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RODRIGO CUMPLIDO

PARÂMETROS BIO-ECOLÓGICOS DA ENCHOVA, *Pomatomus saltatrix* (Linnaeus, 1766), PISCES: POMATOMIDAE, NA ÁREA DA RESEX-MAR DE ARRAIAL DO CABO – RJ, BRASIL

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Trabalho de conclusão de curso, apresentado ao Instituto de Estudos do Mar Almirante Paulo Moreira (IEAPM) e à Universidade Federal Fluminense (UFF), como requisito parcial para a obtenção do grau de Mestre em Biotecnologia Marinha.

Orientador: Prof. Dr. Eduardo Barros Fagundes Netto

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Arraial do Cabo, 30 de abril de 2019

“É bom que não tenhamos de tentar matar a lua, o sol ou as estrelas. Já é ruim viver no mar e ter de matar os nossos verdadeiros irmãos...” - Ernest Hemingway.

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O segredo da sabedoria, do poder e do conhecimento é a humildade” - Ernest Hemingway.

RESUMO

A Enchova *Pomatomus saltatrix* (Linnaeus, 1766), única representante da família Pomatomidae, é uma espécie cosmopolita-panmixa, que forma grandes e velozes cardumes costeiros e/ou oceânicos em águas relativamente profundas, aproximando-se da costa quando a temperatura atinge 12ºC – 15ºC. Seus deslocamentos estão correlacionados aos movimentos de cardumes de pequenos teleósteos como sardinhas e cefalópodes nectônicos como as lulas, presas, sendo vorazmente predados. Na região da Reserva Extrativista Marinha (RESEX-Mar) de Arraial do Cabo - RJ, a espécie possui uma grande importância econômica e social, e representa cerca de 10-15% do desembarque pesqueiro (aproximadas 200 t/ano). As amostras foram obtidas diariamente (de março de 2017 a março de 2018) e de forma randômica, nas peixarias e na Marina dos Pescadores de Arraial do Cabo, onde inicialmente foi realizada uma biometria primária dos espécimes (N=2.057). Juntamente com as amostras, foram registradas informações sobre a localização do pesqueiro (complementação dos dados), o esforço de pesca empregado e o total de captura (kg). Para a dissecção e análises, *a posteriori* e em laboratório, foram comprados 202 espécimes. Os espécimes foram processados para o registro de dados biométricos, incluindo: o Comprimento Total (CT) e Padrão (CP) (ambos em mm); o Peso Total (PT) (g); o peso da gônada (0,01 g); o sexo e o estádio de maturidade/maturação sexual (gônadas) determinado macroscopicamente; o peso do estômago (0,01 g); o Grau de Repleção Estomacal (0-3) e o peso do fígado (0,01 g). O CT médio foi de 541 mm, cobrindo uma amplitude de 201 mm a 915 mm, e o PT médio foi de 1.428,5 g (92,9 a 6000 g). O coeficiente angular “b” da equação exponencial que descreve a Relação Comprimento-Peso (*LWR*) foi de 2.6 e de 9E-05 para o valor de “a” sendo expressa pela equação $Wt = aLt^{b}$ para os sexos agrupados. Para as fêmeas os valores encontrados foram: $Wt = 3E – 05Lt^{2.7}$ e para os machos foram: $Wt = 2E – 05Lt^{2.8}$. Foram analisadas as gônadas dos 202 exemplares adquiridos, 109 fêmeas (53,9%) e 59 machos (29,2%) sendo de 1,84: 1 a proproção sexual (“*sex-ratio*”) e, 34 indeterminados (16,8%). A partir do peso das gônadas e dos fígados, foram calculados o Índice Gonadossomático (IGS) e o Índice Hepatossomático (IHS); e o Fator de Condição Fisiológica de Fulton (K). Os

estômagos foram retirados e o conteúdo foi analisado e identificado, e de acordo com o grau de digestão, seu conteúdo foi classificado em: Totalmente Digerido (TD); Parcialmente Digerido (PD) e Inteiro (I). A análise do conteúdo estomacal mostrou, principalmente, através do Índice de Importância Relativa (%), pequenos teleósteos pelágicos como o principal item alimentar (87,5%), seguido por *Loligo sp.* (6,25%), o que possibilitou a confirmação do hábito alimentar carnívoro e demersal-pelágico; sendo a espécie claramente generalista-oportunista. Foi observado o mesmo padrão alimentar ao longo de todo o período de estudos, sem brusca variação sazonal. A estimativa de idade foi comparada a partir da interpretação de duas estruturas de aposição (otólitos *sagittae* e escamas), estabelecendo-se uma periodicidade anual para a marcação de anéis etários nos otólitos. Foram lidos 199 pares de escamas e 190 otólitos direitos. As leituras foram realizadas por um único leitor, onde foram esclarecidos os padrões de deposição dos otólitos (incrementos), para se determinar as zonas opacas e translúcidas, e validar as marcas anuais de crescimento (anéis etários). No que tange aos parâmetros bio-ecológicos da Enchova, os resultados obtidos foram: a idade máxima registrada foi de 12+ anos (para uma fêmea); as fêmeas apresentaram comprimentos, peso e idade máxima maiores do que os machos; em relação à idade para os sexos agrupados, foram encontrados indivíduos apresentando de 1 a 12 anéis etários, com a predominância de espécimes com 3 anéis, representando 25,74% das ocorrências; os comprimentos retrocalculados médios por idade (otólitos) para os sexos agrupados podem ser representados através da equação linear $y = 192.2x + 349.4$; $R^2 = 0.060$; $p \leq 0.05$ (N=189). A maior parte das distribuições de frequências e classes de comprimento por grupo de idade e sexo foi unimodal (dados paramétricos). Para ambos os sexos, o Índice Hepatossomático (IHS) e o Índice Gonadossomático (IGS) aumentaram principalmente durante o inverno e a primavera-verão respectivamente, atingindo o seu máximo no final do verão, antes do início do provável período reprodutivo. O Índice Gonadossomático (IGS) para os sexos separados variou de 0,09% a 9,18% apresentando os maiores valores durante os meses de abril/2017 (9,18%), maio/2017 (5,02%) e setembro/2017 (5,45%) para as fêmeas. Para os machos, variaram de 0,09% a 7,53% sendo que os valores mais elevados foram encontrados durante os meses de abril/2017 (2,96%) e setembro/2017 (7,53%). Os valores mais

elevados de IGS foram equivalentes às análises macroscópicas das gônadas, nos estádios “B” (em maturação) e “C” (madura) de desenvolvimento gonadal. A Fecundidade Absoluta apresentou o número médio de ovócitos hidratados igual a 696.074, com picos em agosto/2017 e setembro/2017 (evento bimodal); a Fecundidade Relativa (ovócitos / kg de peixe) apresentou o número médio de ovócitos hidratados igual a 305.381,335 e o Diâmetro Médio dos ovócitos foi igual a 1005.08 µm. As análises de fecundidade mostraram que a espécie apresenta desova parcelada e/ou indeterminada (fertilidade). Em relação ao valor de K não houve alta interferência relacionada ao peso das gônadas, sendo a sua variação relativamente homogênea. Tais resultados sugerem a ocorrência de dois períodos de picos reprodutivos (abril e setembro) para a espécie na região (evento bimodal). A fecundidade e o Comprimento Médio de Primeira Maturação Sexual (L_{50}), tendo em vista que as capturas apresentaram relativamente poucos exemplares entre as classes de 200 a 350 mm (juvenís/recrutas), foram estimados, também, com base na análise macroscópica das gônadas dos indivíduos dissecados. O L_{50} foi estimado e assumido em 452 mm para os sexos agrupados; 472 mm para as fêmeas e 415 mm para os machos. A partir destes valores (comprimentos médios) todos os espécimes foram considerados como maduros (L_{100}) e, portanto, participantes ativos nos processos reprodutivos. Para subsidiar um futuro e adequado manejo da pesca, tratando-se de conhecer a biologia da espécie, é importante o conhecimento sobre sua bio-ecologia geral. É recomendado como medida preventiva para o manejo pesqueiro local, evitar as capturas na primavera-verão, período em que foram observados os picos de desova para a espécie.

Palavras-chave: Parâmetros bio-ecológicos. Enchova. RESEX-Mar. Arraial do Cabo – RJ. Manejo pesqueiro.

ABSTRACT

The Bluefish Pomatomus saltatrix (Linnaeus, 1766), the only representative of the Pomatomidae family, is a cosmopolitan-panmixa species that forms large and fast coastal and/or oceanic shoals in relatively deep waters, approaching the coast when the temperature reaches 12ºC - 15ºC. Their displacements are correlated to the movements of shoals of small teleosts like herings and nectonics cephalopods like squid, prey, being voraciously predated. In the region of the Marine Extractive Reserve (*RESEX-Mar*) of Arraial do Cabo - RJ, the species has a great economic and social importance, representing approximately 10-15% of the fish landing (approximately 200 t/year). Samples were obtained daily (from March 2017 to March 2018) and, in a randomized manner, in fishmarkets and in the Fishermen's Harbor of Arraial do Cabo, where a primary biometry of the specimens was initially performed (N=2,057). Together with the samples, information on the location of the fishery (complementation of data), the fishing effort employed and the total catch (kg) were recorded. For the dissection and analysis, *a posteriori* and in the laboratory, 202 specimens were purchased. The specimens were processed to record biometric data, including: Total Length (TL) and Standard (SL) (both in mm); Total Weight (TW) (g); the weight of the gonad (0.01 g); sex and stage of sexual maturity/maturation (gonads) determined macroscopically; the weight of the stomach (0.01 g); the Stomach Repletion Degree (0-3) and the liver weight (0.01 g). The mean TL was 541 mm, covering a range of 201 mm to 915 mm, and the mean TW was 1,428.5 g (92.9 to 6000 g). The angular coefficient “b” of the exponential equation describing the Length-Weight Relationship (LWR) was 2.6 and from 9E-05 to the value of "a" being expressed by the equation $Wt = aLt^{b}$ for overall. For females the values found were: $Wt = 3E - 05Lt^{2.7}$ and for males were: $Wt = 2E - 05Lt^{2.8}$. The gonads of the 202 acquired specimens were analyzed, 109 females (53.9%) and 59 males (29.2%), with a *sex ratio* of 1.84: 1 and, 34 undetermined (16.8%). From the weight of gonads and livers, the Gonadosomatic Index (GSI) and the Hepatosomatic Index (HSI); and the Fulton Physiological Condition Factor (K) were calculated. The stomachs were removed and the content was analyzed and identified, and according to the degree of digestion, their content was classified as: Fully Digested (FD); Partially Digested (PD)

and Integer (I). The analysis of stomach contents showed, mainly, by the Relative Importance Index (%) of small pelagic teleosts as the main food item (87.5%), followed by *Loligo sp.* (6.25%), what made possible the confirmation of the carnivorous and demersal-pelagic food habit; a clearly generalist-opportunistic species. The same food pattern was observed throughout the study period, without abrupt seasonal variation. The age estimation was compared from the interpretation of two apposition structures (*sagittae* otoliths and scales), establishing an annual periodicity for the marking of age rings in otoliths. A total of 199 pairs of scales and 190 right otoliths were read. The readings were performed by a single reader, where the deposition patterns of the otoliths (increments) were clarified, to determine the opaque and translucent zones, and to validate the annual growth marks (age rings). Regarding the bio-ecological parameters of Bluefish, the results obtained were: the maximum recorded age was 12+ years (for a female); females showed longer lengths, weights and larger age than males; in relation to the age for the clustered genders, individuals with 1 to 12 age rings were found, with a predominance of specimens with 3 rings, representing 25.74% of occurrences; the average retrocalculated lengths by age (otoliths) for the grouped sexes can be represented by the linear equation $y = 192.2x + 349.4$; $R^2 = 0.060$; $p \leq 0.05$ (N=189). Most frequency distributions and length classes by age group and sex were unimodal (parametric data). For both sexes, the Hepatosomatic Index (HSI) and the Gonadosomatic Index (GSI) increased mainly during winter and spring-summer respectively, reaching their maximum at the end of the summer before the beginning of the probable reproductive period. The Gonadosomatic Index (GSI) for the separated sex ranged from 0.09% to 9.18%, presenting the highest values during the months of April/2017 (9.18%), May/2017 (5.02%) and September/2017 (5.45%) for females. For males, they ranged from 0.09% to 7.53%, and the highest values were encountered during April/2017 (2.96%) and September/2017 (7.53%). The highest values of GSI were equivalent to the macroscopic analyzes of the gonads, in stages “B” (in maturation) and “C” (maturity) of gonadal development. The Absolute Fecundity presented a mean number of hydrated oocytes equal to 696,074, with peaks in August/2017 and September/2017 (bimodal event); the Relative Fecundity (oocytes / kg of fish) had a mean number of hydrated oocytes equal to 305,381.335 and; the mean oocyte

diameter was equal to 1005,08 µm. Fecundity analyzes showed that the species presents a split and/or undetermined spawning (fertility). In relation to the value of K there was no high interference related to the weight of the gonads, being their variation relatively homogeneous. These results suggest the occurrence of two periods of reproductive peaks (April and September) for the species in the region (bimodal event). The fecundity and the Average Length of First Sexual Maturation (L_{50}), considering that the catches presented relatively few specimens between the classes of 200 and 350 mm (juveniles/recruits), were also estimated based on the macroscopic analysis of the gonads of the dissected individuals. The L_{50} was estimated and assumed in 452 mm for grouped sexes; 472 mm for females and 415 mm for males. From that values (mean lengths) all specimens were considered as matures (L_{100}) and, therefore, active participants in the reproductive processes. In order to subsidize a future and adequate management of the fishery, knowing the biology of the species, it is important to know about its general bio-ecology. It is recommended as a preventive measure for the local fishing management, to avoid the catches in the spring-summer, period in which the spawning peaks for the species were observed.

Keywords: Bio-ecological parameters. Bluefish. *RESEX-Mar*. Arraial do Cabo – RJ. Fishing management.

SUMÁRIO

1. ESTRUTURA DO DOCUMENTO

A Dissertação está organizada em sete partes. A ordenação está definida em: 1. ESTRUTURA DO DOCUMENTO; 2. INTRODUÇÃO GERAL; 3. OBJETIVO GERAL; 4. CAPÍTULO I & Afins; 5. CAPÍTULO II & Afins; 6. CONCLUSÕES GERAIS e; 7. REFERÊNCIAS BIBLIOGRÁFICAS.

Na segunda parte, a Introdução Geral engloba um apanhado acerca dos parâmetros bio-ecológicos da espécie alvo e da área de estudo, citações corroborativas, justificativas, figuras de própria autoria e adaptadas, com o intuito de ilustrar e exemplificar o conteúdo teórico citado, além da devida contribuição do presente estudo para com a respectiva espécie e à área de estudo.

