclusivamente destinada ao mercado externo, sendo os Estados Unidos, o principal comprador e apenas 25% do pargo produzido fica no mercado nacional (BENTES *et al.*, 2017), sendo comercializado em supermercados, raramente se encontra em feiras, na forma de filé, uma vez que os espécimes comercializados localmente em geral são os maiores de 3 kg e são popularmente denominados ‘sacolão’, e estes maiores espécimes detém pouco ou nenhuma importância para exportação (BENTES*et al*., 2017). Essa preferência por indivíduos menores pode vir a desencadear a chamada sobrepesca de crescimento, conceito dado para o efeito das grandes capturas de indivíduas abaixo do tamanho de primeira maturidade sexual, ocasionando uma reduçãona captura anual e acarretando danos bioeconômicos (CASTELLO, 2007; DIEKERT,2012; PETERSEN, 1903).

A preferência do mercado do pargo pela compra de espécimes pequenos com o peso abaixo de 900 g (FREIRE, 2019), tem gerado discussões no âmbito da gestão da pesca, pois tal preferencia desencadeia o comprometimento dos estoques explotados pela pressão de captura de espécimes diminutos (BENTES *et al.,* 2017). Este cenário, norteia as pesquisas recentes voltadas para a busca de informações mais detalhadas a cerca do *status* dos estoques, assim, estudos sobre a biologia reprodutiva que possam elucidar as taxas de recrutamento, parecem indicar um cenário de provável colapso em curto prazo (BENTES *et al*., 2017; FREIRE, 2019).

Os estudos reprodutivos os quais norteiam políticas pesqueiras, geralmente abordam indicar o tamanho de primeira maturidade sexual correlacionado a um tamanho mínimo de captura ou regulamentar as malhas e petrechos de pesca (BENTES *et al.,*2017). No caso do pargo, existe legislação vigente à cerca de atividades relacionadas à sua pescaria, como sua captura e artes de pesca utilizadas na atividade, por exemplo. O dispositivo mais recente, a portaria n°42 de27 de Julho de 2018, regulariza as áreas de pesca, o defeso da espécie (15 de Dezembro a 30 de Abril, anualmente) e limita a frota permissionadas a 250 embarcações devidamente autorizadas (BRASIL, 2018).

Análises sobre a biologia reprodutiva são de extrema importância para um melhor entendimento do ciclo reprodutivo e para a identificação das características biológicas que norteiam a desova das espécies, especialmente as de importância comercial como o pargo, pois são úteis na delimitação de períodos de fechamento de áreas e/ou ambientes mais sensíveis ao sucesso reprodutivo (FLEMING; LAMBERG; JONSSON, 1997).

Dentre as formas de análise da reprodução, reconhecer as fases de desenvolvimento ovocitário e associá-los aos momentos no tempo e às características do espaço, informações primordiais para se pensar em formas de manejo perfazem combinadas às perspectivas de conservação dos estoques (MORGAN, 2008; SOUSA *et al*., 2017). Entre as fases de desenvolvimento dos ovócitos, temos o chamado corpo folicular ou folículo pós-ovulatório (FPO) oriundo das células foliculares e surgem após a desova (VAZZOLER,1996).

As estruturas foliculares, passam processo de hipertrofia, o espaço antes ocupado pelo ovócito o qual foi liberado, se forma uma estrutura constituída por cordões adjacente de células, estes, dobrados em toda a cavidade do folículo, o FPO apresenta forma retangular, com a presença de citoplasma basófilo e ligeiramente granulado (VAZZOLER,1996) e são importantes na tentativa de confirmar os períodos efetivos de desova, já que surgem após o indivíduo liberar o ovócito , e identificar os períodos reprodutivos de estoques alvos de pescarias comerciais de alto valor comercial, como é o caso do pargo, são fundamentais para subsidiar o ordenamento (BENTES *et al,*2017; VAZZOLER,1996) .

Estudos com o FPO ainda são pouco encontrados na literatura, porém estudos já existentes (BROWN - PETERSON *et al* 2011; CHAVES; MAGALHÃES, 1993; GANIAS; NUNES; STRATOUDAKIS, 2007; GANIAS; 2012; GUAIVIRA 2010; QUAGIO-GRASSIOTTO; WILDNER; ISHIBA, 2013; ROMAGOSA *et al*., 2018; TEIXEIRA; FERREIRA; PADOVAN, 2004) demonstraram a importância do reconhecimento deste estágio celular como forma de aumentar a precisão ao se determinar um período de desova.

Estudos feitos sobre a estimativa da desova apontavam que o pargo se reproduz durante o ano todo com dois picos, o de maior intensidade de janeiro à março e o de menor intensidade em outubro (GESTEIRA; IVO, 1973). Porém, Freire (2019) nos seus estudos recentes, apontou que o pico de desova da espécie ocorre entre os meses de janeiro à março, o período mais chuvoso em toda a Amazônia e, associou este evento com o período o qual ocorre maior descarga hídrica na região.

Considerando a limitação de trabalhos com ênfase na reprodução do pargo, que é um recurso de alto valor econômico e destinado quase totalmente ao mercado internacional, pelo comércio estar preferencialmente voltado aos espécimes diminutos, pesando menos 900g, nitidamente juvenis e por último, pela necessidade de medidas mais eficientes demanejo que possam controlar o esforço ou os volumes capturados (FREIRE, 2019; BENTES *et al.,* 2017), este trabalho vem preencher a lacuna de informações sobre a reprodução desta espécie. Por meio de uma análise microscópica, esta proposta vem determinar o período reprodutivo da espécie de forma mais precisa. Especificamente pretende-se identificar o folículo pós ovulatório (FPO), descrever o processo de degeneração e assim consolidar dados que possam trazer a delimitação do período mais intenso da desova de *L.purpureus* com precisão, contribuindo de forma direta com informações que possam subsidiar políticas mais precisas de manutenção dos estoques.

2. JUSTIFICATIVA

O pargo é uma espécie de alto valor comercial que teve as pescarias iniciadas na costa Nordeste e, com o deslocamento da frota para a plataforma Norte, uma intensa pressão pesqueira passou a ser exercida sob o estoque desta região e, por este motivo, estudos indicaram que os estoques desta área já estariam sobre-explotados (DE SOUSA-JÚNIOR; VIANA; SAKER-SAMPAIO, 2002; BENTES *et al*., 2017; FREIRE, 2019). Esta informação está associada ao elevado esforço de pesca em áreas consideradas sensíveis ecologicamente, devido a presença de muitos indivíduos jovens capturados (FONTELES-FILHO, 2007; SOUZA; IVO; SOUZA, 2003; SOUZA *et al.,* 2008).

A problemática do mercado em demandar espécimes menores e consequentemente a capturas de espécimes juvenis talvez seja o principal ponto que deve nortear pesquisas de cenários futuros (BENTES *et al.,* 2017). Assim, os poucos dados e em sua maioria antigos, existentes sobre os aspectos de história de vida,dinâmica populacional e o estado de explotação da espécie precisam ser constantemente revistos e atualizados, devido as modificações biológicas intrínsecas das populações em decorrência da pressão pesqueira (DE SOUSA-JÚNIOR; VIANA; SAKER-SAMPAIO, 2002; FREIRE, 2019). Vários trabalhos ao longo das últimas décadas têm sido realizados com a espécie (ALVES, 1971; BENTES *et al.*, 2017; FREIRE, 2019; FONTELES- FILHO, 1972; FONTELES- FILHO, 1970; FURTADO- OGAWA; MENEZEZ,1972; GESTEIRA; IVO, 1973; IVO, 1973; IVO; GESTEIRA, 1974; MENEZES, GESTEIRA,1974; SOUZA, 2002; SOUZA; IVO; SOUZA, 2003) entretanto, nenhum deles realizou um estudou da reprodução em suas características microscópias, o que é proposto neste plano de trabalho.

Esta proposta de dissertação de mestrado, visa identificar a periodicidade de desova, formação e morfologia do folículo pós ovulatório (FPO) de *Lutjanus purpureus*, considerando sua importância em subsídio de políticas mais conservadoras, neste caso, vizando trazer mais precisão em informações sobre o período de desova do pargo que, em conformidade com as políticas já existentes, espera-se aumentar a acurácia referente ao conhecimento das estratégias reprodutivas de *L. purpureus*, a qual possui alto valor comercial.

3. OBJETIVO GERAL

Estudar a biologia reprodutiva de *Lutjanus purpureus,* por meio da identificação da involução do folículo pós ovulatório (FPO) nas gônadas femininas de *L.purpureus*, fortalecendo a identificação do período de desova mais intenso da espécie a partir de dados da pesca comercial atuante na costa Norte do Brasil.

3.1 Objetivos específicos

- Determinar os picos de desova de *Lutjanus purpureus* a partir de amostras de gônadas oriundas das pescarias comerciais da costa Norte do Brasil;
- Identificar a frequência mensal dos folículos pós ovulatórios de *Lutjanus purpureus*;
- Estudar a formação dos folículos pós ovulatórios de *Lutjanus purpureus* por categoria de tamanho (comprimento furcal).

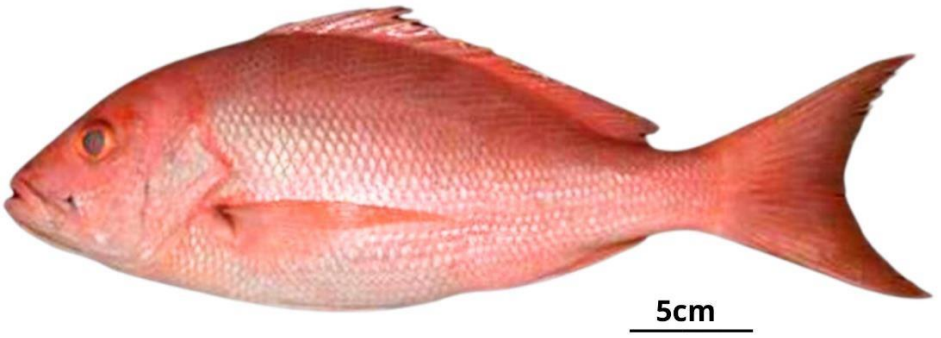
4. REVISÃO BIBLIOGRÁFICA

4.1 Sistemática e características gerais do pargo

Lutjanidae é uma família composta por 17 gêneros e 113 espécies, sendo o gênero *Lutjanus* o de maior importância econômica para a pesca, sendo o gênero mais diverso da família, possuindo 70 espécies (NELSON; GRANDE; WILSON, 2016; CERVIGÓN, 1992)e pode ser encontrado em fundos rochosos e arenosos em profundidades de aproximadamente 200 metros, em sua estão presentes majoritariamente em águas marinhas próximas à borda da plataforma continental, mas algumas espécies podem ser encontradas em regiões que apresentam águas salobras (ACERO; GARZÓN, 1985; ALLEN, 1985; ANDERSON, 2002; CERVIGÓN, 1992; DE SOUSA -JÚNIOR; VIANA; SAKER-SAMPAIO, 2002; SZPILMAN, 2000). Acredita- se que os juvenis ocupem regiões mais rasas da plataforma e mais próximas à costa, em profundidades entre 40 e 60 metros, a distribuição está inserida entre o mar do Caribe até o Brasil (ALLEN, 1985; CERVIGÓN, 1992; SOUZA *et al.*, 2008; SZPILMAN, 2000).