A seguir, na terceira parte, é apresentado o Objetivo Geral do trabalho.

A quarta parte exibe o Capítulo I, os seus Objetivos Específicos e as suas respectivas Hipóteses (H_0 & H_1), com o artigo: "A Review and the Length-Weight Relationship of Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), Pisces: Pomatomidae, at the Marine Extractive Reserve (*RESEX-Mar*) of Arraial do Cabo, Rio de Janeiro State, Brazil" (**publicado**). O estudo baseia-se em uma Revisão Bibliográfica, na Relação Comprimento-Peso (*LWR*), frequências e classes de comprimento e nas análises correlatas aos espécimes.

A quinta parte exibe o Capítulo II, os seus Objetivos Específicos e as suas respectivas Hipóteses (H_0 & H_1), com o artigo: "Age, Growth and Maturity of the Bluefish (*Pomatomus saltatrix* Linnaeus, 1766) along an Upwelling Area in the Southwestern Atlantic Ocean" (**submetido**). A pesquisa estima a idade, aponta a dieta, a fecundidade e os parâmetros bio-ecológicos de crescimento fisiológico, além de fornecer uma revisão bibliográfica afim e corroborativa sobre a espécie.

A sexta parte provê as Conclusões Gerais baseadas nos resultados, discussões e conclusões ao longo da pesquisa, em sua integralidade.

A sétima e última parte lista as Referências Bibliográficas.

2. INTRODUÇÃO GERAL

A Enchova, *Pomatomus saltatrix* (Linnaeus, 1766), pertence ao Reino *Animalia* -> Filo *Chordata* -> Classe *Actinopterygii* -> Ordem *Perciformes* -> Família *Pomatomidae* -> Gênero *Pomatomus* -> Espécie *Pomatomus saltatrix*. Única representante da família Pomatomidae, é um predador pelágico de grande mobilidade (HAMOVICI; KRUG, 1996). É uma importante espécie comercial, também capturada na pesca desportiva, com uma produção pesqueira global total de aproximadamente 20.000 t/ano (FAO, 2016). A espécie possui o corpo alongado, fusiforme e estreito ou comprimido lateralmente coberto por escamas ctenóides-ciclóides pequenas; linha lateral quase reta com 95 a 106 escamas ou escudos; cabeça de tamanho médio com rostro levemente pontudo; boca grande com uma fileira de dentes fortes, triangulares e pontudos na maxila e mandíbula, mandíbula levemente maior que a maxila, final da maxila localizado abaixo do final dos olhos; olhos de tamanho médio; interopérculo curto e estreito, preopérculo longo e largo, subopérculo curto e estreito, opérculo cobrindo as brânquias, estas com 13 a 15 rastros branquiais; nadadeiras peitorais curtas e estreitas, nadadeiras dorsais longas e estreitas (a segunda é mais longa e mais alta na parte anterior que a primeira) com 23 a 28 raios moles e 7 ou 8 raios duros (espinhos), nadadeira pélvica curta e estreita localizada abaixo das nadadeiras peitorais, nadadeira anal longa e estreita (a parte anterior é mais alta e mais larga que a posterior) com 23 a 27 raios moles e 2 raios duros (espinhos), nadadeira caudal longa, larga e furcada, e pedúnculo caudal curto e largo. Com relação à coloração, a espécie possui corpo prateado, dorso azul-esverdeado, laterais ou flancos e ventre prateados, nadadeiras dorsais, anal e caudal amareladas, e mancha escura curta e estreita na base ou na parte anterior das nadadeiras peitorais (DE FIGUEIREDO; MENEZES, 1980; CARVALHO-FILHO, 1994; SZPILMAN, 2000; DE FIGUEIREDO et al., 2002; BERNARDES et al., 2005; HOSTIM-SILVA et al., 2006; FISHBASE, 2013). Muitas vezes a espécie tem o seu nome popular ou vulgar, erroneamente empregado pelos pescadores, centros comerciais, moradores e consumidores locais, como anchova, um clássico caso de sinonímia (regionalismo). Na Figura 1, um dos exemplares de espécimes de

Enchova adquiridos ao longo do trabalho.

Figura 1: A Enchova (*Pomatomus saltatrix*) (Linnaeus, 1766).

Fonte: o autor.

O ancestral comum das populações estudadas remota ao ciclo interglacial Aftoniano II, e a separação cladística é estimada como tendo ocorrido durante os períodos glaciais, provavelmente devido às migrações para refúgios e ao fechamento do Mar Mediterrâneo. O fator mais provável de influência à variação genética das populações de Enchovas parece ser geográfico, como: a distância entre os continentes. Três unidades genéticas (populações) principais de Enchova podem ser identificadas: as americanas (águas do Atlântico Oeste); as espanholas (do leste do Atlântico e do oeste do Mediterrâneo) e; as turcas (do leste do Mediterrâneo, Marmara e do mar Negro) (MIRALLES; JUANES; GARCIA-VAZQUEZ, 2014). Taxas de migração (dispersão (emigração) e recrutamento (imigração)) mais baixas e barreiras genéticas mais fortes inferidas do DNA mitocondrial (herança materna) em comparação com *locos* de microssatélites (herança biparental), sugerem fluxo gênico mediado pelos machos entre as diferentes regiões e maior filopatria em fêmeas. A história de vida, os movimentos migratórios e o subsequente fluxo (*pool*) gênico poderiam explicar a falta de divergência nas populações de Enchovas, mantendo-se assim como uma única espécie pertencente à família Pomatomidae (MIRALLES; JUANES; GARCIA-VAZQUEZ, 2014).

A análise do DNA mitocondrial de espécimes de *Pomatomus saltatrix* sugeriu a existência de uma ação exógena no Oceano Atlântico que, devido à influência ambiental, gera muitos morfotipos (fenótipos), indicando que as populações no Oceano Atlântico Ocidental e Oriental parecem estar isoladas (GRAVES et al., 1992).

É uma espécie cosmopolita-panmixa que ocorre em todas as águas tropicais e neotropicais; exceto no leste e noroeste do Oceano Pacífico (CEPSUL, 2009). No Oceano Atlântico Leste (Oceano Atlântico Oriental), ocorre de Portugal à África do Sul, incluindo o Mar Mediterrâneo e o Mar Negro, a Ilha da Madeira e as Ilhas Canárias; no Oceano Atlântico Oeste (Oeste do Oceano Atlântico), ocorre na região da Nova Escócia, no Canadá e das Bermudas para a Argentina; no Oceano Índico, ocorre em toda a costa leste da África, Madagascar, sul de Omã, sudeste da Índia, Península Malaia e oeste da Austrália e; no Sudoeste do Oceano Pacífico ocorre na Austrália, exceto em seu território norte, e na Nova Zelândia (CEPSUL, 2009). No Brasil (sudoeste do Oceano Atlântico), ocorre em toda a faixa costeira (LUCENA; O'BRIEN, 2005), com ciclos de abundância, por vezes escassos durante anos e, por vezes, em quantidades incríveis que coincidem com os ciclos de abundância das populações de presas (CARVALHO-FILHO, 1994) e, ocorrem em diferentes profundidades (até os 200 m aproximadamente).

Na América do Sul, a Enchova migra anualmente e sazonalmente ao longo da costa e em sentido norte (HOSTIM-SILVA et al., 2006). A espécie migra ao longo da costa seguindo a fronteira ocidental da convergência neotropical entre as correntes oceânicas do Brasil e as Malvinas (*Falklands*) (HAIMOVICI; KRUG, 1996). As capturas sugerem uma migração sazonal a norte: março na Argentina, julho em Rio Grande (RS) e novembro no estado de Santa Catarina (CEPSUL, 2009). Os adultos migram para as áreas de desova, os ovos e as larvas são geralmente transportados ao longo da costa e os recrutas migram para as áreas adjacentes, costeiras e estuários, onde são predominantemente piscívoros e crescem rapidamente (JUANES et al., 1996). A Enchova realiza a deposição dos ovócitos e tem a Fecundidade Parcelada e a Fertilidade Contínua, gerando uma grande quantidade de pequenos ovos durante as suas migrações (DEUEL et al., 1966).

A espécie é facilmente encontrada próxima às praias, ilhas, costões rochosos, áreas batidas com a formação de espuma (alta oxigenação), baías e ao entorno de ilhas. Espécimes menores também podem ser encontrados em águas rasas de até 2 m de profundidade aproximadamente, como nos estuários, mangues e/ou lagunas (CEPSUL, 2009).

A Enchova permanece próxima à superfície durante o seu primeiro ano, com a sua migração podendo ser influenciada principalmente pela temperatura e pelo fotoperíodo. O comportamento de formação de cardumes, na Figura 2, tem início nesta etapa do desenvolvimento e a incorporação ao estoque adulto ocorre entre o primeiro e segundo anos de vida da coorte (KENDALL; WALFORD, 1979). Em grandes cardumes, dispostos principalmente por classes uniformes (homogêneas) de tamanho e não por sexos, os peixes maiores são os que migram mais rápido e afastados da costa (LUND; MALTEZOS, 1970).

Figura 2: Cardume de Enchovas.

Fonte: www.weheartdiving.com.

A Enchova pode ser a única dentre os teleósteos Perciformes, que muda radicalmente os seus perfis hidrodinâmicos. Os benefícios energéticos podem ser variáveis de acordo com a idade, porque os corpos das Enchovas adultas são relativamente mais cilíndricos e menos flexíveis do que os peixes em “Idade 0”, e talvez não consigam obter uma forma natatória tão eficiente. Consideravelmente menos energia é gasta durante os modos para forrageamento. Com a utilização de

TAG's acústicos as Enchovas podem ser detectadas em redes de receptores fixos ou móveis em observatórios oceanográficos. Informações de tais marcas podem localizar os cardumes de Enchovas em áreas acessíveis à pesca. Os modos de natação, velocidades e deslocamentos durante as migrações das Enchovas provavelmente apresentam variáveis (STEHLIK, 2009). As Enchovas são grandes nadadoras, o termo "*saltatrix*" significa "dançarina" em latim, referindo-se à sua grande agitação ao ser fisgada (quando capturada (pesca)).

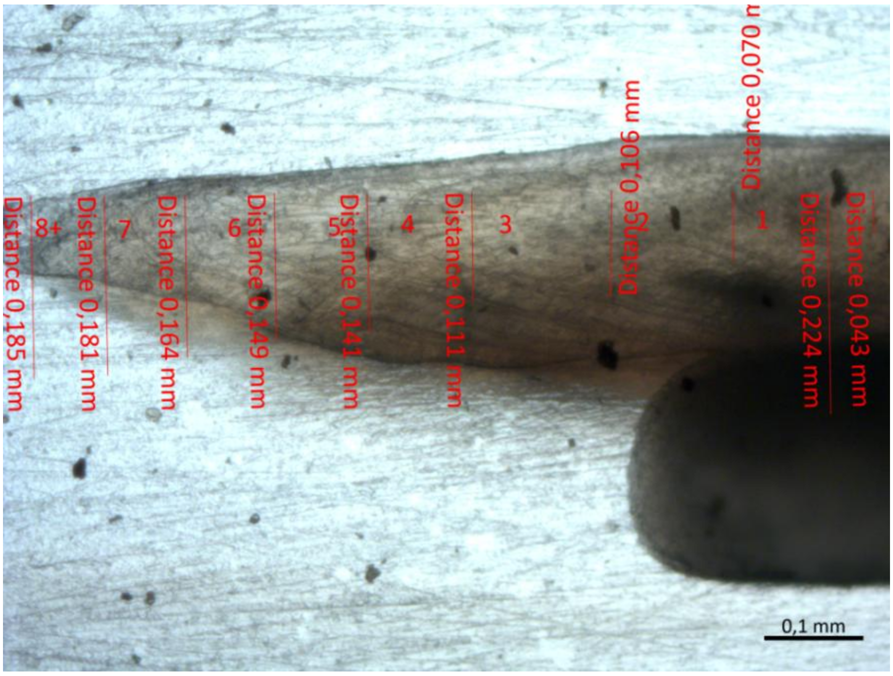
Atualmente os estudos sobre a biologia de peixes têm se concentrado na reprodução e no crescimento, justamente por serem esses os parâmetros mais importantes para se iniciarem as atividades de manejo pesqueiro.

Uma alternativa para se estimar os parâmetros de crescimento é a utilização de métodos indiretos (Relação Comprimento-Peso (*LWR*), entre outros), através de dados de distribuição de frequências temporais de comprimento, que são facilmente obtidos junto às populações biológicas. Esses dados poderão conter informações sobre o comprimento médio nas diferentes classes etárias associadas às coortes (FONTELES-FILHO, 2011).

De acordo com Fonteles-Filho (2011), em populações exploradas, torna-se basal a determinação da variação dos comprimentos e pesos individuais em função da idade, pois somente a partir da estrutura etária é possível avaliar as modificações dinâmicas que o estoque está passando quando submetido à exploração pesqueira. O autor também assegura que a determinação da idade em populações é importante, principalmente como um meio de se calcular os valores do comprimento individual em intervalos regulares de tempo, de modo a ser possível seguir as coortes do estoque capturável, permitindo assim, avaliar em qual *status* de exploração e/ou conservação o estoque pesqueiro se encontra.