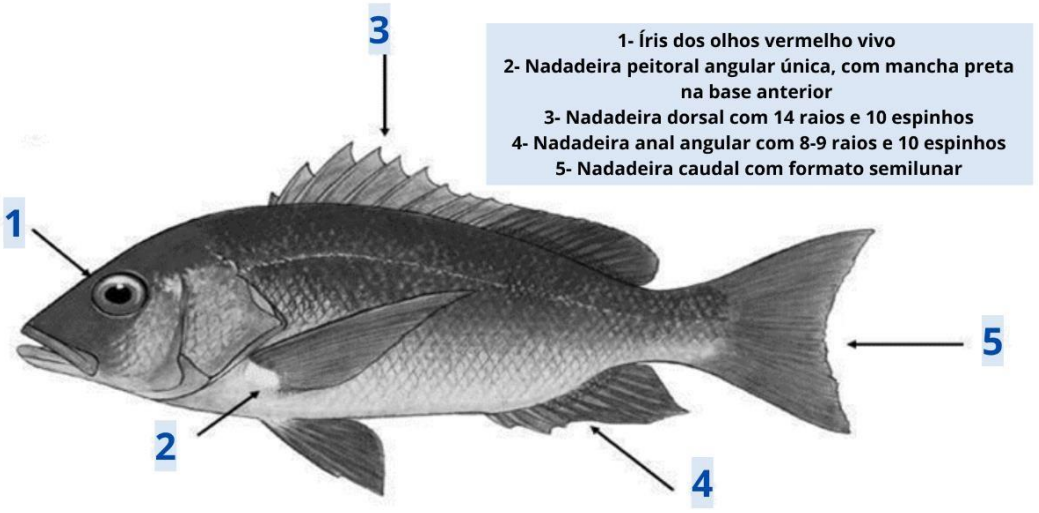
Lutjanus purpureus é conhecido popularmente como red snapper, caribean red snapper, e no Brasil também popularmente chama- se pargo (ANDERSON, 2002; ALLEN, 1985; CERVIGÓN, 1992; SZPILMAN,2000). Possui coloração uniformemente avermelhada, com a íris dos olhos grandes e vermelhos e uma mancha preta sobre a linha lateral. O corpo é relativamente alongado e possui 14 raios em sua nadadeira dorsal (ALLEN, 1985; CERVIGÓN, 1992; SZPILMAN,2000; ANDERSON,2002).

Figura 1- Exemplar da espécie *Lutjanus purpureus* capturado na costa Norte do Brasi



Fonte: Adaptada de: Bentes *et al.,* (2017).

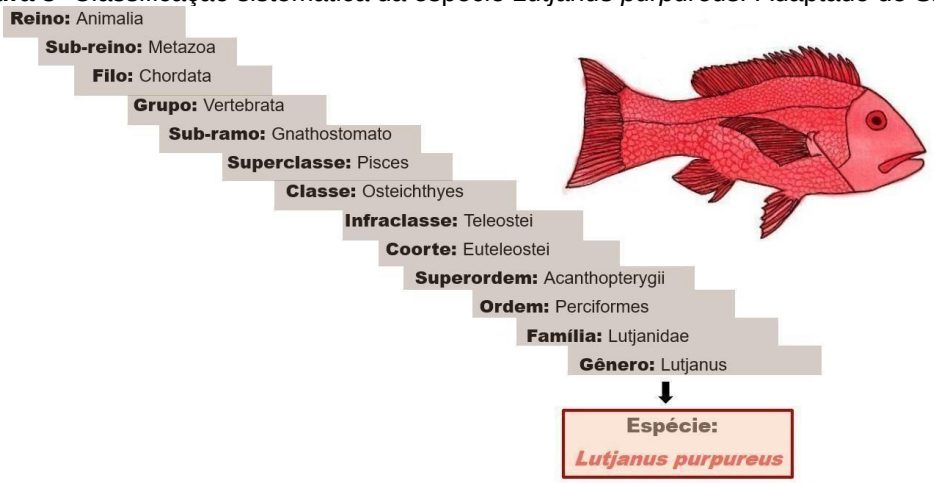
Figura 2- ilustração esquemática das principais características morfológicas de *Lutjanus purpureus*



Fonte: Imagem adaptada de Anderson (2002)

A sistemática de *Lutjanus purpureus* é a apresentada a seguir, conforme modelo de Szpilman (2000), que fez o uso de três chaves classificatórias: Greenwood *et al* (1966), Nelson (1984 e 1994), Eschmeyer (1990 e 1998).

Figura 3- Classificação sistemática da espécie *Lutjanus purpureus.* Adaptado de Szpilman (2000)

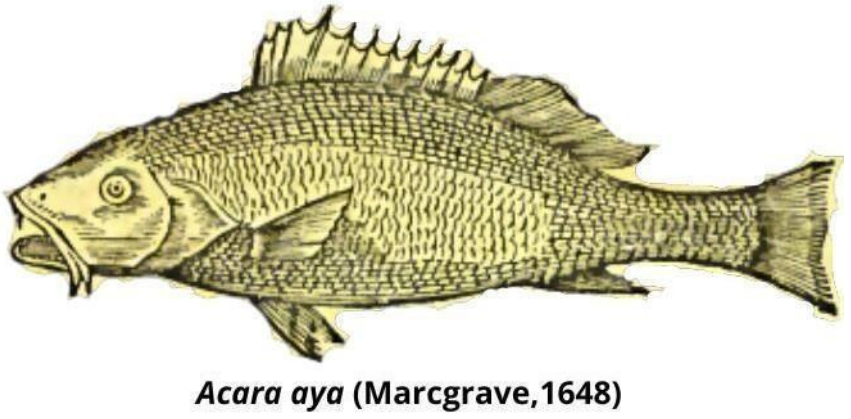


Fonte: adaptado de Szpilman (2000).

Devido às suas semelhanças morfológicas com outras espécie do gênero *Lutjanus*, o pargo sofreu uma série de modificações em taxonomia e ao longo do tempo e vários autores realizaramestudos até chegar ao atual nome científico da espécie desde a sua primeira descrição (figura 6) (MARCGRAVE; PISO, 1648; BLOCH, 1790; BLOCH;SCHNEIDER, 1801; CUVIER,1828; POEY,1860; POEY;1866) .

Segundo registos na literatura, leva- se a crer que George Marcgrave no ano de 1648 foi ocientista pioneiro na descrição e primeiro registro taxonômico da espécie, a qual nominou *Acaraaya* (Figura 4) (MARCGRAVE; PISO, 1648).

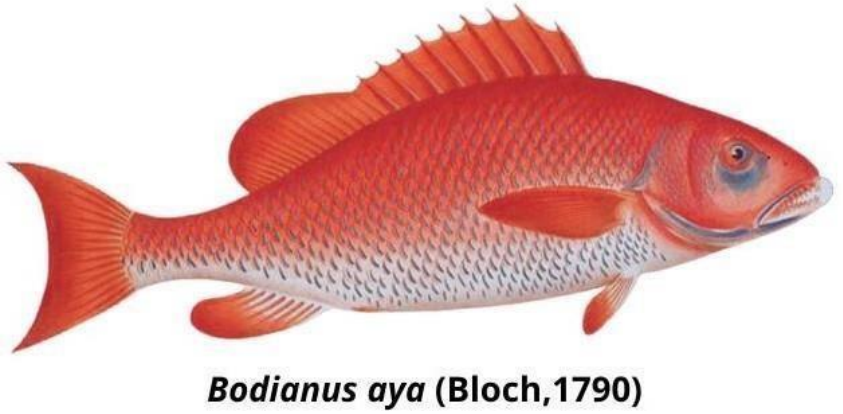
Figura 4 Ilustração *acaraaya*. Imagem Adaptada de (MARCGRAVE; PISO,1648).



Fonte: Adaptado de: MARCGRAVE, G.; PISO, W.1648

Marc Elieser Bloch por sua vez em 1790 realizou uma nova descrição para a espécie incluindo-a no gênero *Bodianus* (BLOCH, 1790) e nesta publicação, foi relatado que esta seria amesma espécie descrita por Marcgrave em 1648, e com isso a espécie passou a ser nomeada como *Bodianus aya* (BLOCH, 1790)(Figura 5) .

Figura 5. Adaptação de Ilustração de *Bodianus Aya* (atualmente *Lutjanus purpureus*) feita por Marc E. Bloch.



Fonte: Ilustração original obtida em: Rare Book Division, The New York Public Library. (1792). Bodianus Aya. Retrieved from https://digitalcollections.nypl.org/items/510d47da-6ac2- a3d9-e040-e00a18064a99

Visando trazer uma maior precisão para a descrição do Pargo, em 1801 Marc E. Bloch eJohann Schneider publicaram uma descrição atualizada e mantiveram a espécie no gênero *Bodianus,* porém os autores realizaram a modificação na nomeclatura da espécie, passando aser *Bodianus ruber* (BLOCH; SCHNEIDER, 1801).

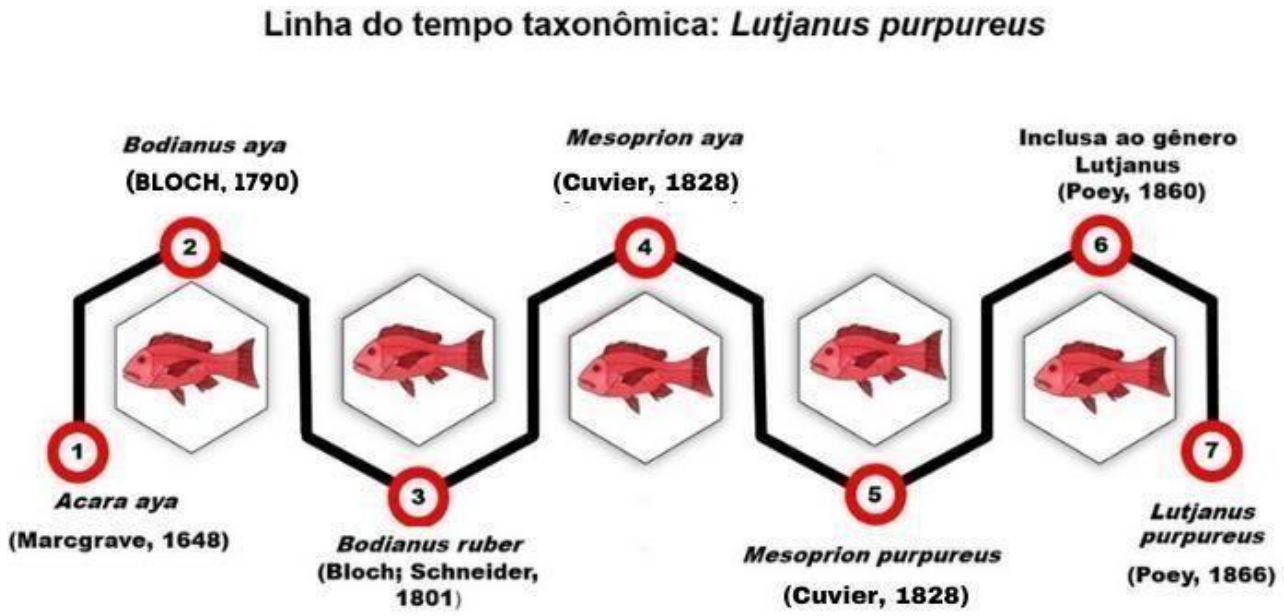
Georges Cuvier no ano de 1828, trouxe questionamentos sobre a descrição de Bloch, poissegundo o autor as descrições que estas foram feitas com o uso de ilustrações já antigas e com detalhes parcos. Logo, a descrição realizada em 1801 por Bloch e Schneider foi considerada derivada da publicação de Marcgrave de 1648 com informações imprecisas, então Curvier no ano de 1828 refez a descrição da espécie, inserido-a ao gênero *Mesoprion* (CUVIER, 1828), coma nomeclatura de *Mesoprion aya* (CUVIER, 1828), mas o autor atribuiu um novo nome a espécie:*Mesoprion purpureus* (CUVIER, 1828) no mesmo estudo.

Felipe Poey em 1860, indicou que *Mesoprion aya*, poderia facilmente ser confundida com a espécie *Mesoprion profundos* (POEY, 1860) (sinônimo da espécie *Lutjanus vivanus*: Lutjanídeo do mesmo gênero do pargo), pois segundo o mesmo, ambas apresentavam olhos detons amarelos (POEY, 1866). Então, no ano de 1875,em uma revisão, Poey (1875) incluiu a espécie ao gênero *Lutjanus* (BLOCH, 1790), devido a sinonímia com o gênero *Mesoprion,* e assim, a espécie passou a ser cientificamente

denominada de *Lutjanus purpureus* (CUVIER, 1828).

Mesmo com questionamentos à cerca da coloração dos olhos da espécie, o autor sugeriu considerar a descrição realizada por Cuvier (1828), devido a descrição realizada por Bloch (1790)apresentar pouca precisão. Nos dias de hoje, a nomeclatura científica utilizada para espécie é atribuída à autoria de Poey (1866) e *Lutjanus purpureus* segue sendo a nomeclatura utilizada nos dias de hoje (FISHBASE, 2021; WORMS, 2021).

Figura 6- Ilustração de linha do tempo da classificação taxonômica da espécie *Lutjanus purpureus.*



Fonte: Esquema adaptado segundo: Marcgrave;Piso (1648), Bloch (1790), Bloch; Schneider (1801), Cuvier (1828), Poey (1890) e Poey (1866).

1.1 Alimentação

Considera-se que o Pargo é um carnívoro e apresenta hábitos alimentares bentônicos e pelágicos (FURTADO-OGAWA;MENEZES, 1972). A dieta dos adultos inclui peixes, crustáceos, moluscos, invertebrados, e organismos planctônicos (ACERO; GARZÓN, 1985; ALLEN 1985; CERVIGÓN, 1992; FURTADO-OGAWA; MENEZES, 1972). Já os espécimes juvenis a sua dieta é rica de organismos invertebrados como: foraminíferos, espongiários, briozoários incrustados entre outros (FURTADO-OGAWA;MENEZES, 1972).

A dieta alimentar de outros lutjanídeos como *L. analis* parece ser similar à de *L. purpureus*, uma vez que diferenças significativas na dieta foram observadas entre as classes de tamanho no arquipélago de Abrolhos, porém estas não notaram-se entre as estações do ano (FREITAS; ABILHOA; COSTA E SILVA, 2011). Relacionando as classes de tamanho, o conteúdo alimentar demonstrou notórias variações: os juvenis (<34,0 cm de comprimento total - CT) apresentaram preferência por crustáceos, nos subadultos (34,1-50,0 cm de CT) notou-se uma dieta diversificada e os adultos (>50,1 cm de CT) dieta baseada em peixes, com ênfase em Anguiliformes (FREITAS; ABILHOA; COSTA E SILVA, 2011). *Lutjanus analis* classifica-se como um predador recifal do tipo generalista, e consome elevada gama de presas em sua dieta (FREITAS; ABILHOA; COSTA E SILVA, 2011).

Estudo feito no México à cerca de hábitos alimentares das espécies *Lutjanus peru* e *Lutjanus guttatus*, apontou que ambas se classificam como predadores polífagos, e dieta diversificada com: peixes, crustáceos e moluscos principalmente, e seu comportamento alimentar é adapta-se mediante a disponibilidade de alimentos (ROJA-HERRERA; CHIAPPA-CARRARA, 2004).

A variabilidade na alimentação de dois lutjanídeos: *Lutjanus synagris* e *Lutjanus griseus* realizado na região de Campeche no México, demonstrou que *Penaeidae* foi principal fonte alimentar na dieta da espécie *Lutjanus synagris* enquanto a de *Lutjanus griseus* foi *Callinetes sapidus* (JUÁREZ-CAMARGO *et al*., 2020). As espécies apresentaram comportamento e posição trófica similar, porém, foi notada uma baixa sobreposição trófica entre elas, associada provavelmente à alimentação das mesmas que ocorrem em distintos ambientes(JUÁREZ-CAMARGO *et al*., 2020). É provável *Lutjanus griseus* alimente- se em manguezais e *Lutjanus synagris* em região marinha (JUÁREZ-CAMARGO *et al*., 2020).

A ecologia alimentar de juvenis de *Lutjanus jocu* na região de riachos e mangues na cidade de Curuçá, no Norte do Brasil, indicou os camarões *Penaeidae* como a principal fonte alimentar da espécie estudada, mostrou alimentação variada condicionada pela época sazonal, sendo que *L.Jocu* apresentou- se especialista no período seco (dieta composta essencialmente por Penaeidae) e generalistas no período chuvoso, alimentando-se de outros crustáceos como Grapsidae, Penaeidae e Porcellanidae (MONTEIRO; GIARRIZZO; ISAAC, 2009).

4.3. Crescimento

Estudo de Souza (2002) apontou que *Lutjanus purpureus* pode atinge a taxa média de crescimento anual de: K=0,091ano^{-1}. Gonzales; Eslava; Silva (1998), com estudos feitos com a utilização de osso hióide, determinaram os seguintes parâmetros: L ∞= 91,99 cm; K = 0,245 ano^{-1}; t_0 = - 0,499 ano.

O estudo mais atual a cerca do crescimento feito com otólitos *sagittae*, foi realizado por Freire (2019), mostrou a variação do comprimento total (CT) de *L. purpureus* de 22,7cm a 88,50 cm e não apresentou diferença significativa entre os sexos (F= 2,35, p>0,05) assim como o peso total em gramas (F= 2,35, p>0,05). A curva de crescimento que fez o uso das estimativas dos parâmetros de von Bertalanffy (VB) ajustada aos dados de comprimento na idade determinado no estudo foi de: CT (cm) = 95,09 [1-exp$^{(-0.06(t+2,6))}$)] (p <0,001; r^2 = 0,99) (FREIRE, 2019). O peso dos otólitos também mostrou ter uma forte ligação com a idade, indicando que a variável tem elevado potencial para ser utilizada para estimativas de idade em grandes amostras (FREIRE, 2019). A autora ainda catalogou a idade máxima observada para espécie, que foi de 34 anos (FREIRE, 2019). Neste estudo constatou-se também que há um crescimento mais lento na região costeira amazônica(FREIRE, 2019).

O crescimento de *Lutjanus campechanus,*espécie do mesmo gênero do pargo, estudado Golfo do México, feito com a análise de borda de *otólitos sagittae* e apontou idades estimadas com variação de 0,5 a 52,6 anos para indivíduos de 104 mm a 1039 mm de comprimento total e de 0,02 kg a 22,79 kg de peso total (WILSON; NIELAND, 2001). Ainda neste estudo, ambos os sexos indicou crescimento rápido (cerca de 8-10 anos de idade) e após este período, a taxa de crescimento mostrou considerável redução (WILSON; NIELAND, 2001). As curvas de crescimento de VB para comprimento total mostraram diferença de crescimento entre os sexos, as fêmeas mostraram- se superior aos machos em tamanho e idade (WILSON; NIELAND, 2001).

Estudo com otólitos de 3 espécies de *Lutjanus*: *L. erythropterus, L. malabaricus* e *L. sebae,* na região de grande barreira de corais (GBR) na Austrália, apontou crescimento lento e longevidade alta nas espécies estudadas, as quais atingiram a idade de: 32 anos, 20 anos e 22 anos, respectivamente (NEWMAN; CAPPO; WILLIAMS,2000).

4.4. Reprodução

Lutjanus purpureus reproduz- se por fecundação externa durante o ano todo, a população distribui-se em agregações e apesar de desovas manterem-se continuas durante o ano todo, existem dois picos reprodutivos da espécie, sendo que o de maior intensidade ocorre no primeiro trimestre e um segundo menos tenso, no mês de outubro (ALMEIDA, 1964; GESTEIRA; IVO, 1973; ROCHA; IVO; LOPES, 1982; SOUZA; IVO; SOUZA, 2003). A primeira maturação sexual do pargo (L_{50}) estimou- se entre 39 e 46cm de comprimento total para fêmeas (GESTEIRA; IVO, 1973; SOUZA; IVO; SOUZA, 2003), porém o estudo mais recente (FREIRE, 2019) mostrou uma taxa menor, que foi a de 32,1cm de comprimento furcal. O comprimento total mostrou variação de 22,7cm a 88,50cm com comprimento médio de 40,22±6,36 cm e sem diferença significativa de tamanho entre os sexos (FREIRE, 2019).

Havia registros de duas hipóteses para explicar um possível padrão migratório reprodutivo de *L. purpureus* (IVO; HANSON, 1982) que foi refutado por Freire (2019), que provou que a espécie realiza agregações reprodutivas, típicas dos Lutjanidae, e que elas ocorrem na região dos recifes amazônicos reedescritos por Moura *et al.* (2016).

Estudos sobre o desenvolvimento ovocitário, são de grande valia para estabelecer protocolos reprodutivos visando promover eficácia reprodutiva para as populações de peixes, buscando evitar a exaustão e esgotamento de estoques das espécies viventes na natureza (SOUTO *et al*., 2017; QUAGIO-GRASSIOTTO; WILDNER; ISHIBA, 2013). Apesar de poucos estudos, voltados mais especificamente o folículo pós ovulatório (FPO), este se mostra ser uma forma de análise do desenvolvimento ovocitário bastante precisa, pois o FPO logo após a desova dos indivíduos, com isso, através do FPO pode-se observar possíveis razões de insucesso no processo reprodutivo e aplicar um manejo objetivando aprimorar a reprodução e desova das espécies alvo dos estudos (ROMAGOSA *et al.*, 2018). Para Lutjanidae, existe estudo sobre a biologia reprodutiva do *Lutjanus jocu* (VIANA, 2018), que foi feito na região de Fernando de Noronha e ao analisarem os períodos ovocitário e a presença do FPO, pois considerou- se a evidência mais confiável para apontar a desova da espécie alvo do estudo,indicaram que a região onde se coletou os espécimes um importante local de desova de *L. jocu*

, ainda sobre a presença de FPO, o estudo indicou A relação entre a presença de FPO recentemente formados (indicando desova ocorreu recentemente) e período lunar, pois o mesmo indicou elevada desova em períodos de lua cheia e em até duas semanas após o primeiro dia lunar (VIANA, 2018).

Em estudo sobre o desenvolvimento ovocitário de *Lutjanus alexandrei,* na ilha de Itamaracá, região litorânea de Pernambuco no Nordeste brasileiro, identificou-se desenvolvimento ovocitário da espécie é do tipo assíncrono nos ovários e fecundidade indeterminada, e a espécie faz a liberação ovos em vários eventos durante o período de reprodução (FERNANDES *et al.,*2016).

4.5. Pesca e avaliação dos estoques de pargo na costa Norte do Brasil

A frota pargueira comercial está constituída por embarcações que atuavam originalmente no litoral nordeste do Brasil e com a crise da redução drástica da biomassa de *L. purpureus* nesta costa, que impossibilitou a manutenção do próprio sistema pesqueiro na região, parte dessa frota passou a atuar no litoral Norte brasileiro (BATISTA; ISAAC; VIANA, 2003; FONTELES-FILHO,2007). Os sistemas de pesca do Pargueiro, atuantes na costa Norte, faz o uso de apetrechos como: espinhéis, linhas de mão e armadilhas, que conhecidas como ‘manzuás ou muzuás’ (BENTES *et al*., 2017; BENTES *et al.,* 2012). O manzuá, também denominado de covo,é uma armadilha utilizada para captura de Pargo e tem sua construção em ferro e revestimento em tela de plástico malha quadrada, com abertura entre nós de 7cm que faz parte revestimento da arte de pesca (BENTES *at al.,* 2017; FREIRE, 2019). O Covo Possui forma octógonal e com comprimento médio de 1 metro e meio (BENTES *et al.,* 2017; FREIRE,2019). Uma das extremidades é por onde ocorre pargo entra, tem a forma semifechada por um tronco de cone em formato circular com a base menor contornada para o interior da armadilha,sendo que a base tamanho maior possui o diâmetro médio de 1,7 metros e a menor o diâmetro 0,25 metros(BENTES *et al.,* 2017; FREIRE, 2019). Já extremidade oposta, onde fica acomoda a “porta de despesca”, esta porta por onde se faz a retirada do pargo pescado contém uma abertura circular com 0,38 m de diâmetro (BENTES *et al.,* 2017; FREIRE, 2019).

A pescaria conhecida como espinhel vertical ou Pargueira, e contruída em uma linha de monofilamento de poliamida e utilizada em pescarias de “linha pargueira com bicicleta” e “caico” e possui dois modelos que se diferenciam pelo comprimento e pela quantidade de linhas secundárias (BENTES *et al.,* 2017; FREIRE; 2019).

O espinhel mais curto, denominado "pargueira", possui uma linha principal com um comprimento médio de 5 metros e cerca de 6 destorcedores (nº 5), além de 20 linhas secundárias com anzóis (nº 5 e/ou 8) e estas linhas secundárias possuem 18cm de comprimento, e são conectadas à linha principal com destorcedores (nº 4 ou 5) Na extremidade inferior dessa armadilha, há um peso em forma cônica de ferro ou pedra com aproximadamente 1 kg (BENTES *et al.,* 2017; FREIRE, 2019). Já o modelo de espinhel mais longo, denominado "rabadela", tem uma linha principal com comprimento médio de 30 metros, 15 destorcedores e 30 linhas secundárias de 0,35 metros de comprimento, com os mesmos destorcedores e anzóis usados na pargueira (BENTES *et al.,* 2017). A principal diferença entre a "rabadela" e a "pargueira" é o tamanho (BENTES *et al.,* 2017; FREIRE, 2019).