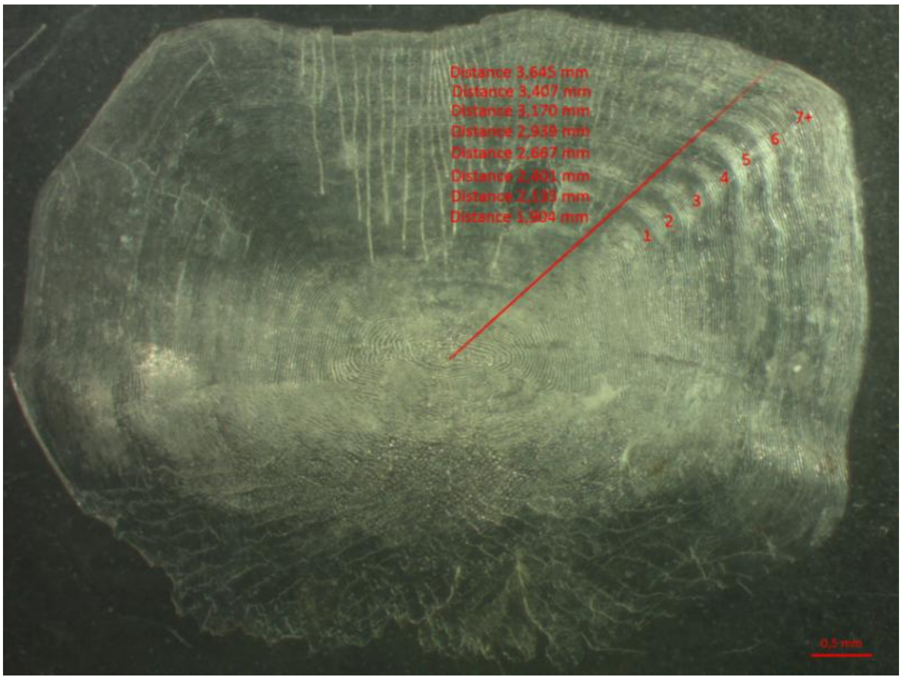
Os estudos de idade e crescimento para a Enchova têm sido realizados, principalmente, com base em vértebras, escamas, otólitos (métodos diretos a partir das análises de estruturas de aposição) e pela análise das distribuições de classes de comprimentos (métodos indiretos) (ROBILLARD et al., 2009). De acordo com Silverman (1975), o tamanho para o surgimento das escamas para *Pomatomus saltatrix* é em cerca de 14 mm de Comprimento Padrão (CP) e após alcançar os 36 mm (CP), a Enchova já tem o seu corpo totalmente recoberto. Para a determinação etária dos espécimes dissecados, as estruturas de aposição utilizadas foram: principalmente os otólitos (do tipo *sagittae*) e as escamas, nas Figuras 3 e 4, respectivamente.

Figura 3: Microscopia de secção, mensuração e contagem dos anéis etários de um otólito *sagittae* direito de Enchova proveniente da área de estudo. Obs.: a mancha escura no canto inferior direito, próxima à escala, é uma “bolha de ar” retida pela resina.



Fonte: o autor.

Figura 4: Microscopia, mensuração e contagem dos anéis etários de uma escama (montada de acordo com a metodologia proposta por Vazzoler (1981)) de Enchova proveniente da área de estudo.

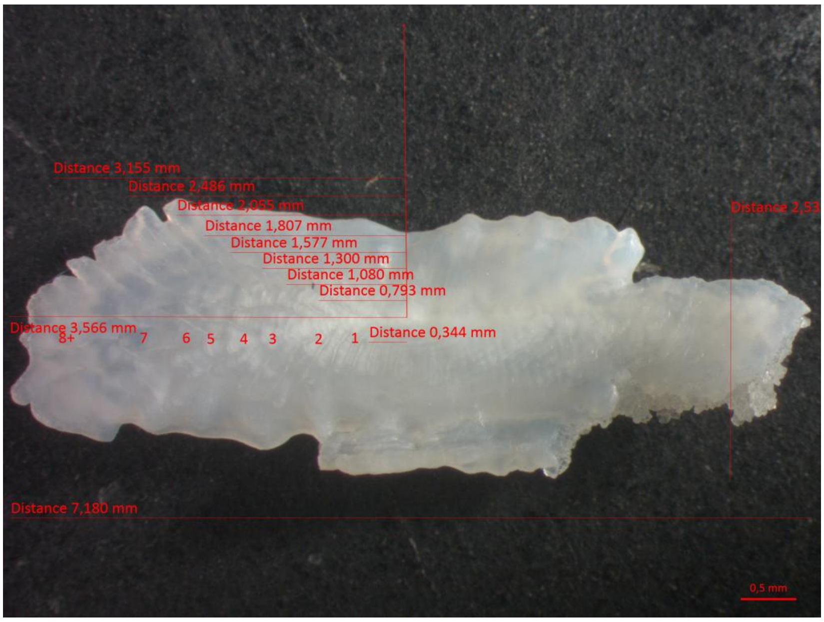


Fonte: o autor.

A temperatura da água varia em função do tipo de habitat e, em particular, a temperatura ideal para o crescimento da Enchova é de 24ºC (BUCKEL et al., 1995).

Os efeitos indiretos da dieta na química dos otólitos (otólito *sagittae*, na Figura 5) incluem taxas de crescimento, desenvolvimento das gônadas e estresse fisiológico. Estes fatores podem ocasionar diferenças na incorporação de elementos químicos aos otólitos. Logo, a dieta pode ser útil para se explicar as fontes desconhecidas de variação ontogênica. Os efeitos da dieta, no entanto, podem influenciar a capacidade de detectar menores diferenças em relação à influência sofrida pela salinidade. Entender os mecanismos por detrás da química resultante de um otólito pode ajudar a determinar com que frequência a formação das marcas de crescimento terão que ser novamente medidas e assim aumentar a utilidade dos otólitos para com a ecologia pesqueira. Uma mudança de dieta planctônica para uma dieta piscívora poderia ser detectável em otólitos de Enchova se a sua história ambiental passada (temperatura da água e química) fosse estável (BUCKEL et al., 2004). A Enchova é uma espécie predominantemente piscívora em todos os seus habitats. O trabalho De Carvalho et al. (2017), possui informações sobre a microquímica (relações entre Sr:Ca e Ba:Ca) de otólitos *sagittae*, como indicadora de habitat, ontogenia, processos de migração e dinâmica populacional.

Figura 5: Vista lateral externa, contagem dos anéis etários e mensuração de um otólito *sagittae* direito inteiro de Enchova proveniente da área de estudo.



Fonte: o autor.

De acordo com Olla et al. (1970), a Enchova tem como principal estímulo para o aumento da motivação de predação o maior comprimento da presa (predador visual). Os elementos básicos da orientação visual (fotoperíodo), influência etária, tamanho, formas de ataque e ingestão são provavelmente semelhantes para a maioria dos predadores primariamente visuais. A presença de presa de tamanho elevado aparentemente representa um estímulo visual mais intenso, restabelecendo um alto grau de motivação alimentar. De acordo com Olla e Studholme (1971) e Morley e Buckel (2014), a temperatura e o tamanho da presa exercem grande influência no comportamento de forrageamento (caça), migração da espécie e sob o seu estresse fisiológico. Em temperaturas mais altas, a Enchova, pelo aumento metabólico e estresse fisiológico, tende a estar mais ativa, investindo mais frequentemente e em maiores presas. Já em temperaturas mais baixas, a espécie modifica o comportamento de seletividade frente ao tamanho da presa, e investe sua energia em poucos mas velozes ataques às presas, em suma, menores.

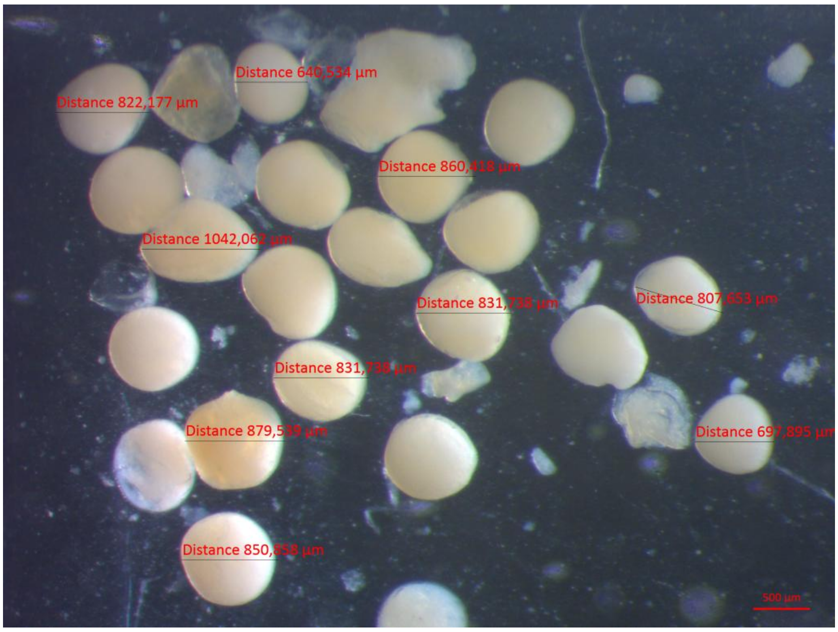
Para a espécie em questão, há principalmente a ocorrência de dois picos reprodutivos ao largo de sua distribuição global (MUELBERT; SINQUE 1996; SILVANO; BEGOSSI 2010, NUNES; HARTZ; SILVANO, 2011). As análises dos ovócitos de Enchovas e testes em laboratório, sugerem que o pico da atividade de desova ocorre no início da noite, perto do pôr do sol (NORCROSS et al., 1974). O desenvolvimento da Enchova de 3 a 17 mm de Comprimento Padrão (CP) é descrito como um processo dinâmico, que começa perto do último estágio larval, por já possuir a maioria dos caracteres dos adultos. Após o término da formação das nadadeiras, em cerca de 13 a 14 mm (CP), as Enchovas são consideradas juvenís. Larvas de pomatomídeos são comparadas às larvas de carangídeos e de scombrídeos (NORCROSS et al., 1974).

O conhecimento do desenvolvimento dos ovócitos (ovário maduro (“C2”), na Figura 6 e ovócitos hidratados, na Figura 7), da Fecundidade, da Razão Sexual (“*sex-ratio*”), do Comprimento Médio de Primeira Maturação Sexual (L_{50}), dentre outros dados, é fundamental para se entender a estratégia reprodutiva de qualquer espécie de peixe (MURUA; MOTOS, 2006). Os estudos sobre as estratégias reprodutivas de peixes permitem melhorar a compreensão dos métodos de produção dos ovos para a avaliação da biomassa do estoque de reprodutores (GANIAS, 2013), bem como para a compreensão da fenologia dos peixes em um cenário de constantes mudanças climáticas (PANKHURST; KING, 2010). Neste ambiente, os dados de estudos de reprodução são de extrema importância à ciência pesqueira, uma vez que, as análises e descrição da estratégia reprodutiva, determinam a adaptabilidade das populações diante da pressão local exercida pela pesca (MORGAN, 2008).

Figura 6: Ovário maduro de Enchova, proveniente da área de estudo, no estádio “C2” de maturação gonadal.

Fonte: o autor.

Figura 7: Microscopia para a contagem e determinação do diâmetro médio dos ovócitos hidratados coletados de uma gônada (ovário) madura (estádio “C2”) de Enchova proveniente da área de estudo.



Fonte: o autor.

As relações entre os fatores exógenos e a maturação gonadal de peixes são discutidas por Vazzoler, Lizama e Inada (1997), onde a luz e a temperatura são considerados como determinantes comuns ao ciclo reprodutivo, iniciando, ou controlando a taxa de desenvolvimento gonadal. Segundo Pörtner (2002), a temperatura influencia a ação de hormônios em diferentes níveis de controle reprodutivo, tal como o processo de ovulação e de desova. A temperatura não está somente relacionada ao ciclo reprodutivo, mas também possui influência direta e indireta na Razão Sexual ("*sex-ratio*") entre machos e fêmeas, ou no início da primeira maturação sexual (RIBEIRO; MOREIRA, 2012).

De acordo com Sparre e Venema (1998), o Fator de Condição Fisiológica de Fulton (K, crescimento) está relacionado com a taxa metabólica dos peixes, variando em função da temperatura e/ou da latitude. Com isso, peixes de águas tropicais (baixas latitudes) tendem a apresentar um K maior do que espécies de águas frias ou neotropicais (altas latitudes). Se uma espécie crescer muito rapidamente, atingirá o comprimento máximo cedo, e terá um valor de K menor do que se ela tivesse crescido lentamente e atingido tamanho maior (FONTELES-FILHO, 2011). O mesmo é válido para o Índice Gonadossomático (IGS; relação entre os pesos: gônadas/corpo).

Segundo Querol e Gomes (2002), o Índice Hepatossomático (IHS) de teleósteos relaciona-se à mobilização das reservas energéticas necessárias ao processo de vitelogênese, à maturação das gônadas e à atividade reprodutiva.

Segundo Vazzoler (1981), entende-se por Comprimento Médio de Primeira Maturação Sexual (L_{50}) o comprimento no qual 50% dos indivíduos analisados já iniciaram o processo reprodutivo (gônadas em estádios de maturação "B", "C" e "D"). O Comprimento Médio de Primeira Maturação Sexual (L_{50}) pode variar entre as distintas áreas de distribuição da espécie (CHAMPAGNAT, 1978a). Diferenças no Comprimento Médio de Primeira Maturação Sexual (L_{50}) geralmente são atribuídas à disponibilidade de alimento e à temperatura (HEMPEL, 1965); aos fatores genéticos (WOOTON, 1998); à predação ou pressão pesqueira (JENNINGS; KAISER; REYNOLDS, 2001) ou; ainda ao uso de diferentes métodos de amostragem e/ou análises (FROESE; BINOHLAN, 2000).

O Índice de Performance de Crescimento (ϕ') calculado para a Enchova, representa uma excelente ferramenta para a precisão das estimativas dos parâmetros de crescimento, considerando a relação natural entre o Comprimento Assintótico (L_∞) e o Fator de Condição Fisiológica de Fulton (K, crescimento), o que permite comparar equações de crescimento, entre as diferentes regiões, possibilitando aferir a confiabilidade dos ajustes no tempo e no espaço (FONTELES-FILHO, 2011). Espécies que apresentam rápido crescimento e extenso período reprodutivo são aparentemente menos vulneráveis aos efeitos da pesca. Essas populações sofrem maior influência de mudanças climáticas, e sua abundância oscila de um ano a outro, devido aos fatores que determinam o sucesso do seu recrutamento (PINSKY et al., 2011).

Os predadores naturais das Enchovas são os grandes peixes, tais como os tubarões (*Chondrichthyes*) e outros grandes teleósteos (*Osteichthyes*), principalmente os atuns, que atingem alta velocidade natatória para a caça (WILK, 1977).

Em relação à dentição, a espécie compartilha aspectos únicos da substituição de dentes com as barracudas (*Sphyraena barracuda* Walbaum,1792), um sphyraenídeo e/ou também com os scombrídeos. O que reforça a conclusão de que a Enchova está mais relacionada principalmente aos sphyraenídeos e scombrídeos do que aos carangídeos. As barracudas assim como as Enchovas exibem uma única fileira de dentes angulares, substituição intraóssea de dentes e poros de substituição. A presença dos poros de substituição é de particular interesse no estabelecimento da homologia do padrão de substituição dentária, fornecendo uma fonte potencialmente rica de informações de caracteres anatômicos para se examinar as inter-relações filogenéticas (BEMIS; GIULIANO; MECGUIRE, 2005). A Figura 8 ilustra essa dentição característica à Enchova.

Figura 8: Dentição característica da espécie estudada: a Enchova.

Fonte: o autor.