A pescaria descrita como “pesca de bordo” que usa o petrecho “linha pargueira com bicicleta”: a junção de um guincho manual, popularmente conhecido como “bicicleta” e a linha “pargueira” ou a “rabadela”, por meio de um destorcedor (nº 6) a um cabo de monofilamento (200-400m) (BENTES *et al.,* 2017; FREIRE, 2019).

Mensurar o esforço empregado pelos sistemas de pesca direcionados à captura de *L.purpureus* é uma tarefa complexa, uma das causas é a grande quantidade de embarcações envolvidas na pescaria deste estoque (BENTES *et al.,*2017; FREIRE, 2019). Na costa Norte Amazônica, foram identificadas 224 embarcações direcionadas à pesca de *L. purpureus*, mas destas, somente 176 estavam devidamente registradas e licenciadas para pescar (FREIRE, 2019). Das embarcações registradas, a maioria (96%) desembarcam o pescado no município de Bragança e o restante (4%) na cidade de Belém (FREIRE, 2019).

Freire em seu estudo (2019) catalogou 11 pontos de desembarque na costa Norte, distribuídos nos municípios de Bragança (7 portos catalogados), Augusto Corrêa (2 portos catalogados) e Belém (2 portos catalogados). A maioria dos trapiches (pontos utilizados para desembarque, pesagem e classificação dos que é capturado) é construído em madeira de forma bem simples cobertos com telhas de metal ou fibrocimento (FREIRE, 2019) de todos os locais listados pela autora, apenas 3 possuíam estrutura para o beneficiamento da produção, sendo dois situados na cidade de Belém, capital do estado do Pará (FREIRE,2019).

Em relação à produção pesqueira, registrou-se: 1880 desembarques nas temporadas de pescas, destes 1024 em 2016 onde foi capturado o volume de 4.629 t e 856 desembarques em 2017 onde foi capturado o volume de 3.982 t, a produção total, capturada durante o período do estudo foi de 8.612,0 t, sendo que a maior produção desembarcada foi no mês de agosto de 2016 (612,9 t) (FREIRE, 2019).

Em relação às estimativas de mortalidade total, natural e por pesca , encontra-se na literatura alguns estudos realizados com diferentes séries de dados e metodologias voltados para avaliação do estoque o pargo (IVO; GESTEIRA, 1974; GONZÁLES; ESLAVA;SILVA, 1998; SOUZA, 2002; FONTELES-FILHO, 2007). É de extrema importância a constante atualização e aompanhamento destes valores, pricipalmente a taxa de mortalidade por pesca (F), já que estes podem ser utilizados como indicadores para a situação da gestão da pesca e do estoque de pargo (BENTES *et al.,* 2017).

Estudo de Ivo e Sousa (1988) utilizando o método de Fox (1970), por meio de dados de toda a área de pesca do pargo no período de 1967 a 1987, estimou o esforço ótimo de 2.074 x 10^3 anzóis-dia. O modelo de produção de Fox (1970) é um modelo exponencial de rendimento excedente que visa a otimização da exploração de populações de peixes, e baseia- se em determinar do nívelótimo de esforço, sem trazer efeitos negativos o estoque explotado, e tem como objetivo trazer sustentabilidade para a atividade (FOX,1970; IVO; SOUSA,1988).

Buscando obter uma avaliação mais atualizada dos estoques d o Pargo, estudo realizado com dados coletados por meio do Projeto FIP (*Fisheries Improvement Project*), durante dois anos apresentou um levantamento inicial dos estoques pelo modelo da curva de captura convertida em comprimentos, e indicou um estado de sobrepesca (Taxa de explotação de E=0,79; Mortalidade por pesca F= 0,21-1,27). Portanto, para favorecer um equilíbrio ecológico- econômico, sugere- se um acompanhanmento destes estoques, juntamente com a iniciativa do próprio setor produtivo (BENTES *et al*., 2017).

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CAPÍTULO 1: Padronizado de acordo com as normas da revista Fisheries Research-
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Recent findings of spawning and fishing management recommendations of redsnapper, *Lutjanus purpureus* (Poey, 1866), on the Amazon Continental Shelf, Brazil

ABSTRACT

Red snapper, *Lutjanus purpureus*, is one of the main fishing resources of the Amazon continental shelf. Due the valuation of the small species (<900g), drastic loses of catches with an effort increase das been observed. To identify reproductive processes through cellular structures, this research used histology of female gonads to identify oocyte formations and gonadal tissues indicative of reproductive processes to verify the efficiency of the current fisheries management. Theperiods of higher frequency of post ovulatory follicles (POF) were translated as intense spawning andhad the peak observed in the month of April, judging by the limitations of collection in the spawning period of the species. Besides POF, hydrated oocytes had a peak occurrence in July, suggesting reproductive continuity or a second peak in this period because atresic follicles and atresia tissues were also identified in this same period. Given the characteristics of the fishery, which preferentially acts on very young individuals, it is suggested that the closed season be extended to July of each year, to ensure an effective increase in reproduction of the spawning stock.

Key words: reproduction, oocyte development, FPO, large scale artisanal fishery;, Lutjanidae, Brazilian North coast; Amazon, ODS14.

1. INTRODUCTION

Lutjanus purpureus (Lutjanidae) has been exploited on the Brazilian Northern Continental Shelf since the 1960s (FONTELES-FILHO, 1972) with at least two well-defined fishing systems, whose social, ecological, and economic aspects are still poorly understood. However, the capture of red snapper, *L. purpureus*, is almost exclusively directed to the external market, and the landed volumes are still poorly monitored, causing a mismatch between the few statistical production data available and the amount reported in the Brazilian foreign trade control system (Siscomex) (BENTES *et al.*, 2017, FREIRE, 2019, MINISTÉRIO DA ECONOMIA,2021).

Because it is a species of significant market value, 75% of what is captured is destined for export, only 25% of the production of red snapper remains in the domestic market (BENTES

et al., 2017), being sold in supermarkets, rarely in fairs, in the form of filet (BENTES *et al*., 2017; FREIRE, 2019; MARTINS *et al.,* 2021;).

Export-type specimens are preferably up to 900g, juveniles, usually caught under gravel beds or rhodolith reefs (ARAÚJO *et al.*, 2021; FREIRE, 2019; MOURA *et al.*, 2016;). This preference for smaller individuals has clearly induced an inordinate eagerness of catches, in the face of estimates of the number of clandestine vessels being greater than that of licensed ones (FREIRE, 2019). The effect of overfishing growth (large catches of individuals below the size of first sexual maturity, causing a reduction in the annual catch and entailing bioeconomic damage) seems to be an imminent consequence and indications have been verified in the ports of landing (CASTELLO, 2007; DIEKERT, 2012; PETERSEN, 1903; TAGLIORO *et al.*, 2021).

The traditional export of small specimens has stimulated studies on the reproductive strategies of the species that may subsidize estimates of recruitment rates. In this sense, the classical forms of management based on the size of first sexual maturity correlated to a minimum capture size, the regulation of fishing gear mesh, the closure of areas or fishing seasons, have been replaced or complemented by more dynamic studies and based on ultra-structures such as cellular and DNA analyses, etc. (BENEVIDES, 2011, FREIRE, 2019, GESTEIRA; IVO, 1973; SOUZA; IVO; SOUZA, 2003).

Traditionally, there were two hypotheses to explain a possible reproductive migratory pattern of *L. purpureus* that was refuted by Freire (2019), who proved that the species performs reproductive aggregations, typical of the Lutjanidae, and that they occur in the region of the Amazon reefs recently measured by MOURA *et al.* (2016). From the identification of this new biome, the assessment of impacts generated by fishing activities that occur in the area has become even more imperative and initiatives of this nature have been supported by several funding agencies in Brazil and worldwide (BENTES *et al.*, 2017).

The snapper has external fertilization, with spawning occurring continuously throughout the year, but with two peaks, with one of greater intensity in the first quarter and a second peak in the month of October (ALMEIDA, 1964; GESTEIRA; IVO, 1973; ROCHA; IVO; LOPES, 1982). Freire (2019) in recent studies, pointed out that the spawning peak of the species occurs between the months of January to March, the period of higher water discharge in the region.

The first sexual maturation (L_{50}) has been estimated between 39 and 46cm of total length for females (GESTEIRA; IVO, 1973; SOUZA; IVO; SOUZA, 2003) however, the most recent study (FREIRE, 2019) estimated at 32.1cm furcal length. The total length in the landings between 2016 and 2017 ranged from 22.7cm to 88.5cm with a mean length of 40.22±6.36 cm and no significant size difference between the sexes (FREIRE,2019).

Among the most recent forms of analysis of reproduction, recognizing the phases of oocyte development and associating them with moments in time and the characteristics of space,make up primordial information to think about ways of management combined with the prospectsof stock conservation (MORGAN, 2008; SOUSA *et al.*, 2017). Among the stages of oocyte development, we have the so-called follicular body or post-ovulatory follicle (POF) from follicularcells that arise from empty follicles after spawning and its identification has been important to confirm the effective periods of spawning that, in commercial fisheries of high commercial value,as is the case of snapper, are fundamental to subsidize the management (BENTES *et al.*, 2017).

Studies with FPO are still little found in the literature, but those already existing (GANIAS NUNES; STRATOUDAKIS, 2007; GANIAS,2012; QUAGIO-GRASSIOTTO; WILDNER; ISHIBA, 2013; BROWN - PETERSON *et al., 2011*; GUAIVIRA 2010;ROMAGOSA *et al.*, 2018; CHAVES; MAGALHÃES, 1993, TEIXEIRA; FERREIRA; PADOVAN, 2004) have demonstrated the importance of recognizing this cellular phase to increase accuracywhen determining a spawning period.

Judging by the limitation of studies focusing on the reproduction of dentex, which is a resource of high economic value and destined entirely for the international market, by the trade being preferentially focused on small specimens, less than 900g, clearly juveniles, and finally by the need for more efficient management measures that can control the effort or the volumes captured, this work will contribute with more data on the reproductive activity of this species, based on recent biological data that may indicate changes in the reproductive characteristics of the species through comparisons with previous studies. Through microscopic analysis, this study determined the reproductive period of the species using cellular structures indicative of spawning such as hydrated oocytes (HO - indicating the beginning of spawning), post ovulatory follicles (POF - indicating recent spawning), atresic follicles (ATP - indicating late spawning and beginning of the regenerative process) and atresia tissues (ATY - denoting stage of total regression after spawning), also presents a first chronology of the involution process and thus consolidates data that can be used to delimit the most intense spawning period of the species, contributing directly with information that can subsidize more precise policies for stock maintenance.

2. MATERIAL AND METHODS

2.1. Study area

The specimens were collected, monthly between the years 2016 and 2017 in the area of commercial fleet activity on the Amazon continental shelf, which extends from the Cape Orange

region in the state of Amapá (51° W), to the Bay of São Marcos in the state of Maranhão (46° W). The area is characterized by the presence of sedimentary sand banks with gravel (GUALBERTO; EL-ROBRINI, 2005). In contrast, the continental shelf substrates outside the Amazon delta are composed of sand, silt and clay, mainly from the mouth of the Amazon River (SILVA *et al*., 2009). The enormous discharge of water and sediments from this river forms an extensive freshwater plume that extends into the tropical North Atlantic, and varies in size according to seasonal fluctuations in rainfall patterns in the Amazon region (SILVA *et al.*, 2009).

An extensive coral reef area (~ 56,000 km) was recently measured on the Brazilian Amazon coast (MOURA *et al.*, 2016; FRANCINI-FILHO *et al.*, 2018). This ecosystem has unique characteristics that may harbor many endemic species (FRANCINI-FILHO *et al.*, 2018). Several commercial catches occur in this area, due to the variety of species, including that targeting *L. purpureus* (MOURA *et al.*, 2016).