Atualmente, a pesca continua a ser uma das principais fontes de impacto nos ambientes marinhos e costeiros, contribuindo para uma grande perda global de biodiversidade (BENDER et al., 2014). No sudoeste do Oceano Atlântico, os padrões de exploração de recursos marinhos são semelhantes aos relatados em todo o mundo (HALPERN et al., 2008), com declínios populacionais generalizados e estoques colapsados (REZENDE; FERREIRA, 2004). A baixa atenção que principalmente a pesca artesanal recebe na maior parte do mundo (PAULY, 2006) manifesta-se em estatísticas potencialmente enganosas, o que pode excluir ou subestimar e mascarar substancialmente os dados relativos à pesca (PAULY; ZELLER, 2016), visto que essa arte pesqueira, em larga escala, representa altos índices da produção global total.

As principais capturas de Enchovas na costa leste dos Estados Unidos (WILK, 1977) e sudeste da África (VAN DER ELST, 1976) são efetuados a partir da pesca desportiva, e em outras regiões, tais como no Mar Negro (TURGAN, 1959), noroeste da África (CHAMPAGNAT, 1978b) e sul do Brasil (HAIMOVICI; KRUG, 1982), a pesca comercial é a mais importante. Estima-se que 23% de todos os estoques de pesca marinha no Brasil estão sendo totalmente explorados e 33%

estão sendo sobreexplorados, incluindo o da Enchova e os de espécies de níveis tróficos inferiores (FREIRE; PAULY, 2010). A história da produção no Brasil mostra diferentes níveis ao longo do tempo, com tendência à diminuição das capturas e a um futuro colapso. Durante a década de 70, a produção foi de cerca de 16 mil toneladas, enquanto na década de 80 desceu para 8 mil toneladas, claro índice de sobreexploração. Nas duas últimas décadas, há um indício de que se tem mantido estável em torno das 4 mil toneladas. No início dos anos 70, a pesca era 400% maior. O estado do Rio de Janeiro é conhecido por manter uma produção relativamente constante desde a década de 90, produzindo anualmente cerca de 1 mil toneladas (CEPSUL, 2009). Em Arraial do Cabo - RJ, a Captura por Unidade de Esforço (CPUE) variou de 14,2 t/hora em 1996 para 0,3 t/hora em 2004, com uma média anual de 4 t/hora (BENDER et al., 2014); englobando os diferentes esforços pesqueiros empregados para a captura da Enchova. Atualmente, apresenta uma produção pesqueira média de 200 t/ano (Fundação Instituto de Pesca de Arraial do Cabo - FIPAC, dados não oficiais). Uma flutuação em relação à produção pesqueira pode ser sazonal e devida, por um lado, à abundância variável de Enchovas em relação às condições climáticas, a presença ou não de presas e, por outro lado, a captura incidental por outros esforços de pesca não direcionados: Fenômeno de Lee (LEE, 1920). Esta abundância esporádica pode ser devida a diversos fatores, incluindo os movimentos costeiros de migração das praias até águas mais profundas além do alcance pesqueiro limitado à sua captura (BUCKEL; CONOVER, 1997).

A Enchova é um dos principais recursos pesqueiros dentre os desembarques na Marina dos Pescadores de Arraial do Cabo (RESEX-Mar). Todavia, mesmo frente à sua importância para com a atividade local, ainda são poucas as informações disponíveis na literatura sobre a pesca e as possibilidades de manejo das capturas nessa região. Sob o ponto de vista de recurso vivo-pesqueiro, a Enchova é considerada como uma espécie Vulnerável (FAO, 2011). Nesse caso, o monitoramento das pescarias da Enchova na RESEX-Mar de Arraial do Cabo deverá ter uma função mais preventiva (manejo pesqueiro), evitando assim um futuro colapso desse importante recurso pesqueiro (DE MORAES et al., 2008).

Estudos sobre o manejo pesqueiro da Enchova, também são desenvolvidos ao longo da costa leste americana (WILSON; NIELSEN; DEGNBOL, 2001), entre outros. De acordo com a comparação entre os estudos e o levantamento de dados realizado por Acarli et al. (2013), o tamanho mínimo ideal da malha para a rede de emalhar (espera) para a Enchova deve ser maior do que os 25 mm; a fim de se evitar a captura de juvenís (recrutas). A Instrução Normativa Brasileira MMA N.53 / 2005 estabelece atualmente, dentre outras espécies de peixes, um tamanho mínimo de captura igual a 350 mm para a Enchova (BRASIL, 2005). Essa norma apresenta baixa aceitação regional e se estende pelo litoral dos estados do Espírito Santo; São Paulo; Paraná; Santa Catarina; Rio Grande do Sul e no Rio de Janeiro (onde o tamanho mínimo de captura, os petrechos de pesca corretamente empregados (anzóis e afins) e o (s) período (s) de defeso ainda não é (são) atribuído (s)) (CEPSUL, 2009). Em relação aos petrechos de pesca, os anzóis longos, com farpa e/ou farpela, do tipo maruseigo, produzem uma taxa de mortalidade significativamente maior do que os outros tipos, pois o anzol pode ser engolido e penetrar órgãos vitais, tais como: o esôfago; as brânquias (guelra) e o estômago. Os anzóis simples (maruseigo) são os mais propensos a causar lesões branquiais (guelra). As garatéias (anzol triplo) com ou sem farpa e/ou farpela são os mais propensos a causar ferimentos na mandíbula e as múltiplas lesões. A lesão branquial (guelra) é a responsável pela maior taxa de mortalidade por pesca dos espécimes capturados. As maiores taxas de mortalidade pela pesca podem ser explicadas, em parte, pelo estresse fisiológico associado a um aumento no tempo de manuseio dos espécimes para a remoção dos anzóis, para a sua soltura e aos efeitos das múltiplas lesões por eles sofridas (AYVAZIAN; WISE; YOUNG, 2002). Partindo do consenso de que a Enchova é uma espécie generalista-oportunista extremamente voraz, a Figura 9 ilustra o que pode ocorrer durante a sua captura, levando-a a morte imediata e/ou em caso de fuga, logo após um curto período de tempo.

Figura 9: Espécime de Enchova, capturado na área de estudo, apresentando a parede estomacal perfurada por um anzol simples do tipo maruseigo com farpa e/ou farpela (indicado pela pinça).

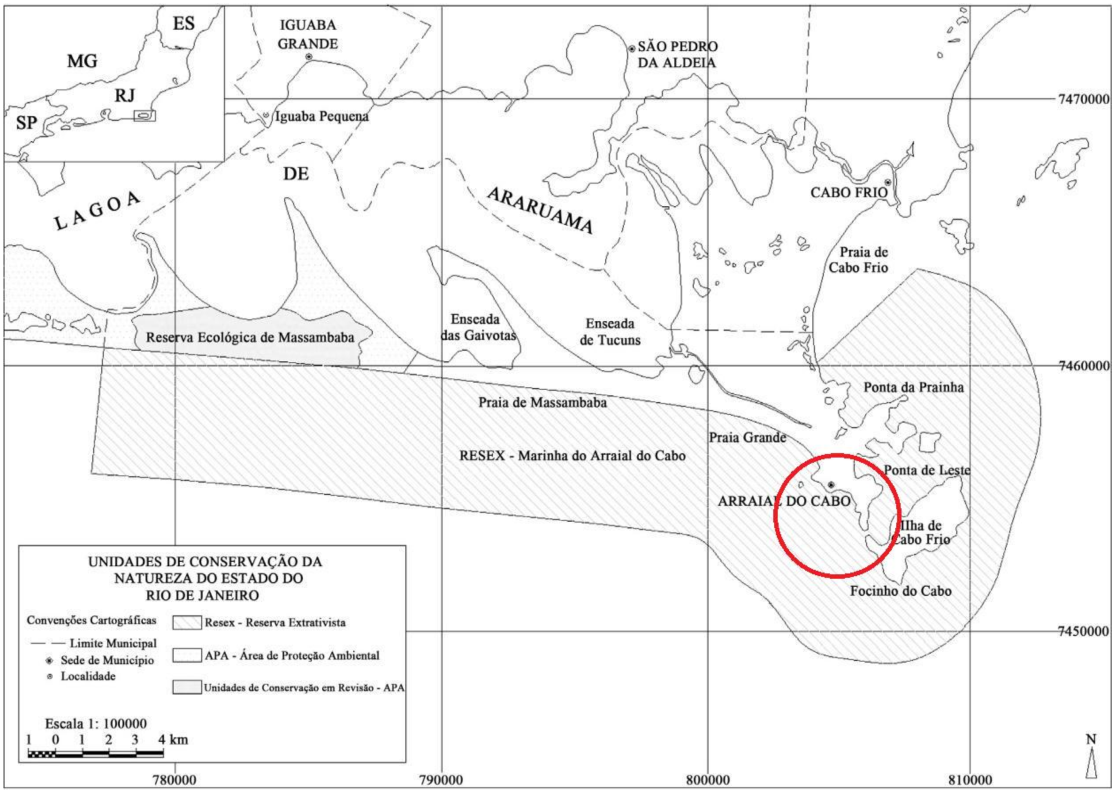
Fonte: o autor.

De acordo com Britto (1999), a pescaria em Arraial do Cabo apresenta dois principais núcleos: o primeiro compreende pescadores que limitam suas atividades às praias e áreas que circundam a costa (*inshore*), inserindo-se, neste caso, a pescaria de cerco por canoas; o segundo está relacionado a pescadores que capturam seu pescado em águas *offshore* ("mar aberto"), no qual se incluem as pescarias de bote e a de traineira. Essas modalidades de pesca são classificadas como artesanais, já que as embarcações apresentam Tonelagem Bruta de Arqueação (TBA) menor do que 20 t. Além disso, essas embarcações não possuem sistema de conservação do pescado, apresentam menor poder de pesca e reduzida autonomia de mar (BRANCO; REBELO, 1994). A atividade pesqueira na RESEX-Mar de Arraial do Cabo é contínua, anual, realizada em diferentes pesqueiros e tem apenas como fator limitante as condições meteorológicas. Atualmente, o município de Arraial do Cabo, pode ser considerado como um dos núcleos pesqueiros mais tradicionais do estado do Rio de Janeiro (BR), devido aos seus altos índices de produção (SILVA, 2004), e é uma das cidades com a maior produção pesqueira no país (BRASIL, 2005).

A ideia de se criar a Reserva Extrativista Marinha (RESEX-Mar) de Arraial do Cabo - RJ (Lat.23ºS - Long.42ºW), costa leste do estado do Rio de Janeiro, uma Unidade de Conservação para o uso sustentável, surgiu como uma alternativa proibitiva às frotas pesqueiras industriais que vêm das grandes cidades invadindo os mares locais desde os anos 80 (SEIXAS, 2008). Foi a primeira Reserva Extrativista Marinha do Brasil, criada por um decreto presidencial em 3 de janeiro de 1997 (KRUEL; PEIXOTO, 2004). O estabelecimento de um Sistema Nacional de Unidades de Conservação (SNUC) pela Lei nº 9.985 / 2000 provocou algumas mudanças na definição de reserva extrativista no Decreto 98.897 / 90, que a descreveu como um território destinado à exploração auto-sustentável de recursos naturais por populações extrativistas. É gerida pelo Órgão Federal Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), criado pela Lei Federal 11.516 de 28 de agosto de 2007. Nesses termos, a RESEX-Mar torna-se um instrumento de gestão associada dos recursos naturais e ecossistemas marinhos, pois distribui o poder de decisão entre o Estado e as comunidades que usufruem destes recursos (DE MORAES et al., 2008).

A região da RESEX-Mar de Arraial do Cabo (Lat.23ºS - Long.42ºW), Figura 10, localiza-se na costa leste do estado do Rio de Janeiro, sudeste do Brasil. A região tem uma característica importante: uma projeção única da costa em relação ao Oceano Atlântico Sudoeste, o que a torna um dos pontos costeiros que mais avança em direção ao mar. O seu aspecto geográfico e oceanográfico é determinante para o sistema da ressurgência (≤18ºC (limiar térmico assumido)), que promove o afloramento das águas frias ricas em nutrientes, provenientes da Água Central do Atlântico Sul (ACAS), tendo os seus picos durante a primavera e o verão (VALENTIN, 1994). Este fato torna a região altamente produtiva (produção primária), logo, rica em espécies de níveis tróficos inferiores e que possivelmente servirão como presa às espécies de níveis tróficos superiores, como é o caso da Enchova. A ocorrência da ressurgência na região possibilita condições extremamente favoráveis às atividades pesqueiras.

Figura 10: Mapa da Reserva Extrativista Marinha (RESEX-Mar) de Arraial do Cabo - RJ.



Fonte: Mapa da Reserva Extrativista Marinha (RESEX-Mar) de Arraial do Cabo - RJ. A área circulada, em vermelho, corresponde à área de maior produção pesqueira da Enchova. Fonte: Adaptado do Atlas de Unidades de Conservação da Natureza, Governo do estado do Rio de Janeiro / SEMA, 2001.

O presente estudo se faz importante, por contribuir com os poucos estudos afins, já existentes, e por alertar para a real necessidade de um manejo pesqueiro efetivo para a conservação do estoque local da Enchova.

3. OBJETIVO GERAL

Identificar, compilar e divulgar os parâmetros bio-ecológicos da Enchova, *Pomatomus saltatrix* (Linnaeus, 1766), Pisces: Pomatomidae, proveniente da área da Reserva Extrativista Marinha (RESEX-Mar) de Arraial do Cabo – RJ, Brasil; de forma a contribuir para com o futuro manejo pesqueiro e a conservação do estoque local e até mesmo do sudeste do Brasil.

4. CAPÍTULO I: 1º ARTIGO (PUBLICADO)

Título: “A Review and the Length-Weight Relationship of Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), Pisces: Pomatomidae, at the Marine Extractive Reserve (*RESEX-Mar*) of Arraial do Cabo, Rio de Janeiro State, Brazil**”**

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OBJETIVOS ESPECÍFICOS:

- Estimar as curvas de crescimento, a partir da distribuição de frequências de classes de tamanho e da Relação Comprimento-Peso (*LWR*);
- Descrever a variação da Razão Sexual (“*sex-ratio*”) e de comprimentos e;
- Comparar os dados obtidos às informações pretéritas (Revisão Bibliográfica).

HIPÓTESES NULAS (H_o):

- Não há variação na Relação Comprimento-Peso (*LWR*) e/ou na distribuição de frequências de classes de tamanho ao longo dos meses (estações; sazonalidade) do ano amostrado e entre os sexos e;
- O crescimento da espécie é totalmente Isométrico.

HIPÓTESES ALTERNATIVAS (H_1):

- Há variação na Relação Comprimento-Peso (*LWR*) e/ou na distribuição de frequências de classes de tamanho ao longo dos meses (estações; sazonalidade) do ano amostrado e entre os sexos (fêmeas > machos) e;

- O crescimento da espécie é Alométrico Negativo (“b” < 3) para as fêmeas, espécimes de sexo indeterminado e para os sexos agrupados. Para os machos foi considerado como Isométrico (“b” = 3 ou próximo).