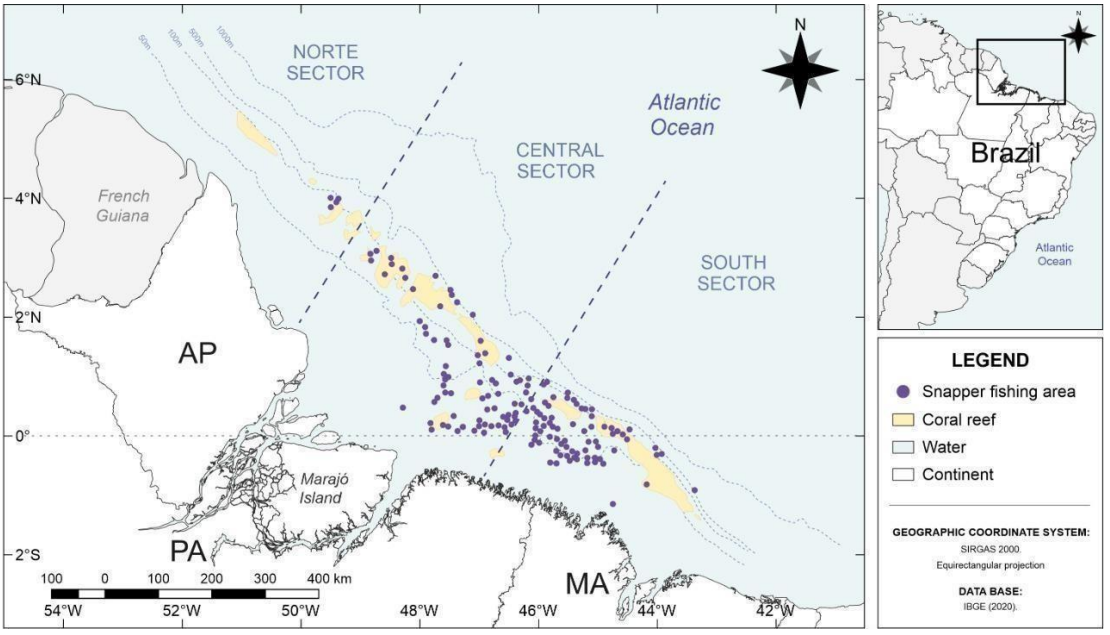

Figure 1- Red snapper (*Lutjanus purpureus*) capture areas on the Brazilian Amazon continental shelf

2.2. Biological data collection and laboratory screening

The samples were collected through the FIP North project (Fisheries Improvement Project) in the period from May / 2016 to February / 2018, during the fishing seasons that occur from May 1 to December 14 (determined by Brazilian Normative Instruction No. 42 of July 27, 2018).

In the laboratory, the captured individuals were identified using specialized identification keys (CERVIGÓN, 1992; ANDERSON, 2002; ALLEN, 1985) then the total length - TL in centimeters (measured from the anterior portion of the snout to the end of the upper lobe of the caudal fin) and the total wet weight (W in kilograms) were recorded, besides confirming the sex of all specimens.

The gonads were extracted, macroscopically identified as to the stages of maturation according to the scale based on the (modified) classification of Alves (1971) and the nomenclature proposed by Brown-Peterson *et al*. (2011), and was assigned to one of four classes: IMM (immature); DEV (developing); SPW (spawning ability) and REG (regressing or regenerating) for females and IMM, SPW and REG, for males. In this work, only female snapper (120 in total) was used for the reproductive inferences.

2.3. Histology and reproductive indicators

The collected gonads went through a fixation process in BOUIN solution (15 parts of picric acid, 5 parts of formaldehyde and 1 part of acetic acid) (VAZZOLER, 1996). After fixation for a period of 24 hours, the specimens were transferred to 70% alcohol. After fixation, the gonads were inserted into histological cassettes and histological slides were prepared following the standard protocol for preparing histological sections by Vazzoler (1996).

In the laboratory, the material was wrapped in paraffin to make blocks from which sections were made with the aid of a microtome. These sections, with thicknesses between 5 µm and 7µm, were placed on microscope slides and then stained with Harris hematoxylin. The next step involved the immersion of the slides in eosin and finally, in alcohol and xylene.

From each gonad collected, 1 histological slide with two sections was prepared, whose cells were first identified and described the indicative structures of spawning (hydrated oocytes - HO , post ovulatory follicles - POFs, atresic follicles - ATP, and evidence of atresia in the muscle bundle - ATY), described, counted, and measured. Histological description of developmental stages and classification followed existing terminology in the literature (WEST, 1990; BROWN-PETERSON *et al.*, 2011; LOWERRE-BARBIERI, 2011).

In addition to the counting and description of cell types, the areas of the identified POFs were calculated using Zen 3.4 blue edition software, coupled to a Zeiss Axio Scope A1 microscope, considering the scale in micrometers (μ).

Table 1 - Histological stage terminology according to Brown- Peterson *et al.,* (2011). PG = primary growing oocytes; CA = cortical alveoli; Vtg1=primary vitellogenic; Vtg2 = secondary vitellogenic; Vtg 3= tertiary vitellogenic; OM = maturing oocyte; GVM= germinal vesicle migration; GVBD = germinal vesicle rupture.

Phase	Terminology	Macroscopic and histological features
Immature (never spawned)	Immature, virgin	Small ovaries, often clear, blood vessels indistinct. Only oogonia and PG oocytes present. No atresia or muscle bundles. Thin ovarian wall and little space between oocytes
Developing (ovaries beginning to develop, but not ready to spawn)	Maturing, early developing, early maturation, mid-maturation, ripening, previtellogenic	Enlarging ovaries, blood vessels becoming more distinct. PG, CA, Vtg1, and Vtg2 oocytes present. No evidence of POFs or Vtg3 oocytes. Some atresia can be present. Early developing subphase: PG and CA oocytes only
Spawning capable (fish are developmentally and physiologically able to spawn in this cycle)	Mature, late developing, late maturation, late ripening, total maturation, gravid, vitellogenic, ripe, partially spent, fully developed, prespawning, running ripe, final OM, spawning, gravid, ovulated	Large ovaries, blood vessels prominent. Individual oocytes visible macroscopically. Vtg3 oocytes present or POFs present in batch spawners. Atresia of vitellogenic and/or hydrated oocytes may be present. Early stages of OM can be present. **Actively spawning subphase: oocytes undergoing late GVM, GVBD, hydration, or ovulation.**
Regressing (cessation of spawning)	Spent, regression, postspawning, recovering	Flaccid ovaries, blood vessels prominent. Atresia (any stage) and POFs present. Some CA and/or vitellogenic (Vtg1, Vtg2) oocytes present.
Regenerating (sexually mature, reproductively inactive)	Resting, regressed, recovering, inactive	Small ovaries, blood vessels reduced but present. Only oogonia and PG oocytes present. Muscle bundles, enlarged blood vessels, thick ovarian wall and/or gamma/delta atresia or old, degenerating POFs may be present.

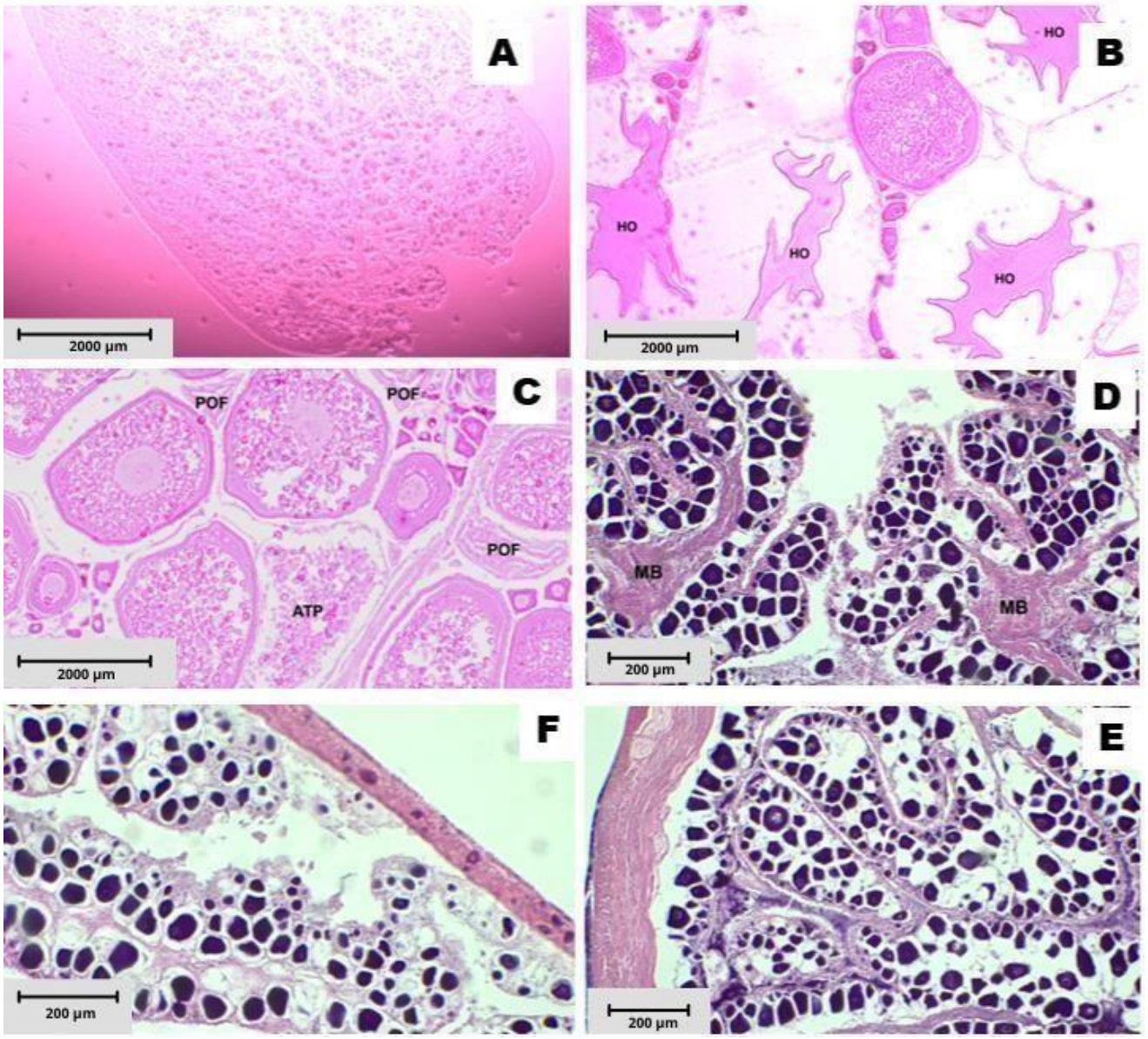

Figure 2 Histological images of the oocyte development stages of *Lutjanus purpureus*, captured on the Amazon continental shelf between the years 2016 and 2017. A - ovary in the immature phase, B - ovary with imminent spawning capacity (presence of OH = hydrated ovocyte); C - ovary with recent spawning (presence of POF = post ovulatory follicle, ATP - indicating cell death) ; D - ovary in regression phase E - ovaries in regression phase that with thicker muscle bundles (MB), thicker and irregular ovarian wall and the presence of atresia (which differs from the immature phase); F - ovary in immature phase.

A total of 120 slides of 120 females of *Lutjanus purpureus* were observed and of these, 61 were used in this study because they were in spawning state (mature and spawned ovaries classified macroscopically). The cell types indicative of spawning were identified, counted, and in the case of POFs the area was recorded using Zen 3.4 blue edition software.

2.4 Data analysis

The number of cells per typology, as well as the area of the POFS were tested between months and specimen size classes by means of a test of means (one way ANOVA and factorial) considering a 5% error.

For analysis, a direct linear response ordering method - RDA (Redundancy Analysis) was chosen, which does not require the assumptions of variance analysis since permutations are performed on the data. In this model, the response variables are projected onto a system of axes where axis one (one) explains a percentage of the variability in the data set, axis two (two) explains another smaller percentage, and so on. The goal of this analysis was to find relationships (if any) between two sets of data.