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A Review and the Length-Weight Relationship of Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), Pisces: Pomatomidae, at the Marine Extractive Reserve (*RESEX-Mar*) of Arraial do Cabo, Rio de Janeiro State, Brazil

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Abstract

The bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), the only representative of the Pomatomidae family, is a key fishing resource that represents a substantial part of the landings at *RESEX-Mar* of Arraial do Cabo-RJ. The species is broadly distributed throughout the continental shelf in tropical and warm temperate waters of the Atlantic, Pacific and Indian Oceans. It forms pelagic, large and fast moving shoals in relatively deep offshore waters, and draws close to the coast when temperatures reach from 12˚C to 15˚C. Its displacement is conditioned to the movement of shoals of small fish such as herings; shrimp and squid, all of which are preyed upon. This work had the main purpose of evaluating the growth of bluefish through the distribution of length frequency (One-Way-ANOVA) and the Relationship between Total Length—TL (mm) and Total Weight—TW (g)-LWR; from daily data collections from March/2017 to March/2018. The analyzed specimens were obtained at fish markets of Arraial do Cabo-RJ and fish landings at the Fishermen's Harbor of Praia dos Anjos. They were randomly sampled from fragmented cohorts of the local stock. A total of N = 2057 specimens were primary analyzed. TL values varied from 201 mm (minimum) in February/2018 to 915 mm (maximum) in September 2017. The average TL was of 541 mm and the average TW of 1428.5 g. The value of angular coefficient "b" in the potential flow was 2.6, and the value of "a" was 9E−05, expressed by the equation $W = aL^b$ for overall, where W = TW and L = TL. Values of $W = 3E-05L^{2.7}$ were found for females and $W = 2E-05L^{2.8}$ for males. Knowledge over their general biology is extremely important when it comes to knowing the ecology of this species for subsidize a future and adequate fishery management.

Subject Areas

Aquaculture, Fisheries & Fish Science, Zoology

Keywords

Bluefish, Fishing Resource, LWR, Subsidize Fishery, Future Management

1. Introduction

The bluefish (*Pomatomus saltatrix*, Linnaeus, 1766) belongs to the order Perciformes and to the Pomatomidae Family [1]-[7]. The species reaches average length of approximately 600 mm, maximum length of approximately 1300 mm, average weight of approximately 3000.0 g and maximum weight of approximately 14,400.0 g [1] [3] [4] [5] [6] [7]. The bluefish presents different growth ratios between sexes, with females tending to be larger. The length at first maturity varies from 250 mm to 430 mm [8]. The maximum age registered is of 14 years [9].

It is a cosmopolitan species that occurs in all tropical and neotropical waters [1] [3] [4] [5] [7] [10], except at the east and northwest of the Pacific Ocean in **Figure 1** [6] [7] [10]. In the East Atlantic Ocean (Oriental Atlantic Ocean), it occurs from Portugal to South Africa, including the Mediterranean Sea and the Black Sea, Madeira Island and Canary Islands; in the West Atlantic Ocean (Western Atlantic Ocean), it occurs in the region of Nova Scotia, in Canada and from Bermuda to Argentina; in the Indian Ocean it occurs throughout the east coast of Africa, Madagascar, south of Oman, southeast India, Malay Peninsula and west Australia; and in the Southwest Pacific Ocean it occurs in Australia, except for its northern territory, and in New Zealand in **Figure 1** [5] [7] [10]. In Brazil (Southwest Atlantic Ocean), it occurs throughout the entire coastline in **Figure 1** [11] [12]; with abundance cycles, sometimes scarce for years and sometimes in incredible quantities that coincide with the abundance cycles of the populations of prey [2]. The space and time analysis of the bluefish distribution in icthyoplankton and of spawning times suggest mainly two stocks in the North Atlantic (Florida Stocks), as well as another in the South Atlantic [13] [14] [15].

In South America, bluefish migrate annually along the coast, northward and seasonally [6]. The species migrates along the coast following the western boundary of the neotropical convergence between the ocean currents of Brazil and Malvinas (Falklands) [16]. Captures suggest seasonal migration upwards: March in Argentina, July in Rio Grande-RS (BR) and November in the state of Santa Catarina (BR) [10]. The bluefish is a migratory pelagic coastal and oceanic

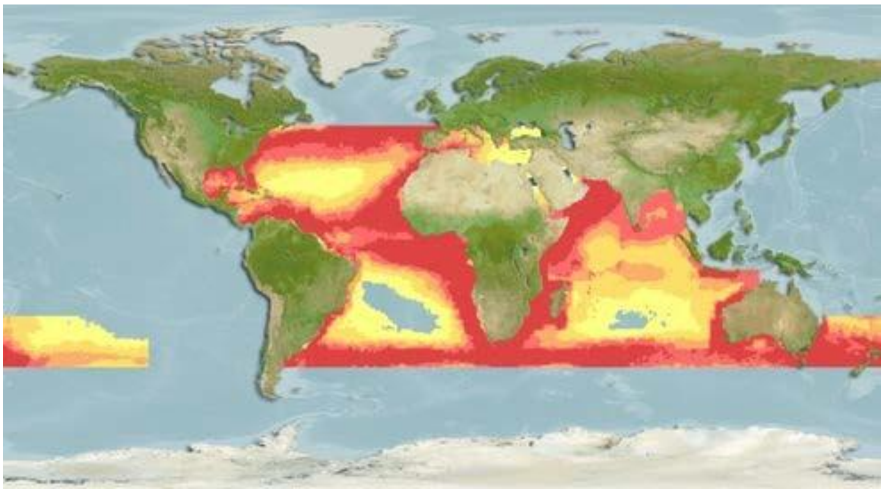


Figure 1. Geographic distribution of Bluefish (*Pomatomus saltatrix*, Linnaeus 1766). Source: www.aquamaps.org.

species that moves close to the water surface along the continental shelf. Adults migrate to spawning areas, eggs and larvae are usually transported along the coast and the recruits migrate to coastal areas and estuaries where they are mainly piscivorous and grow fast [17]. Bluefish perform apportion egg deposition and have ongoing fertility, generating a great quantity of small eggs during spring migration [18] [19].

It is easily found near shores, especially in surf areas, islands, rocky coasts, agitated areas with foam formation, bays, areas estranged from the coast and around islands. Smaller specimens can also be found in shallow waters of up to 2 m deeper, estuaries, the young specimens can be found in mangrove forests and lagoons [1]-[7] [10]. Large adult specimens are usually seen by themselves, often associated to billfish and elasmobranchs, while young, with a Total Length (TL) lower than 250 mm, and medium-sized specimens, form small shoals. These shoals can reach up to thousands of individuals [7], and usually draw close to the coast when temperatures reach from 12˚C to 15˚C [20].

Bluefish are great swimmers, powerful and voracious predators, the term "*saltatrix*" means "dancer" in Latin, referring to its great agitation when hooked; who feed off different small and large fish, shellfish such as cephalopods and especially squids, as well as crustaceans, at larvae stage, bluefish feed mainly off copepods [21] [22]. A study conducted in the south of Brazil examined the stomach contents of 516 bluefish specimens [22]. The authors found that, during summer, *Pomatomus saltatrix* basically fed off four species (*Loligo sanpaulensis*/Brazilian squid or São Paulo squid, *Artemesia longinaris*/Argentine shrimp, *Mullus argentinae*/Argentine goat fish and *Paralonchurus brasiliensis*/Banded croaker) while, during fall and winter, *Pomatomus saltatrix* mainly fed off *Engraulis anchoita* (Argentine anchovy). The authors concluded that the seasonal variation in the diet of the bluefish is related to the availability of prey in the studied area, which confirms the species' opportunist behavior. The search for a dietary pattern over time showed a clearly opportunist characteristic, with no preference over prey, and of daytime or crepuscular habit. The presence of organisms along all levels of the water column indicates a demersal-pelagic behavior [23]. There are records of bluefish shoals that kept on attacking and killing even after having satisfied their appetite [5] [6] [7]. Bluefish are capable of eating twice their weight per day. When they attack small fish, bluefish tear them to pieces. There are records of bluefish that regurgitated their food to attack again and also records of a preference for larger prey. Studies show that larger prey excite bluefish in such way that they attack even after being satiate. The bluefish have a compulsion for killing, which makes them a controller of many species' populations, especially of small teleosts from lower trophic levels. When these populations become scarce, bluefish shoals tend to migrate [2].

The reproduction of this species apparently happens in offshore waters, with eggs and pelagic larvae developing while they approach near shore [2], throughout the year, in warmer waters and seems to be seasonal at high latitudes [10]. Despite its larvae capacity for long distance dispersion, the gene flow between the subpopulations is extremely limited [24]. The bluefish has a PLD (Pelagic Larval Duration) oceanic, large and relatively long, which, by the action of the wind and currents, facilitate its global dispersion.

Analysis of the mitochondrial DNA of specimens of *Pomatomus saltatrix* suggested the existence of an exogenous action in the Atlantic Ocean that, due to environmental influence, generates many morphotypes [25]. A recent study indicated that the populations in both Western and Eastern Atlantic Ocean seem to be isolated [25].

In the South Atlantic of the USA, spawning happens from March to May, September to November and May to August [27]. Spring and summer spawning, generate neonates that migrate from the estuaries to the continental platform of the USA during the beginning of fall, while adults are found at the continental platform during summer and fall [28]. Spawning in the Gulf of Mexico may occur in April and from April to November [29]; larvae are rare in the west of the Gulf. In the Brazilian coast, spring spawning probably happens in the south, near the Rio Grande-RS (BR) coast, at Parcel dos Carpinteiros. According to the methods of analysis used and quoted by [10], the Gonadosomatic Index (GSI) of captured males at Rio Grande-RS (BR) shows a higher value in November, while the Gonadosomatic Index (GSI) of females is high from October to March, with peaks in November and March, indicating apportioned egg deposition. Spawning, seasonal migration and life cycle are strongly linked to temperature. Spawning occurs in superficial waters with temperatures varying from 20˚C to 26.8˚C [17].

The bluefish, in **Figure 2**; is an important fishing resource all over the world, representing a large share of all fish landings of Arraial do Cabo-RJ. Its fishing activity is intense, using purse seines, dragging nets, hand lines, gill nets and many others [30].

Currently, fishing continues to be the main source of impact on marine and coastal environments, contributing to the global loss of biodiversity [31] [32]

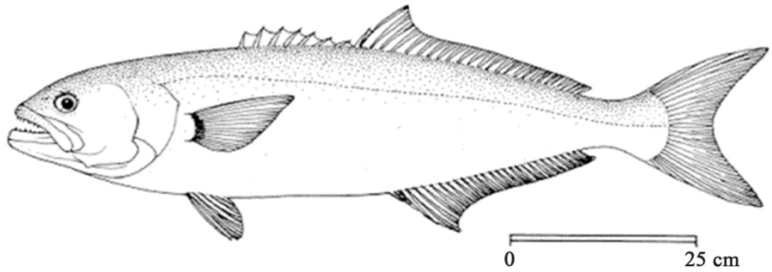


Figure 2. Left-flank view of the Bluefish (*Pomatomus saltatrix*, Linnaeus, 1766). Source: www.fishbase.org.

[33] [34]. In the Southwest Atlantic Ocean, the patterns of marine resource exploitation are similar to those reported all over the world [33] [34] [35] [36], with generalized population decreases and collapsed stocks [34] [37] [38] [39]. The history of production in Brazil shows different levels over time, with the tendency to downfall. During the 70's, production was around 16 thousand tons, while in the 80's it went down to 8 thousand tons. For the last two decades, it has been stable around 4 thousand tons, a clear index of over exploitation. In the beginning of the 70's, fishing was 400% higher. The state of Rio de Janeiro is known for keeping a constant production since the 90's, annually producing around 1 thousand ton [10]. It is estimated that 23% of all marine fishery stocks in Brazil are being totally exploited and 33% are being over exploited, including species of lower trophic levels [40] [41] [42].

The bluefish is framed into the category of over exploited living resources, those that, from such a high level of capture of specimens of all ages, show a reduction lower than safe levels in biomass, potential to spawn and future captures [43]. A management plan must be developed, aiming to recovery the stock and the sustainability of the species' fishing [43]. Brazilian Normative Instruction MMA N.53/2005 currently establishes, among other species of fish, a minimum of 350 mm size for captured *Pomatomus saltatrix*, specimens with possible first spawning already performed and possible matures, as long as there is no use of gill nets or part in amateur fishing competitions. This norm has a poor regional validity and extends through the coast of the states of Espírito Santo (BR); Rio de Janeiro (BR) with fishing tackle or prohibition not yet attributed; São Paulo (BR); Paraná (BR); Santa Catarina (BR) and Rio Grande do Sul (BR) [10].

Size variation has important implications on many aspects of fisheries science and population dynamics [44]. Studies on Length-Weight Relationship (LWR) are very limited [45]-[50]. The study of LWRs is considered important to obtain different types of information such as growth rates, age structures, age at first maturity, stock discrimination and studies on population dynamics [50]-[58] to subsidize futures and betters fisheries managements around the world. Other than that, LWRs can also be used to find the relative condition factor, establishing performance equations to estimate the number of fish landings and compare the population in space and time [59]. LWRs are usually calculated through linear regression of data transformed into logarithms. According to the literature, the Ordinary Least Square Method (OLS), or "predictive" regression [60], is the most commonly applied method to estimate LWR's parameters. Parameter "b" of the LWR equation ($W = aL^b$), where W = Total Weight (TW) and L = Total Length (TL), also known as the isometry coefficient, has an important biological meaning, indicating the rate of weight increase related to length increase. Variability in the value of "b" is usually detected among different populations of the same species or within the same population at different times. This may be a reflection of changes in conditions related to feeding, reproduction or migratory activities of individuals [61] [62]. The maximum length and weight are important parameters used to study life histories and fisheries science. Therefore, it is important to regularly update the maximum size of commercially relevant species [63].

The idea of creating the Arraial do Cabo Marine Extractive Reserve (RESEX-Mar), a Conservation Unit (UC*s* or CU*s*) for sustainable use, emerged as a comeback to the industrial fishing fleets that come from big cities and have been invading the seas of Arraial do Cabo since the 80's [64] [65], conducting fishing activities in areas used by local artisanal fishermen. It was the first Marine Extractive Reserve in Brazil, created by a Presidential Decree in January 3, 1997 [66]. The establishment of a National System of Conservation Units (SNUC) by Law N. 9.985/2000 caused some changes in the definition of extractive reserve in Decree 98.897/90, which described it as a territory purposed for autosustainable exploitation of natural resources by extractive populations, managed by Chico Mendes Institute of Biodiversity Conservation (ICMBio), created by Federal Law 11,516 of August 28, 2007. In these terms, the RESEX-Mar becomes a co-managed instrument of natural resources and marine ecosystems, for it distributes the power of decision among the State and the communities of people who use these resources [67].