Separate matrices were constructed for each dependent variable (each row, a sample, in this case, the quantities of cell types per specimen), and, all of them were related to a second matrix - 'treatment' - where the independent variables (month - April to November; year - 2016 and 2017; size classes - TL1 (28-35 cm), TL2 (35.1-40 cm), TL3 (40.1-45 cm) and TL4 (45.1-50 cm); and weight - W1 (<200g),W2 (201-500g),W3 (501-800g), W4 (801-1000g) and W5 (>1000g) were listed one by one. After performing the RDA, the Monte Carlo test was used which performed permutations (in this case, 9999) that assessed the robustness (significance) of the results.

The analyses were run in R software version 4.0.3 (R Development Core Team, 2020) using the vegan package (OKSANEN *et al*., 2019) and CANOCO 7.0 software (Software for Canonical Community Ordination).

3. RESULTS

A total of 120 females and 61 males of *L. purpureus* (67% and 33%, respectively) were analyzed in this study, with a mean total length of 41,5 4,74cm for females and 41,7 4,74cm for males. All cell types related to reproduction were identified in the females analyzed, with higher peaks of OH in the months of July and November, but without statistical significance (F=0,84,

p>0,05), and POFs in April (F= 2,57 p 0,05). Atresic follicles and atresia tissues of the regressed individuals were found in larger quantities in August and September (F=0,19, p>0,05) (Table 2).

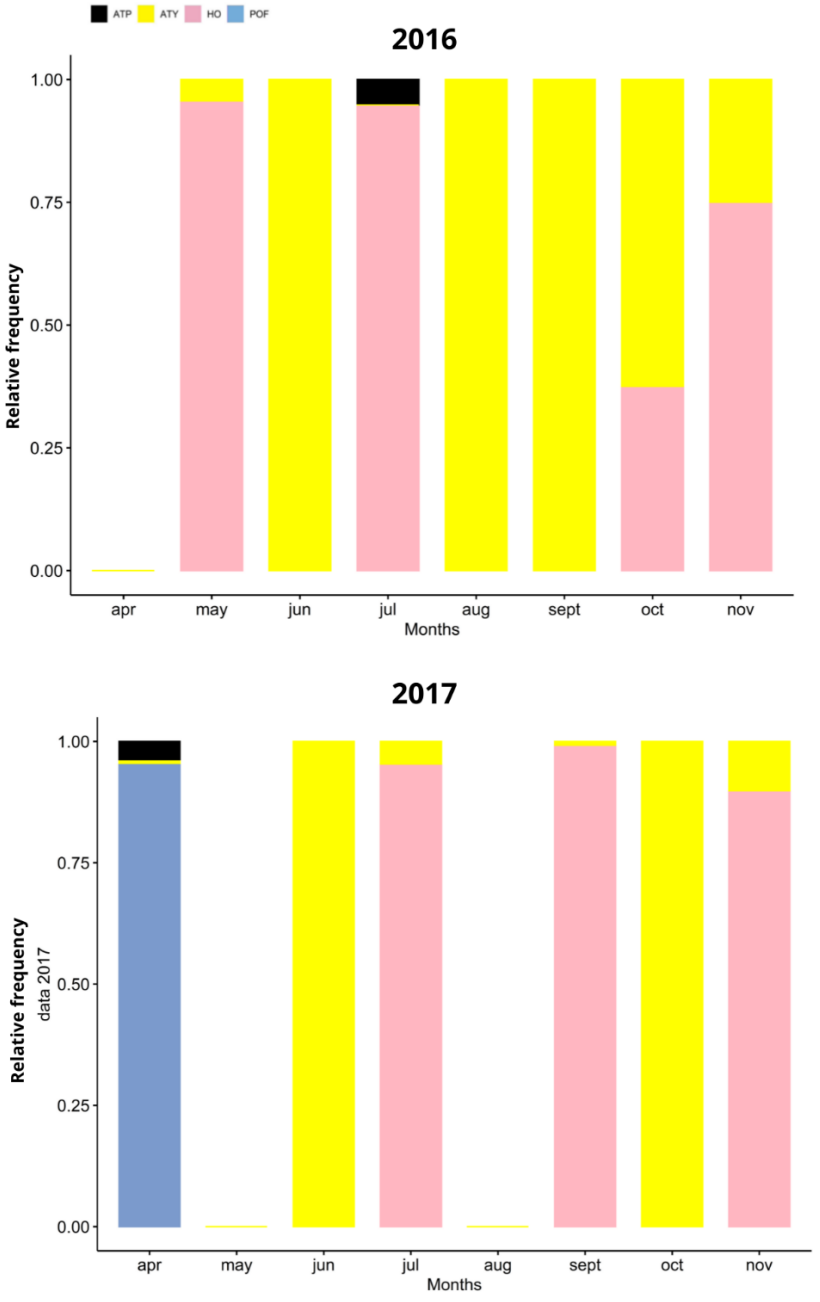

Figure 3 Relative frequency (y-axis) monthly (x-axis) of cell types indicative of spawning of *Lutjanus purpureus* caught by the large-scale artisanal commercial fleet in the years 2016 and 2017 on the Amazon continental shelf : HO - hydrated follicle -represented in the graph by pink color; POF - post ovulatory follicle, represented in the graph by blue color; ATP - atresic follicle, represented in the graph by black color and ATY - tissue in atresia, represented in the graph by yellow color).

The frequency of cell types in relation to sizes showed no significant difference in the period studied (Table 2), however, the tendency for a decrease in POFs as a function of species size was evident in the 43.1 to 50 cm total length classes (F=0,14;p>0.05).

Table 2- Results of one way and factorial analyses of variance of the number of cells indicative of spawning (hydrated oocyte - HO; post ovulatory follicle - POF; atresic follicle - ATP and tissue in atresia - ATY) per total length category (CATTL in cm) of *Lutjanus purpureus* caught on the Amazon continental shelf between April and November 2016 and 2017. Df = degrees of freedom; Sum Sq = sum of squares; Mean Sq = meanof squares; F = Fisher's test; Pr = probability; dashes refer to untested data.

Dependent variable	Factor	Df	Sum Sq	Mean Sq	F value	Pr(>F)
HO	TL category	3	166	55,25	0,1448	0.9328
	Month	7	2053	293.35	0.7690	0.6147
	TL category x month	17	5459	321.13	0.8418	0.6419
	Residuals	93	35478	381.48		
POF	TL category	3	3575	1191,7	2,577	0.571
	Residuals	117	54112	462,5		
ATY	TL category	3	1,53E-26	5,09E-27	0.2693	0.8469
	Month	7	6,84E-26	9,77E-27	0.5171	0.8123
	TL category x month	13	4,89E-26	3,76E-27	0.1990	0.9979
	Residuals	23	4,34E-25	1,89E-26		
ATP	Month	1	220.5	220.5	-	-
	Residuals	0	0.0	-		

All independent variables together accounted for 97% of the variability of the data, and the RDA ordination diagram confirmed the highest occurrence of POFs in April and the highest representativeness of HO between the months of July and September (Figure 4). The decomposition of the axes by size and weight categories showed higher correlations of POF with TL4 and W5 classes and of HO with TL2 and W2 and W3, denoting spawning since TL2 class (Figure 5).

A reduction in the quantity and area of post ovulatory follicles, suggesting reduced reproductive capacity of the specimens, was observed from the 43.4 - 45.4 cm (TL3 and TL4) class (snapper over 650g) (Figure 5).

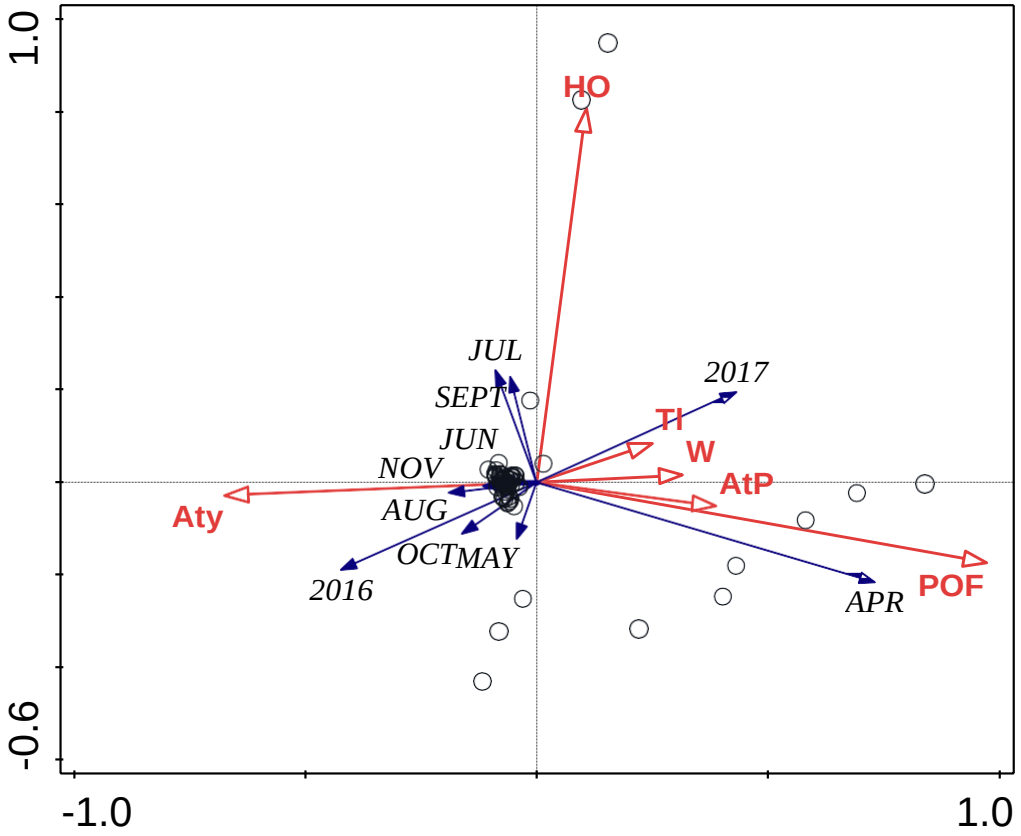

Figure 4 – Ordination diagram of the cell typologies indicative of spawning (HO: hydrated oocyte, POF: post-ovulatory follicle, AtP: atresic follicle and ATY: presence of atresia) and the weight (W in grams) and total length (TL in cm) classes resulting from the redundancy analysis (RDA) of *Lutjanus purpureus* caught on the Amazon continental shelf in relation to the months of April to November in the years 2016 and 2017. W1= <200 g; W2= 201-500 g; W3= 501-800 g; W4=801-1000 g; W5= >1000g; TL1= TL2=28-35 cm; TL3= 35.1-40 cm; TL4= 40.1-45 cm, TL5= 45.1- 50 cm.