Currently, the city of Arraial do Cabo, may be considered as one of the most traditional fisheries nuclei in the Rio de Janeiro State, due to its production indexes [68]. According to national statistics, these indexes place Arraial do Cabo-RJ among the cities with the greatest fishery productions in the country [69]. This kind of pressure may lead to the depletion and abandonment of the management model agreed upon in local cultures [67].

The main purpose of this work is evaluating the growth of bluefish through the distribution of length frequency (One-way-ANOVA) to provide information on the Length-Weight Relationships (LWRs) of bluefish (*Pomatomus saltatrix*, Linnaeus, 1766) a key captured fishing resource that represents a substantial part of the landings at RESEX-Mar, coast of Arraial do Cabo-RJ. And through daily collection, of data from commercial captures bought, for a year, reveal possible changes undergone by the species during its growth throughout the months (season annual distribution). Considering that the region is an important

RESEX-Mar, a Conservation Unit for sustainable use, it also has the purpose of summarize information on fishing activities and captures of the species to the community. These data will be presented to the local agencies in order to subsidize a future and better fisheries management of the studied area. And, if possible, the model of the present study can be applied to other conservation units around the world; since, currently, there are few related studies.

2. Materials and Methods

2.1 Studied Area

Located on the east coast of Rio de Janeiro State, the region of Arraial do Cabo (Lat. 23˚S - Long. 42˚W), in **Figure 3**; presents favorable conditions for fishing activities.

The region has an important characteristic: a unique ocean projection in comparison to the coast, which makes it one of the locations in the Brazilian coast that most advances towards the sea. The geographical aspect is determinant to an upwelling's situation system, that brings up cold waters rich in nutrients from the South Atlantic Central Water (SACW/ACAS), with peaks during spring and summer [70] [71].

The Arraial do Cabo-RJ RESEX-Mar has a marine range of three miles off the coast toward the ocean and 56,769 hectares of water line, according to approximate geographic coordinates: Western Limit: Southern Boundary—22˚56'21" -

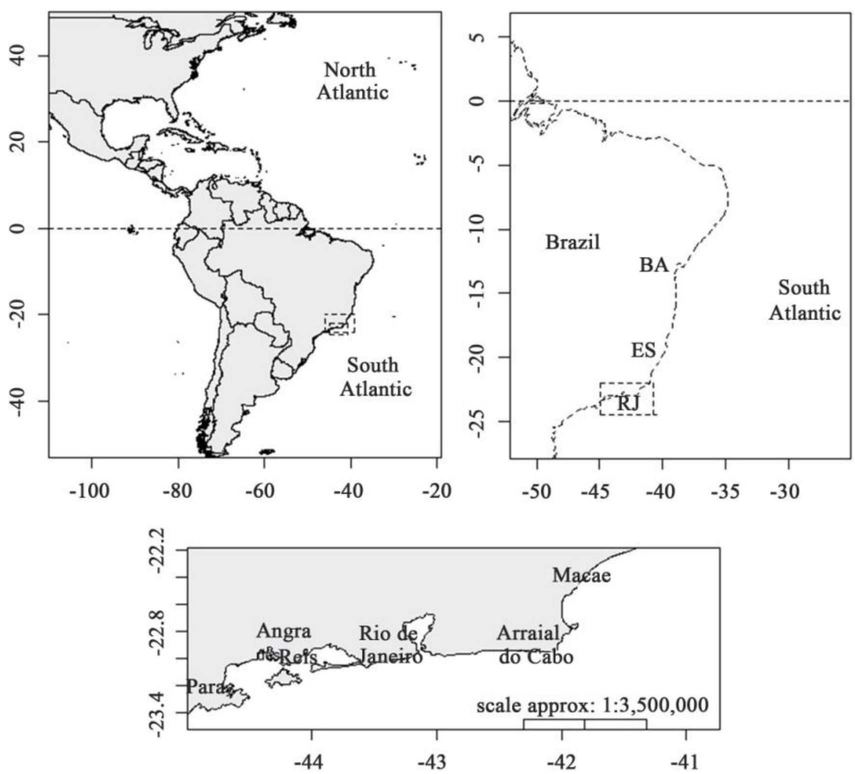


Figure 3. The Brazilian coast, with the location of Arraial do Cabo (Lat. 23˚S - Long. 42˚W), located on the east coast of the Rio de Janeiro State, southeast of Brazil.

Eastern Boundary—042°18'02''; Northwestern Limit: Southern Boundary—22°56'00'' - Eastern Boundary—041°55'30''; Southern Limit: Southern Boundary—23°04'00'' - Eastern Boundary—041°55'30''; Southeastern Boundary: Southern Boundary—23°04'00'' - Eastern Boundary—042°18'02'', between Massambaba Beach, at Pernambuca, and Pontal Beach, at the border of Cabo Frio [67] in Figure 4.

2.2 Samplings

The samples were collected daily between March/2017 and March/2018 from fish markets of Arraial do Cabo-RJ, fish landings at the Fishermen's Harbor at Praia dos Anjos (RESEX-Mar) and also from data conceived by the Fishing Institute Foundation of Arraial do Cabo (FIPAC). The specimens, visually identified only by their external morphology, were captured in different ways such as hand lines, long lines, dragging nets, gillnets and beach nets. They were randomly sampled from fragmented cohorts of the local stock according to monthly production and the availability of copies for sale; so that there was an integral comprehension of the different size classes from the catches originated by the different fishing efforts. For procedures, a primary biometry, of fresh specimens,

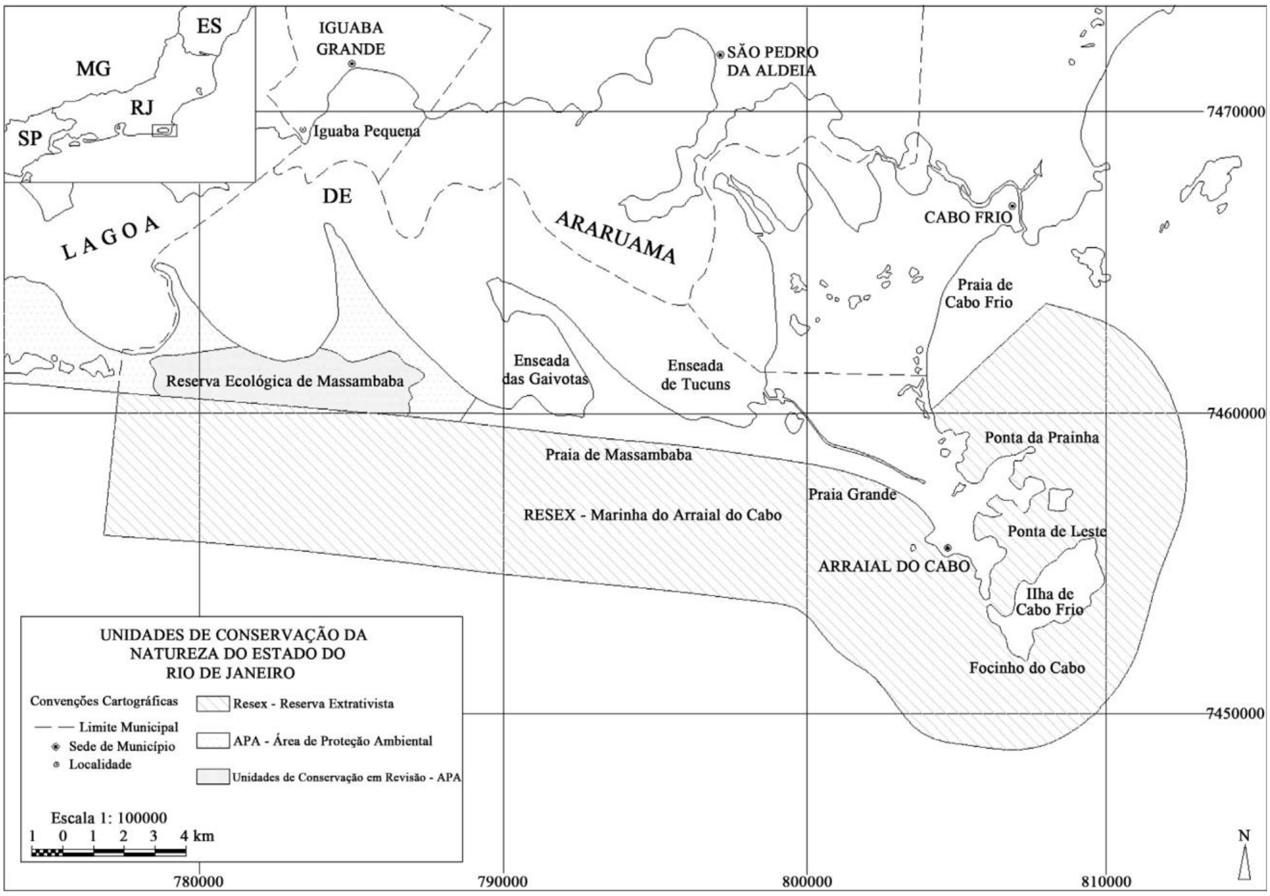


Figure 4. Map of Arraial do Cabo-RJ Marine Extractive Reserve (RESEX-Mar). Source: Adapted from the Nature Conservation Units Atlas, Government of Rio de Janeiro State/SEMA, 2001.

was carried out *in loco*. For dissection, *a posteriori*, samples bought were taken to the laboratory as quickly as possible and then frozen. Fish had their Total Length (TL) determined in millimeters (mm), from the initial end (mouth) to the final end (end of the caudal fin), starting from zero, with their left flank facing up, on the graduated ruler; and their Total Weight (TW) determined in grams (g) on the electronic balance, Marte AC10k model.

2.3 Analysis

The estimated values of LWRs were calculated using the equation $W = aL^b$ [72]. This may be shown in a linear regression way after the logarithmic transformation through log W = log(a) + b log(L), where W represents the Total Weight-TW (g), and L the Total Length-TL (mm), "a" is the intercept and "b" is the parameter of the inclination growth curve. The null hypothesis of Isometric Growth (H0 b = 3) were assumed. If inclinations (b) were significantly different from 3, for growth types will indicate Allometric Positive (b > 3) or Allometric Negative (b < 3) [73]. The value of "b" is considered as a regularly distributed logarithm [74] and reflects the species's morphology [75]. For sex determination, only the classification according to the macroscopic visual analysis of the gonads was performed. The Analysis of Variance ANOVA (One-Way) and Tukey test were employed to evaluate if there was differences among the samples between the months. The degree of association (correlation) between variables was calculated through the R^2 determination coefficient (0 to 1). All of the statistical analyses were confronted by the level or significance of $p \leq 0.05$.

The descriptive statistics derived from the use of statistic functions of MICROSOFT EXCEL® 2007 and of STATISTICA™.

3. Results

In total, N = 2057 bluefish were collected and, among them, N = 202 were bought and dissected. Females (N = 109/53.9%) slightly prevailed over Males (N = 59/29.2%), being 1.84/1 the *sex ratio* proportion; and over samples of Unsexed specimens (N = 34/16.8%). The term "Unsexed" refers to those specimens, to which the authors were unable to identify the sex, from the macroscopic visual analysis of the gonads only, since they are extremely filamentous, thus hindering their sexual differentiation. According to the results, there was low statistically meaningful differences between months in terms of length and weight ($p \leq 0.05$), with Females tending to be larger between sexes. Minimum and maximum bluefish's Total Length (TL) varied between 201 mm, in February/2018, and 915 mm, in September/ 2017, respectively. The average TL was of 541 mm and the average Total Weight (TW) of 1428.5 g.

The LWRs showed high association (correlation) between length and weight of bluefish, all confronted by the level or significance of $p \leq 0.05$. The values of R^2 (0 to 1) for Females, Males, Unsexed specimens and for Overall were, defined as 0.990; 0.988; 0.981 and 0.932, respectively. The LWRs, for Females, Males, Unsexed specimens and for Overall were defined as W = 3E−05L$^{2.7}$; W = 2E−05L$^{2.8}$; W = 6E−05L$^{2.6}$ and W = 9E−05L$^{2.6}$, respectively in **Figure 5**. The LWR's parameters of fish are affected by the external environment, degree of stomach fullness, maturity of the gonads, diet, sex, etc. In the present study, we especially reference the general upwelling's peaks influence [76] [77] [78].

The LWR's "b" parameters usually vary from 2.0 to 3.5 [79]. In the present study, the estimated growth coefficient (b), for Females, Males, Unsexed specimens and for Overall, were within the references expected interval of 2.50 - 3.33 (they were: Females "b" = 2.781, (deviation (H0 b = 3) = 0.219); Males "b" = 2.844, (deviation (H0 b = 3) = 0.156); Unsexed specimens "b" = 2.657, (deviation (H0 b = 3) = 0.343) and Overall "b" = 2.617, (deviation (H0 b = 3) = 0.383)), all showed low deviation. According to the results of the present study and according to the references compared, the type of growth of the bluefish were Allometric Negative (b < 3), for Females, Unsexed specimens and for Overall. For Males, the type of growth was considered Isometric (b = 3, or next) in **Figure 5**.

In the present study, the results of the averages for TL and for TW, for overall fishes, showed that the month of May (autumn) of 2017 and the month of February (summer) of 2018 presented the highest (627 mm and 2061.3 g) and the lowest (435 mm and 822.6 g), respectively. For the separated sexes, bought and dissected specimens, the highest averages (556 mm and 1569.2 g) were in June (winter) of 2017 and the lowest averages (274 mm and 289.5 g) were also in February (summer) of 2018.