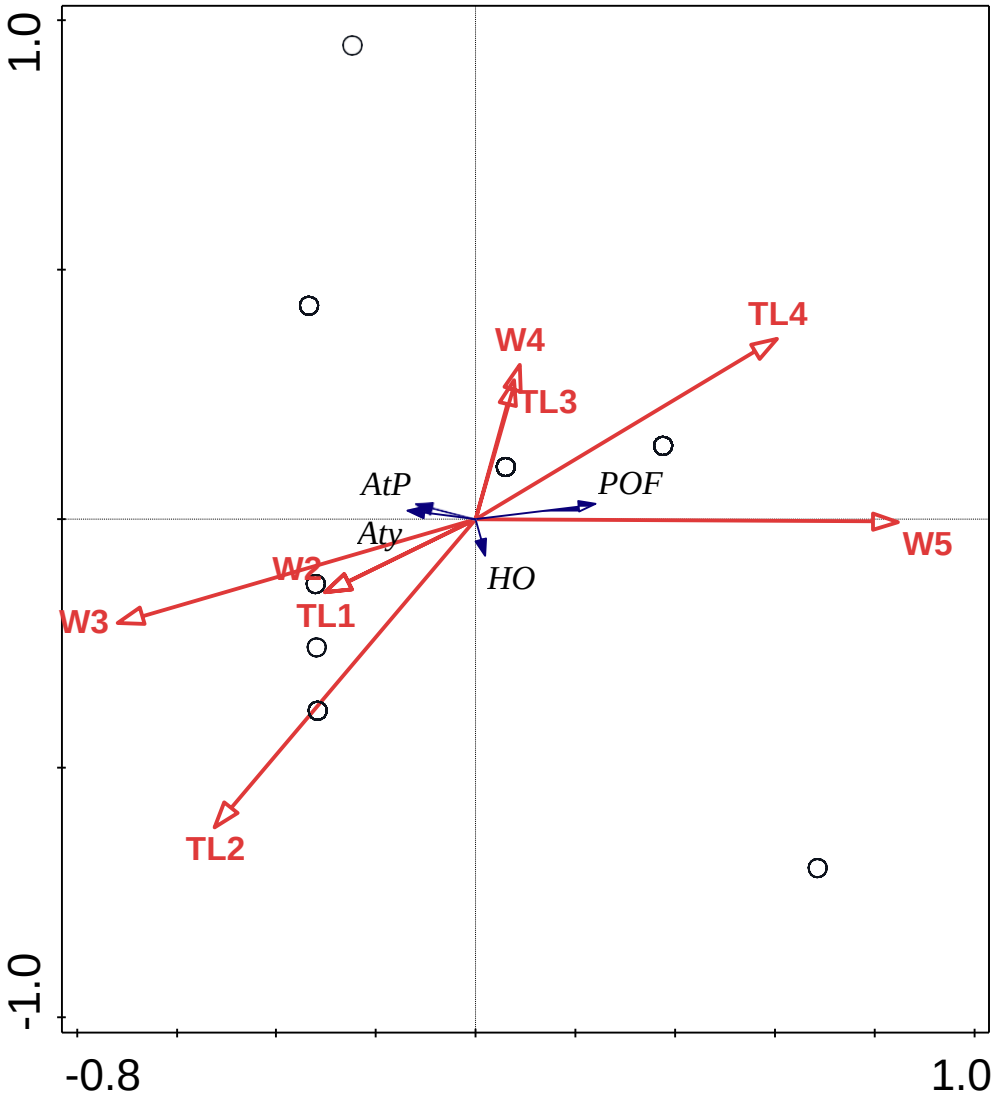

Figure 5 Ordination diagram of the indicative spawning cell typologies (OH, POF, ATP and ATY) and the weight (W in grams) and total length (TL in cm) classes resulting from the redundancy analysis (RDA) of *Lutjanus purpureus* caught on the Amazon continental shelf between the years 2016 and 2017. W1= <200 g; W2= 201-500 g; W3= 501-800 g; W4=801-1000 g; W5= >1000g; TL1= TL2=28-35 cm; TL3= 35.1-40 cm; TL4= 40.1-45 cm, TL5= 45.1- 50 cm. HO= hydrated oocyte, Aty= tissue in atresia, AtP= Atresic follicle, POF= post ovulatory follicle.

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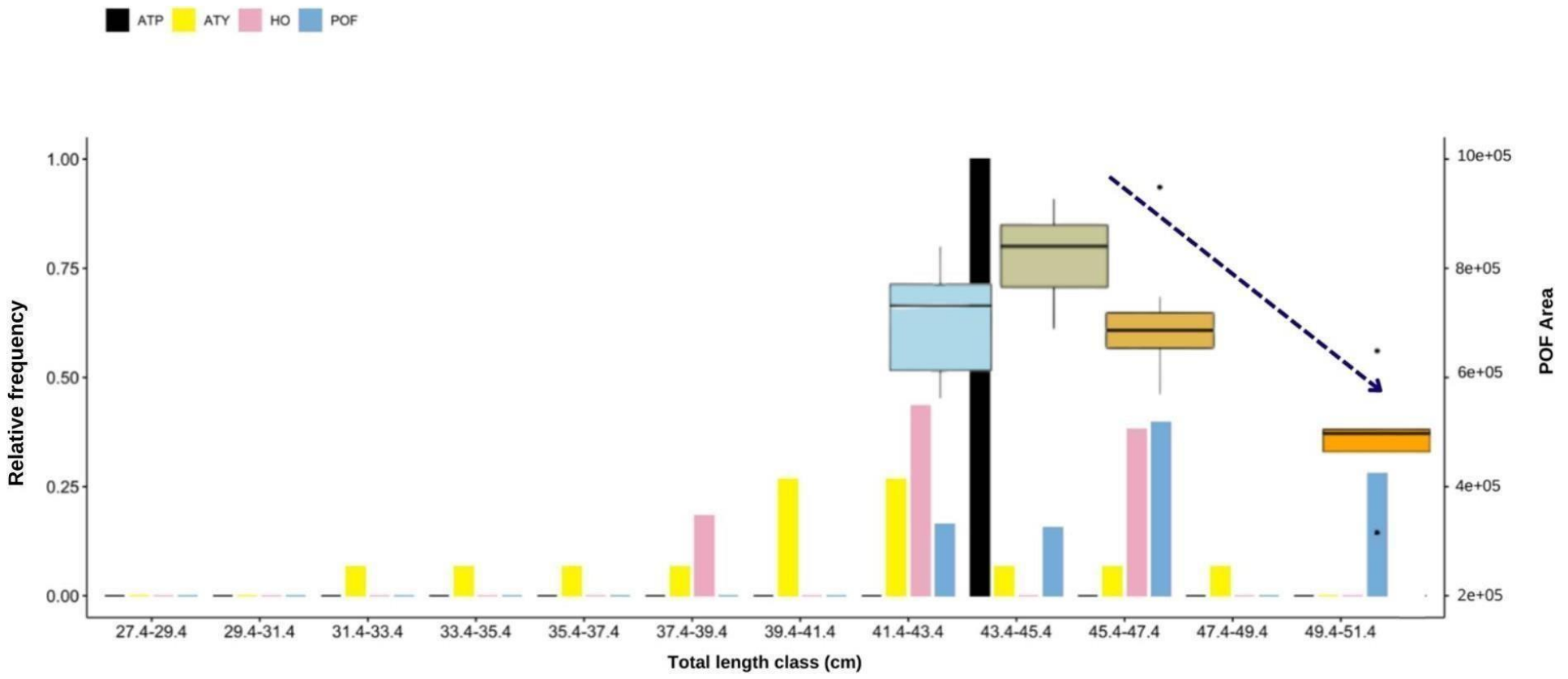

Figure 6 Relative frequency (y-axis) of cell types indicative of spawning (HO = hydrated follicle; POF - post ovulatory follicle; ATP - atresic follicle and ATY - tissue in atresia) and area of POF (z-axis - box plot of mean, standard deviation and maximum and minimum values) by total length class (cm; x-axis) of *Lutjanus purpureus* caught on the Amazon continental shelf between the years 2016 and 2017. The dotted line is the declining trend of the mean area of POFs by size class.

4. DISCUSSION

Fishing ban and/or minimum size limits for snapper have been instituted in Brazil since 1984 (PORTARIA SUDEPE N° 10, DE ABRIL DE 1984) (Table 3) with little or no practical effect from the point of view of maintenance of spawning stock and capture systems (LUCENA-FRÉDOU *et al*., 2021, OCEANA, 2020). The snapper, since the mid-1960s when the fishery was observed along the Amazon continental shelf, has had targeted regulations, judging by its expressive commercial value compared to other species that induced an exponential growth in catches and effort (FREIRE *et al*., 2022).

The situation of the snapper on the Amazon continental shelf, goes through situations of ineffective attempts at management (Table 03) that necessarily has to do with the fishing area, low enforcement and even the many opportunities for corruption, which makes the trade and consumption of snapper a threat to sustainability, as well as a generator of poverty. With the migration of the fleet from the Northeast of Brazil to the Amazon continental shelf, the effort in the first area has been rekindled, due to the significant reduction in fish production (FREIRE *et al.*, 2022).

Thus, in a cyclical manner, the projection of trends in the snapper fisheries in the northern region of Brazil is of a gradual but short-term collapse, since even with the inclusion of *Lutjanus purpureus* as a vulnerable species (IUCN, 2021), catches remain intense and with average catch sizes on the order of 28 cm total length (FREIRE 2019; FREIRE *et al*., 2022; Figure 07).

Table 3 Brazilian regulations governing the *Lutjanus purpureus* fishery in chronological order:

REGULATION	SUBJECT OUTLINE
Order n. 28, of 27.10.1981 (SUDEPE) - **Revoked**	Suspends the omission of the previous construction permission for vessels designed to catch snapper (*Lutjanus purpureus*), in the federal territory of Amapá until the limit between the states of Alagoas and Sergipe (mouth of the São Francisco river)
Order n. 10, of 09.04. 1984 (SUDEPE) - **Revoked**	It defines the minimum catch size for snapper (*Lutjanus purpureus*), in the area from the north of Amapá until the border between the States of Alagoas and Sergipe (mouth of the São Francisco River).
Normative instruction n. 04, of 11.03.2004 (MMA) – **Revoked**	It limits the fishing fleet that catches snapper (*Lutjanus purpureus*), in the area from the northern limit of Amapá to the border of the states of Alagoas and Sergipe (mouth of the São Francisco River).
Normative instruction Nº 13, of 13.04.2004 (IBAMA)-	Regulates the international marketing of snapper (*Lutjanus purpureus*) individuals with length less than 41 cm for the catches made in accordance with IBAMA Order 172/2002.

Normative instruction n. 07, of 15.07.2004 (MMA) – **Revoked**	Establishes the methods and fishing gear allowed for the capture of snapper (*Lutjanus purpureus*), the minimum catch size and the closed season for the northern limit of Amapá until the border of the states of Alagoas and Sergipe (mouth of the São Francisco River).
Normative instruction n. 05, of 21.05.2004 (MMA) -**Revoked**	Publishes the list of freshwater and saltwater species of invertebrates (80+10), bony fish (141+31) and cartiloginous fish (16+6) aquatic and endangered, overfished or threatened with overexploitation (*L.purpureus* considered threatened with overfishing)
Normative instruction n. 28, of 09.09.2005 (IBAMA) – **Revoked**	Establishes the minimum catch size for snapper (*Lutjanus purpureus*) in the area between the northern boundary of the state of Amapá and the boundary of the states of Alagoas and Sergipe (mouth of the São Francisco River).
Normative instruction n.80, of 28 December 2005 – **Revoked**	Allows, until June 30, 2006, the capture of snapper (*Lutjanus purpureus*).
Normative instruction n. 168, of 04.09.2007 (IBAMA) – **Current**	Allow the transformation of the balance of the number of motorized boats in the fleet that operates in the capture of snapper (*Lutjanus purpureus*), as defined in the Normative Instruction MMA nº 004, of March 11, 2004, from boats with total length less than or equal to fifteen meters to boats with total length greater than fifteen meters.
Normative instruction n. 22, of 18.10.2007, extended by Normative Instruction n. 26, of 26.11.2007 (SEAP) - **Art. 1º current**	Convert 20 (twenty) openings originating from the snapper fishing permit (*Lutjanus purpureus*) dealt with in SEAP Normative Instruction 001, of 2005, destined for access for vessels with a total length equal to or less than 15 meters, into 10 (ten) openings for vessels with a total length greater than 15 meters, to operate in the snapper fishery in the area between the northern limit of Amapá, to the border of the States of Alagoas and Sergipe (mouth of the São Francisco River).
Interministerial Normative instruction n. 01, of 27.11.2009 (MPA/MMA) - **Revoked**	It is prohibited the fishing operation of vessels authorized to catch the snapper (*Lutjanus purpureus*), in the area between the northern limit of the State of Amapá until the border of the States of Alagoas and Sergipe (mouth of the São Francisco River), in waters shallower than 50 (fifty) meters deep.
Interministerial Normative Instruction n. 08, of 08.06.2012 (MPA/MMA) - **Current**	It establishes fishing area limitations; - annual fishing ban; monitoring, control, and inspection measures; permitted fishing methods; measures for substituting the authorized vessel; market control measures, for companies that operate in the capture, conservation, processing, industrialization, or commercialization of the species; sanctions and penalties related to the Environmental Crimes Law and its regulation.
Order n° 73, of 26.03.2018 (MMA) - **Current**	For the endangered species listed in Appendix I of this Order, sustainable management may be allowed.
Order nº 43, of 31 january 2014 (MMA) – **Current**	Establishes the National Program for the Conservation of Endangered Endangered Species Program - Pró-Espécies, with the objective with the objective of adopting prevention, conservation, management, and management, with a view to minimizing the threats and risk of extinction the risk of extinction of species.
Order nº 228, of 14.06.2018 (MMA) – **Current**	Recognizes the species *Lutjanus purpureus* (Pargo; Red snapper) as susceptible to exploitation, study or research and establishes the respective conditions.
Order nº 42, of 27.07.2018 (SEAP) – **Current**	Defines rules for the sustainable use and recovery of stocks of the species *Lutjanus purpureus* (pargo; red snapper).