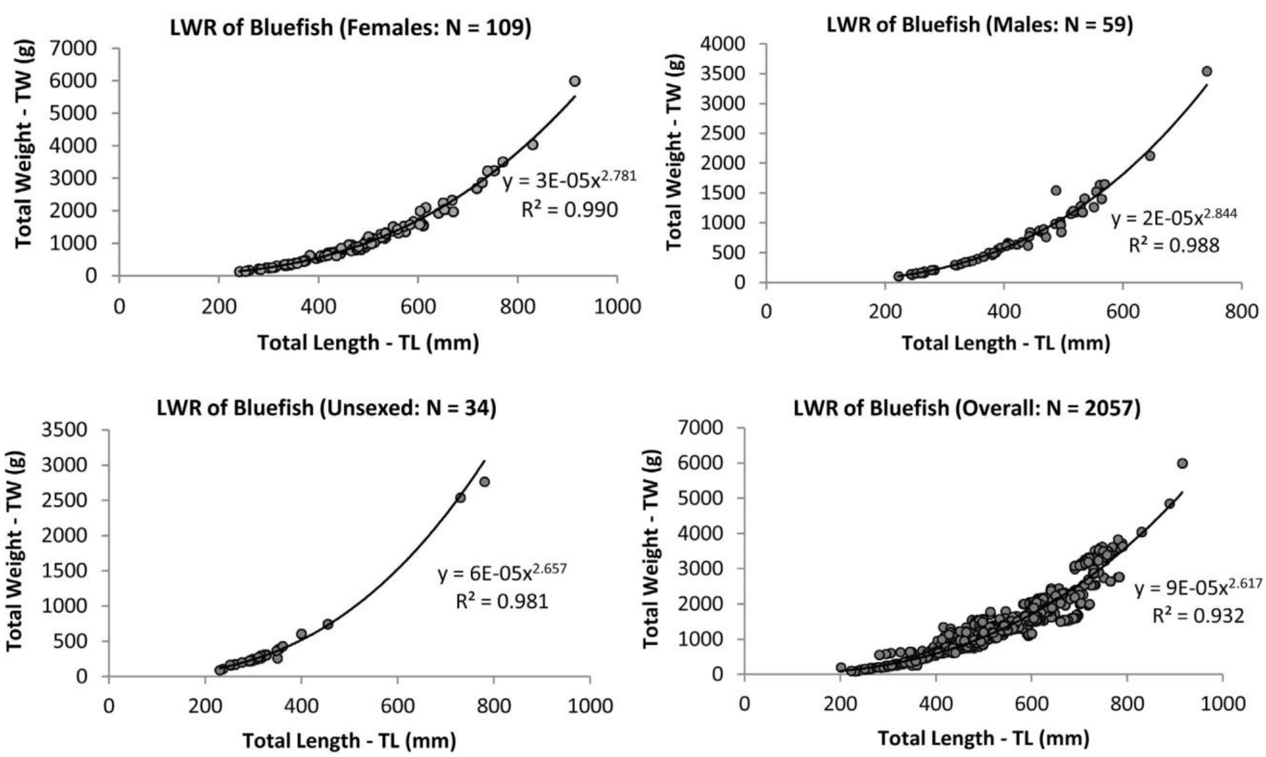


Figure 5. The general Length-Weight Relationships (LWRs/p ≤ 0.05) of the Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), Pisces: Pomatomidae, from the area of Arraial do Cabo-RJ RESEX-Mar, Brazil.

The distributions of TL Classes (mm) for the bluefish, in the present study, mostly presented a normal growth curve, corroborating with the description of the references and with being expected in **Figure 6**.

The monthly distribution of TL Classes (mm) for the separated sex, according to production and the availability of copies for sale, presented smaller difference and standard deviation among the means as expected in **Figure 7**, probably, caused by the lower number of samples (N).

For Overall, the monthly distribution of TL Classes (mm), according to the analysis below (One-way-ANOVA) employed to evaluate if there were differences among the monthly samples, with the Tukey test presenting $F = 94.6$ and $p = 0.0$ ($p \leq 0.05$) and with the result of Kruskal-Wallis test (KW) of 822.5; $p = 0.0$ ($p \leq 0.05$), showed a low difference between the averages of the growth rates between the months sampled thus presenting low standard deviation too in **Figure 8**.

4. Discussion

Studies demonstrate that most fish do not change their body shapes as adults [75]. Very strong deviations of $b = 3$ usually result from questionable studies [74] [75]. The Length-Weight Relationship parameters are extremely important for the biology of fish and their fisheries management [80]. The Le Cren's concept hypothetically affirms that the ideal "b" value for fish is 3, indicating an Isometric Growth that is broadly used as a scale in the study of LWRs [81]. Different "b" values refer to fishing periods, abiotics ecological factors, food provision, spawning conditions, etc. The type of growth of the species may change

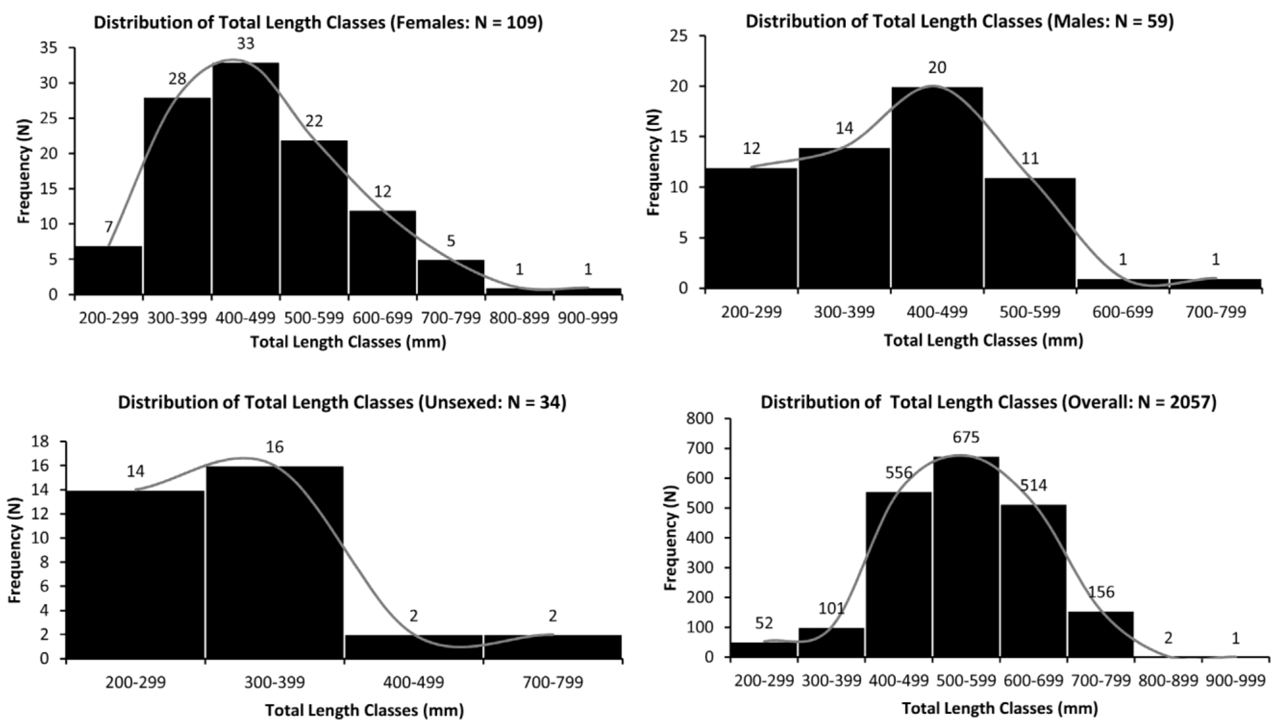


Figure 6. The general Distribution of Total Length Classes (mm) of the Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), Pisces: Pomatomidae, from the area of Arraial do Cabo-RJ RESEX-Mar, Brazil.

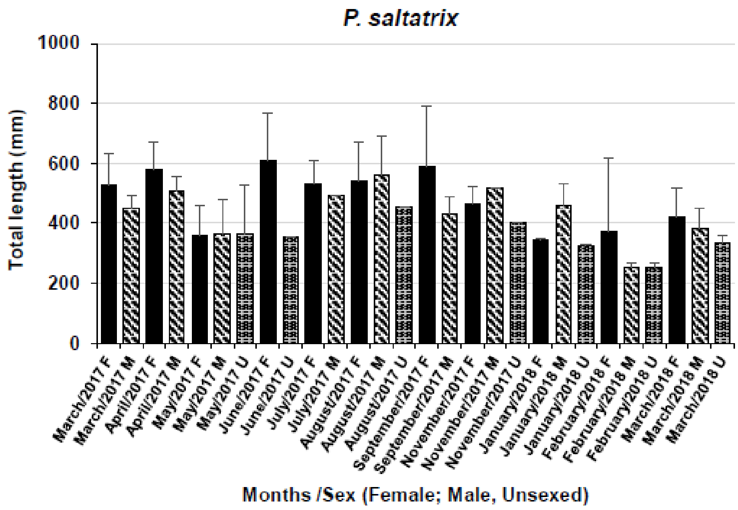
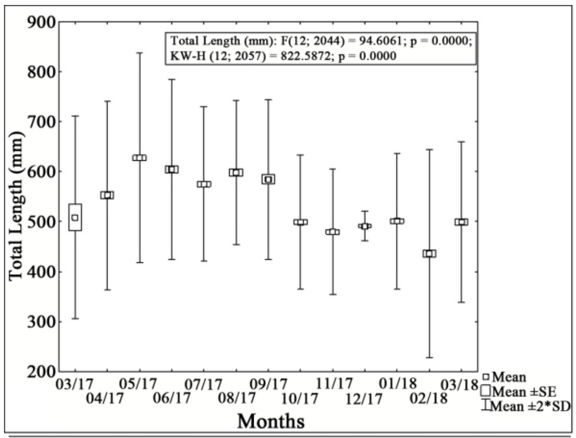


Figure 7. The monthly distribution of Total Length Classes (mm) for the separated sex of Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), Pisces: Pomatomidae, from the area of Arraial do Cabo-RJ RESEX-Mar, Brazil.



Tukey HSD test for Total Length (mm). (*$p < 0.05$)

Months	03/17	04/17	05/17	06/17	07/17	08/17	09/17	10/17	11/17	12/17	01/18	02/18
04/17	n.s.											
05/17	*	*										
06/17	*	*	n.s.									
07/17	n.s.	n.s.	*	n.s.								
08/17	*	*	n.s.	n.s.	n.s.							
09/17	n.s.	n.s.	*	n.s.	n.s.	n.s.						
10/17	n.s.	*	*	*	*	*	*					
11/17	n.s.	*	*	*	*	*	*	n.s.				
12/17	n.s.	n.s.	*	*	*	*	*	n.s.	n.s.			
01/18	n.s.	*	*	*	*	*	*	n.s.	n.s.	n.s.		
02/18	n.s.	*	*	*	*	*	*	*	*	n.s.	*	
03/18	n.s.	*	*	*	*	*	*	n.s.	n.s.	n.s.	n.s.	*

Figure 8. One-way-ANOVA: Mean values, standard deviation and significance analysis (Tukey's test, Kruskal-Wallis Test and p'*s*) of the Total Length values (mm) for Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), Pisces: Pomatomidae, from the area of Arraial do Cabo-RJ RESEX-Mar, Brazil.

among locals. Intra-specific variations in the Length-Weight Relationships might happen due to variations in ecological conditions of habitats, in physiology or in any of those [59]. Other than that, these differences depend on time and size of the sample, greatest amplitude, on the non-selective fishing equipment, on seasonality, fishing pressure, reproductive season, etc.

When comparing LWRs available in the literature, one can find and extensive variability of parameters for this species in **Figure 9**. Variables related to sampling include the size of the sample, the distribution of length, the type of length measurement, while nutritional conditions represent the intrinsic biological variability [82].

It is known that individuals in populations that are exposed to high levels of mortality and/or fishing pressure will respond by reproducing in medium size and lower ages [83]; with the LWR's Relationship growths parameter "b" tending to present Allometric Negative ($b < 3$) or Allometric Positive ($b > 3$). Parameter "b" of the LWR equation ($W = aL^b$), where W = Total Weight (TW) and L = Total Length (TL), also known as the isometry coefficient, has an important biological meaning, indicating the rate of weight increase related to length increase. Variability in the value of "b" is usually detected among different populations of the same species or within the same population at different times. This may be a reflection of changes in conditions related to feeding, reproduction or migratory activities of individuals [61] [62].

The pattern for bluefish captures through the years has shown significant reductions in the local stock. During the 60's, great captures were averaged in

References	Location	N (sample size)	Sex	Length range (mm)	Length Type	a (Parameter of LWR)	b (Parameter of LWR)	Growth Type
[88]	South Atlantic	-	Overall	-	TL	0.010	2.770	A−
[89]	Middle Black Sea	-	Overall	-	TL	0.038	2.560	A−
[90]	South Coast of Brazil	92	Overall	240.0 - 480.0	TL	6.00E-06	3.050	I
[91]	South Coast of Brazil	275	Overall	86.0 - 250.0	TL	6.79E-06	3.050	I
[92]	Atlantic	-	Overall	86.0 - 910.0	TL	0.091	3.010	I
[45]	Middle Coast of Brazil	67	Overall	480.0 - 755.0	-	0.059	2.500	A−
[93]	Aegean & Marmara Sea	2817	Overall	84.0 - 453.0	FL	0.006	3.220	-
[46]	Middle Black Sea	76	Females	143.0 - 217.0	TL	0.011	2.920	I
		67	Males	132.0 - 217.0	TL	0.015	2.790	A−
		143	Overall	132.0 - 217.0	TL	0.013	2.860	A−
[48]	Middle Black Sea	820	Overall	92.0 - 234.0	TL	0.003	3.320	-
[47]	Eastern Black Sea	14	Overall	116.0 - 222.0	TL	0.003	3.330	A+
[94]	North Marmara Sea	290	Overall	106.0 - 240.0	TL	0.032	2.520	A−
[23]	Black Sea	25	Overall	125.0 - 202.0	TL	0.009	3.000	-
[49]	South Marmara Sea	503	Females	131.0 - 370.0	TL	0.010	2.960	I
		447	Males	123.0 - 473.0	TL	0.010	2.970	I
		280	Unsexed	130.0 - 316.0	TL	0.015	2.830	I
		1230	Overall	123.0 - 473.0	TL	0.010	2.950	I
[50]	Middle Black Sea	-	Overall	135.0 - 236.0	TL	0.008	3.120	A+
The Present Study	Southeast Coast of Brazil	109	Females	241.0 - 915.0	TL	3.00E-05	2.781	A−
		59	Males	222.0 - 741.0	TL	2.00E-05	2.844	I
		34	Unsexed	230.0 - 780.0	TL	6.00E-05	2.657	A−
		2057	Overall	201.0 - 915.0	TL	9.00E-05	2.617	A−

I: Isometric; A+: Positive allometric and A−: Negative allometric.

Figure 9. Extra Compiled: A table of the Length-Weight Relationships (LWRs) of Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), from different studies, years and locations; including the present study.