The identification of reproductive activities outside the legal fishing ban periods, is of critical importance in studying the life history evolution of the snapper and understanding the adaptability of their characteristics to environmental conditions (KRABBENHOFT *et al.*, 2014; MEADOR; BROWN, 2015; STEVENSON; BRYANT,2000; TAO *et al.*, 2018).

Thus, this work, even with the limitation in obtaining data during the fishing ban, revealed an important reproductive continuity of *Lutjanus purpureus* beyond that instituted by fishing ban (Decemberto April). This finding opens discussions about the use of other tools to gauge the reproductivedynamics of the species more accurately, at the expense of the imminent collapse of the snapper fishery in the face of earlier and more recent overfishing events in traditional fishing countries such as China and Indonesia (LIU *et al*., 2022). On the other hand, a control of the fleet, especially the clandestine one, would be an option given the total ignorance of these actors and the ways in which they act, even in the face of restrictions such as the need for tracking (for boats larger than 15m) and annual licensing.

Energetic adjustments that optimize processes that ensure species continuity, such as reproductive processes, appear to be relatively common biological phenomena in the face of fishing pressures and recently, a mathematical model of productivity "enhancement" has been devised based on the prey-predator relationship, fishing being the predator, in this context (PERISSI *et al.*, 2017; LOTZE; WORM, 2009; BAILEY, 2016).

It is evident, that in the case of fisheries, in addition to fishing factors, there are climate change, habitat loss among others that, in the case of snapper are evident as the fisheries are conducted under a coral bank (MOURA *et al.* 2016).

Moreover, until the early 2000s, management approaches to *Lutjanus purpureus* were still based entirely on macroscopic analyses which, although practical, can mask ultrastructural processes such as the continued appearance of POFs after the official fishing ban period. Nuñez and Duponchelle (2009) and later Brown-Peterson *et al.* (2011) tried to reduce the mismatch between macro- and microscopic observations of gonads by developing a new scale also based on histology. However, this terminology is still rarely used due to the need for histological processing. Judging that these follicles form and disappear in a maximum period of just over 100 hours (maximum of 5 days) (GANIAS *et al.,* 2007), significant percentages of spawning still occur outside the fishing ban and, in addition, POFs have even shorter cycles, therefore difficult to detect, in tropical environments, whose average sea temperature is higher (approximately 27ºC±2; MOURA *et al*., 2016) than in temperate environments (GANIAS *et al.,* 2007).

The highest percentage of hydrated oocytes, indicative of imminent spawning, was identified in the month of July, in specimens of the 42 cm total length class, but HOs are recorded since the 38 cm class. The POFs observed in this study also decrease in size according to the length of the specimens, signaling a probable reduction in the reproductive capacity of older individuals, as happens with other teleosts (MIRANDA *et al.,* 1999). The

evolution in POF shape is allometric because the surface area of the POF along the lamellar epithelium decreases at a slower rate than the total area of the follicles. As a result, over the course of degeneration, POF consecutively change from an irregular shape to a semiretangular shape and finally a triangular shape, providing an additional morphological criterion useful for determining POF stage (McDONOUGH *et al*., 2005).

In addition to the difficulties of detecting ultra-structures in tropical environments, the multiple spawning pattern, common in the species *L. purpureus* (GONZÁLEZ and LUGO, 1997), *L. campechanus* (BROWN-PETERSON; BURNS; OVERSTREET, 2009; BRULÉ *et al.*, 2010; KULAW *et al.*, 2017), *Lutjanus synagris* (FREITAS *et al*., 2014), *Lutjanus peru* (SANTAMARÍA- MIRANDA *et al.,* 2003), *Lutjanus guttatus* (ARELLANO-MARTÍNEZ *et al.*, 2001), and *Lutjanus alexandrei* (FERNANDES *et al.*, 2012), with asynchronous oocyte development in mature females (SPW), indicates the production of multiple batches of eggs during the spawning period. Snapper typically spawns in reproductive aggregations, which can be mapped by on-site observation (by divers or underwater camera systems) or by analysis of catch variation, with areas with higher than average CPUEs (catch per unit effort) indicating reproductive aggregations, as observed in *Lutjanus cyanopterus* (MALAFAIA *et al*, 2021), *Lutjanus cubera* (MOTTA *et al.*, 2022), *Lutjanus jocu* and *L. synagris* (FRANÇA; OLAVO, 2015) and *Lutjanus gibbus* (NANNINGA; SPAET, 2017).

Extensive reproductive periods are also common in tropical fishes (JOHANNES, 1978; GRIMES, 1987; CLARO *et al.*, 2003; FRY *et al.*, 2009; LOWERRE-BARBIERI *et al.*, 2015; KULAW *et al.*, 2017) and the recognition of spawning periods as critical moments in the life cycle of these species should be the main foundation for public policies.

The identification of POFs and HO, in this study, suggests a revision of fishing ban, since the month of July, outside the fishing ban has shown to have a high reproductive peak, should be an option of immediate order for the maintenance of stock recruitment. Additionally, identifying and prohibiting illegal fishing should also be an imperative action, since losses may be even greater than those estimated in the recently released mapping and, moreover, according to Freire *et al.*, (2022), the information about the catches of these control devices are far from reality, just by comparing the data with the records of *Lutjanus purpureus* export systems published in the official electronic spreadsheets (MINISTÉRIO DA ECONOMIA, 2021).

Because we found individuals able to reproduce below the L_{50} determined for the species and in off-fishing ban periods, it is valid to think about the creation of new mechanisms for a less harmful fishing to the reproductive population, such as traps with greater selectivity. The fact that this study corroborates the results obtained by Freire (2019) in relation to the L_{50}, reinforces the need to review measures to reduce the pressure imposed on the fish stock

addressed. Keeping the reproductive rates of the species updated can help control the impact of fishing on the stocks.

In addition to the studies already applied for the understanding of the snapper fishery, interdisciplinary studies are suggested, aiming to include social actors, their motivations and internal factors included in fishing activity, an example of studies is the so-called vulnerability index that makes an analysis addressing factors that may influence the success of the fishery in question, factors such as: ecological vulnerability, vulnerability, socio-economic and socio-ecological vulnerability (JARA *et al.*, 2020).

In addition to studies on the biology of the species that was clearly explicit in this study the importance, studies in the Amazon reef region need greater scientific efforts, because it is a sensitive area and high symptoms of stocks living in that region, is also a placewhere there is a high rate of fishing activity, so it is necessary to greater knowledge of this region (MOURA *et al.* 2016; GUALBERTO; EL-ROBRINI, 2005). Microscopic analysis aligned to macroscopic of the involution period of aquatic organisms has been demonstrating effectiveness in the course of studies performed (HEINS; BROWN-PETERSON,2022, BROWN- PETERSON *et al.*, 2011; LOWERRE-BARBIERI *et al.*, 2015, HONJI *et al.*,2022) however, in addition to histological studies other aspects about reproduction would be of extreme importance about investigating the reproductive behavior such as addressing the larval life stage of the species and the influence of the lunar phase on the spawning of the species (CONSTANTE- PÉRES; CASTILLO- RIVERA; SERRATO- DIAZ, 2022; FALFAN *et al.*, 2007).

It is important to emphasize that, for a greater accuracy in the spawning period, it is necessary that collections are made throughout the year, including during the closed season, for a real monitoring of the life cycle of the species and to generate greater reliability in the conduct of work (VIANA, 2018; MALAFAIA *et al.*, 2021; MOTTA *et al.*, 2022).

Fishing certainly assumes a clear and harmful role in the loss of *Lutjanus purpureus* recruitment potential on the Amazon continental shelf, reducing the capacity to maintain stocks. In this case, in addition to the policies already in place and the extension of the fishingban, a more effective control of mapping and clandestine vessels is also needed. In addition, and considering that the snapper fishery has significant social importance in the region, think about the vulnerability of fishermen regarding the possibility of breaking rules.

Forms of control of invoices of entry and exit of raw material in the industries associated with the maps on board, which already exist, could also be configured as a practice that would limit the unrealistic production records, besides, of course, the records of percentages by

category of captured size. Evidently, the fishing statistics of product entrance in the industries, considering the register by fishing license and, besides this, linked to a "quota" per vessel considering the urn capacity of each boat could also be an attempt to regulate the captures in face of the current total lack of control.

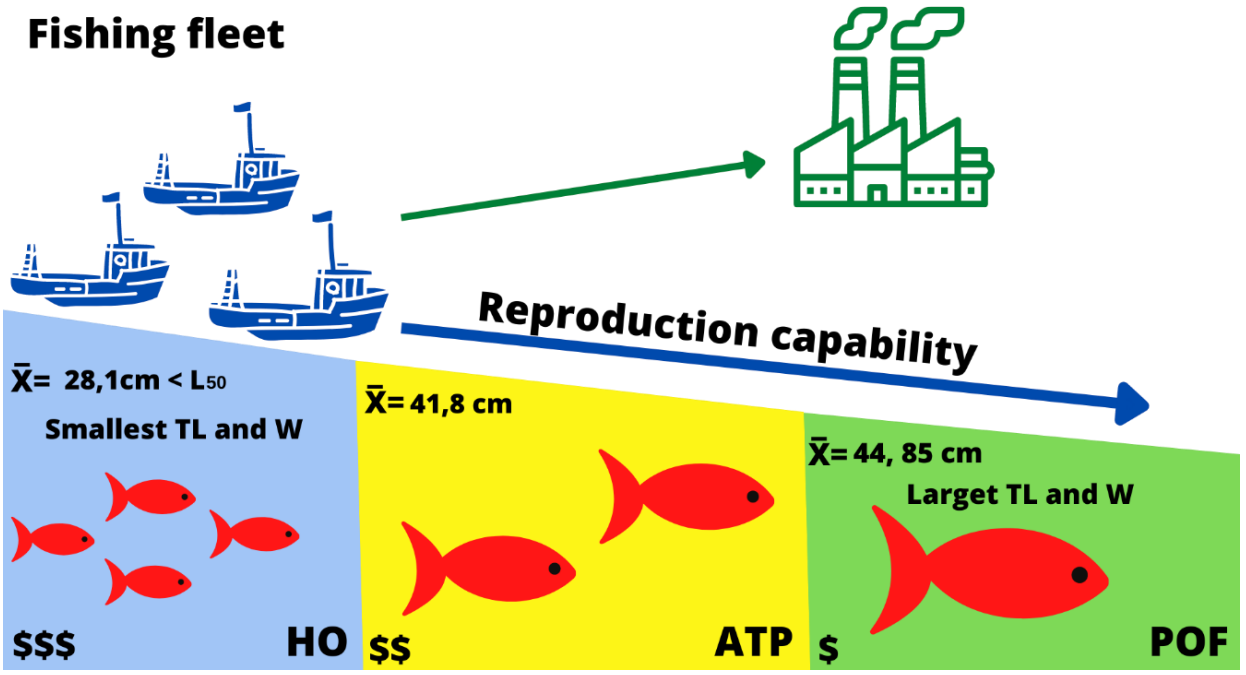

Figure 7- Diagram of the proportion of commercial categories, prevalence of hydrated oocytes (OH), atrophic follicles (ATP) and post-ovulatory follicles by size and weight of *Lutjanus purpureus* caught by the large-scale artisanal fleet operating in the Amazon continental shelf from samples from the years 2016 and 2017. The numbers refer to the export valuation by size (TL) and weight (W) of the specimens; the blue line is indicative of the reduction in reproductive capacity by size of the species according to the present study.

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ANEXO 1- Regras de submissão da revista Fisheries research

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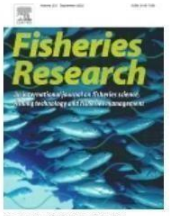

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Cancer Research UK, 1975. Cancer statistics reports for the UK. http://www.cancerresearchuk.org/ aboutcancer/statistics/cancerstatsreport/ (accessed 13 March 2003).
Reference to a dataset:

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