18,000 kg. From the 80's on, production started to decrease. Nowadays, around 370 kg of bluefish per day is considered great. Studies show that, in fifty years (1960 to 2010), the quantity of captured bluefish in a good day has decreased in approximately 70%. A study showed that the Capture per Unit Effort (CPUE) varied from 14.2 tons per hour in 1996 to 0.3 ton per hour in 2004, with a yearly average of 4 tons per hour [34]. According to data provided by FIPAC, the total monthly capture of bluefish, resulting from the productive sum between all fishing efforts, from January/2017 to February/2018, varied from 8559 to 14,326 kg, presenting the lowest capture of 2361 kg in September/2017 and the highest, corresponding to 14,326 kg, in February/2018. In Arraial do Cabo, impacts on marine ecosystems have affected the environmental base lines of three consecutive generations [34]. The captivity of bluefish showed signs of excessive effort and a possible excessive fishing.

The bluefish is considered as Vulnerable (VU *A*2*bd*), due to data uncertainty, but there is no regulation or national listing to guarantee its protection [84] [85] [86]. In this case, the monitoring of Arraial do Cabo-RJ RESEX-Mar should have a more precautionary function [67]. Measures for conservation, suggested by many, include the reduction of fishing efforts by purse seines and a capture limit for juveniles [87]; the official determination of a closure season, of 4 months-December 1 to March 31, during the summer-autumn spawning and upwelling's peaks, as well as the establishment of a minimum capture size of 350 mm, specimens with possible first spawning already performed and possible matures, probably avoiding the capture of recruits; reinforcing that the Rio de Janeiro State (BR) is without fishing tackle or prohibition yet attributed [10].

Studies suggest a need for improved monitoring of all fisheries, including often neglected small-scale fisheries, and illegal and other problematic fisheries, as well as discarded by-catch [95]. The low attention that small-scale fisheries endure in most parts of the world [95] [96] manifests itself in potentially misleading statistics that are submitted annually by member countries of the Food and Agriculture Organization of the United Nations (FAO), which may exclude or substantially underreport small-scale fisheries data [95] [97].

The most important trend of the world marine fisheries catches is not one of "stability" as carefully suggested earlier by FAO, but one of decline [95]. Until now artisanal and subsistence fisheries generate about one-third to one-half of the total global catch, as assessed by catch reconstructions for all maritime countries of the world [95] [96] [97].

For the monthly analysis of Overall, there was a greater difference between the means of TL (mm) and a greater standard deviation, since for the monthly analysis between separated sexes a smaller difference and a smaller standard deviation were found, probably caused by the lower number of samples (N). However, it can be observed that there is significant difference between the TL Classes (mm) monthly. Any standard deviation, more pronounced, is possibly caused by the entry of new recruits throughout the year (season annual distribution).

The statistical test used was the Analysis of Variance-ANOVA (One-Way). It is a parametric test used to verify if there are differences between the means of a given variable (response variable. Ex.: TL Classes (mm)) in relation to a treatment with two or more categorical levels (predictor variable. Ex.: Months). The Tukey test for mean comparison was applied when the "F" test was significant (at the present study, Tukey test presenting $F = 94.6$ and $p = 0.0$ ($p \leq 0.05$)). The Kruskal-Wallis test (KW) was also applied (results at the present study: 822.5; $p = 0.0$ ($p \leq 0.05$)). It is a nonparametric test used to compare three or more categorical levels. It is used to test the null hypothesis that all categorical levels have equal distribution functions against the alternative hypothesis that at least two of the categorical levels have different distribution functions, has no restriction on the comparison. The degree of association (correlation) between variables was calculated through the R^2 determination coefficient (0 to 1), and all showed high association (correlation) with $R > 0.9$. All of the statistical analyses were confronted by the level or significance of $p \leq 0.05$.

5. Conclusions

The present study, with the great feedback of the local fishermen, have identified the months of November and December (spring and summer) of 2017; January, February and March (summer and summer-autumn) of 2017 and 2018 as the reproductive peaks of larger adult individuals (spawning peaks) and the month of March (summer-autumn) of 2017 and February (summer) of 2018 as the most productive, periods coinciding with the peaks of the local upwelling. It was observed that in 2017 the bluefish was the sixth most captured species in the studied area. Is a remarkable fishing resource around the world, accounting for approximately 12.7% (200 T/year) of all fish landed in the region of Arraial do Cabo-RJ.

For effects of a better future fisheries management, it would be necessary calculate and establish lower exploitation levels in reason of inaccuracies calculations in Maximum Sustainable Yield (MSY), obtained when the instantaneous fishing mortality rate is approximately equal to the natural mortality rate. Where values and the abiotic variables in the processes of reproduction and growth, still not well known.

The explored stock in the region may be formed by one single cohort that, during its period of growth, changes local and spawning season or apportioned, or of many different subpopulations.

The present study should be used to compare the data obtained with other studies that were carried out in different times and places. Results can be used by biologists as a reference during researches of local fisheries. Other than that, it is very important to provide recent data for dynamic analysis of populations, locals stocks and others.

The knowledge over bluefish biology is extremely important to the ecology and conservation *status* of this species.

Considering that the region is an important RESEX-Mar for sustainable use, collected more information on fishing activities and captures of the species are real necessary. Providing these data to local agencies in order to subsidize a future and better fisheries management of the studied area and, if possible, to other conservation units around the world, since there are few related studies, is fundamental.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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5. CAPÍTULO II: 2º ARTIGO (SUBMETIDO)

Título: “Age, Growth and Maturity of the Bluefish (*Pomatomus saltatrix* Linnaeus, 1766) along an Upwelling Area in the Southwestern Atlantic Ocean”

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OBJETIVOS ESPECÍFICOS:

- Aplicação Biotecnológica Marinha: preparar, ler, avaliar e validar a estrutura de aposição a ser empregada (escamas *versus* otólitos) às análises das marcas de crescimento e faixas etárias (anéis etários) da espécie;
- Estimar a idade;
- Determinar os parâmetros bio-ecológicos de crescimento, associados à leitura e interpretação dos anéis de crescimento em otólitos (método direto) e aos índices fisiológicos (K; *HSI* e *GSI*) dos espécimes amostrados;
- Utilizar a identificação macroscópica dos estádios de desenvolvimento das gônadas femininas (ovários) e masculinas (testículos), durante os meses do ano, para indicar o seu ciclo reprodutivo (tipo) e determinar o (s) período (s) pico (s) de desova;
- Estabelecer a relação do Índice Gonadossomático (*GSI*) e o seu potencial reprodutivo através das análises de fecundidade/fertilidade;
- Estimar o Comprimento Médio de Primeira Maturação Sexual (L_{50});
- Apontar a dieta e;
- Comparar os dados dos parâmetros bio-ecológicos gerais obtidos às informações pretéritas (revisão bibliográfica).

HIPÓTESES NULAS (H_o):

- Não é possível estimar as idades dos espécimes dissecados da região e;

- Os parâmetros bio-ecológicos de crescimento das Enchovas provenientes da área da RESEX-Mar de Arraial do Cabo – RJ, são homogêneos, sem variação mensal (sazonal) e/ou em relação aos índices fisiológicos (maturação).

HIPÓTESES ALTERNATIVAS (H_1):

- É possível estimar as idades dos espécimes dissecados da região (1+ a 12+ anos) e;
- Os parâmetros bio-ecológicos de crescimento das Enchovas provenientes da área da RESEX-Mar de Arraial do Cabo – RJ, são heterogêneos, com relativa variação mensal (sazonal) e/ou em relação aos índices fisiológicos (maturação).

Parâmetros bio-ecológicos de crescimento fisiológico das Enchovas analisados: Idade (Age); *Back-calculation* (retrocálculo); *MI* (IM); K; *HSI* (IHS); *GSI* (IGS); L_{50} (Comprimento Médio de Primeira Maturação Sexual); *Lc* (Comprimento médio de captura) e ϕ' (Desempenho de Crescimento).

Age, Growth and Maturity of the Bluefish (*Pomatomus saltatrix* Linnaeus, 1766) along an Upwelling Area in the Southwestern Atlantic Ocean

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Abstract

Age estimation, the growth and the first-maturity-length approximation of the Bluefish (*Pomatomus saltatrix*) were analyzed along an upwelling area in the Southwestern Atlantic Ocean. A total of 190 right otoliths, 199 pairs of scales, information on N=2,057 (total) and N=202 (dissected) specimens sampled during landings at the Marine Extractive Reserve (*RESEX-MAR*) of Arraial do Cabo – RJ between March/2017 and March/2018 were used. Age and growth were estimated by count and measurement of increments of the *sagittae* otoliths and scales, for comparation. First-maturity-length was estimated by the lengths and the macroscopic analysis of the gonads. For the both sexes, the average of the Condition Index and the average of the Hepatosomatic Index increased especially during the autumn-summer and winter-summer respectively, reaching maximum values by the end of the spring and summer respectively, before the start of a new probably spawning period. The average of the Gonadosomatic Index was higher in September/2017 and is believed to correspond to one of the spawning peaks. The analysis of marginal increment enabled the confirmation of annual periodicity of opaque and translucid zones in otoliths. The maximum age found was of 12+ years for a female. Females usually were older, larger and heavier than males. The growth curves were crossed with the back-calculated size of the ages for bio-ecological growth estimates too. The average length and age at first maturation were estimated and assumed from 452 mm to 1-12+ years for grouped sexes; 472 mm to 1-12+ years for females and; from 415 mm to 1-10+ years for males. In order to subsidize a future and an adequate management of fishing it is important to know about its general and specific biology.

Keywords: Age estimation; the growth; the first-maturity-length; Bluefish; management of fishing.

1. Introduction

The Bluefish (*Pomatomus saltatrix*, Linnaeus 1766) is an important species, with a global harvest of approximately 20,000 t/year [1]. It belongs to the Perciformes order and to the Pomatomidae family [2]. It is a cosmopolitan-panmixa species and occurs in all tropical and neotropical waters, except at the eastern and northwestern of the Pacific Ocean [2] [3]. In Brazil (Southwestern Atlantic Ocean), it occurs along the entire coast [4]; at different depths (up to 200m). The Bluefish has its cycles of abundance directly related to the cycles of abundance of its prey [5]; varying seasonally. Its fishing activity is intense, with the use of purse seines, trawls, hand lines, gillnets and others [6]. The history of Brazilian fishing over the Bluefish illustrates different levels throughout the decades, with a tendency towards a probable future collapse. Its production, during the 70's was of around 16 thousand tons. In the 80's, it dropped to 8 thousand tons, a clear index of overexploitation. In the last two decades, it has remained stable, around 4 thousand tons. In the beginning of the 70's, its fishing production was 400% higher. The Rio de Janeiro State is known for maintaining a homogeneous production since the 90's, producing approximately 1 thousand tons per year [3]. It is estimated that 23% of all Brazilian marine stocks, including species of lower trophic levels, are being fully exploited, and that 33% are being overexploited [7]. The Bluefish represents a large portion of the total fishing landings at the Marine Extractive Reserve (*Reserva Extrativista Marinha; RESEX-Mar*) in Arraial do Cabo – RJ, reaching between 10-15% (approximately 200 tons per year) of these landings [*FIPAC* (*Fundação Instituto de Pesca de Arraial do Cabo – RJ*), unofficial data].

The Bluefish inhabits different marine habitats (larvae, juveniles and adults), estuaries (optional or semi-dependent nursery areas) and mangroves (especially juveniles), where there is less chance of predation [3]. They swim near the coast when ocean temperatures vary from 12ºC to 15ºC [8]. The minimum temperature for the occurrence of Bluefish larvae are 15ºC to18ºC and pelagic juvenile Bluefish are13ºC to 15°C [9].

The Bluefish is a migratory coastal and pelagic oceanic species, which moves near the surface of water (euphotic zone) [10]. The continental shelf water, characterized by salinity <35, is divided into coastal water (33.6) and shelf-break water (33.6 to 35.0) [11]. In South America, the Bluefish migrates annually and seasonally along the coast to the north, following the western boundary of the neotropical convergence between the ocean currents of Brazil and the Malvinas (Falklands) [2] [12]. In Brazil, it usually migrates in groups of uniforms lengths and not by sex [12]. An analysis of seasonal activity changes of migratory fish must consider the probable interrelationship between exogenous (abiotic) and endogenous (physiological) factors. It seems plausible to suppose that hormonal changes due to general or specific external stimulus are partially responsible for the increase of its locomotive activity. Such changes in its activity and responsiveness can be important components of migratory and reproductive behavior. Adults migrate to spawning areas with or without thermoclines and bathymetric variables, with temperatures varying from 17ºC to 26.8°C [10].

The spawning of this gonochoric (dioecious) species apparently occurs in offshore, superficial and clearer waters, with eggs and passive pelagic larvae (ichthyoplankton) or active pelagic larvae (neuston or nekton), developing as they get closer to the coast [5]; characterizing the "Stage-Duration" mechanism. They reach the spawning peak usually at 22ºC with few spawning happening in temperatures lower than 18ºC (thermal upwelling threshold) and no spawning in temperatures lower than 13ºC and with salinity from 26.6 to 31.7 [13]. In high latitudes, deeper and colder waters, it seems to be seasonal [3]. Eggs and larvae are probably transported along the coast by a complex pattern of horizontal and vertical moves. In the south part of the U.S. Atlantic Ocean, spawning occurs from March to May, from September to November and from May to August [14]. In the Gulf of Mexico, it may occur in April and from April to November [15]. In Brazil, the spring spawning probably happens in the south, close to the coast of Rio Grande (Rio Grande do Sul State (BR)) [3]. It was indicated as a split or undetermined spawning [3]. Bluefish lay eggs and show probably continuous or undetermined fecundity (split spawning), generating a large quantity of small eggs during migration [16]. The Bluefish has an adapted, high, oceanic, numerous and relatively long PLD (Pelagic Larval Duration), in some regions with the larvae surviving for up to 8 days, during which, by the action of the winds, surface currents, more vigorous currents along the continental shelf boundary, different masses of water, oceanographic condition and behavior or life history, have their global dispersion facilitated [13] [16]. Despite its larvae dispersion capacity in long distances, the gene flow among subpopulations is limited [17]. As a result of its vast distribution and of the existence of oceanographic boundaries, species may be formed by multiple different populations, but there is not enough information [18]. The recruitment dynamics of the Bluefish seems to be intrinsically connected to annual migrations for spawning of the adult population. Its spawning, seasonal migration and life cycle are connected to water temperature and salinity.

The Bluefish presents different growth patterns between sexes, females usually grow faster, are larger, heavier and live more than males. The temperature of the water varies according to the type of habitat and, in particular, the ideal temperature for Bluefish growth is 24ºC [19]. The first-maturity-length tends to varies from 350 mm to 400 mm and the maturity is reached in specimen of "(0.7)/1-2" years [12] [20]. The maximum age registered is 14 years at the Chesapeake Bay region [21]. The age and first-maturity-length are key parameters in the analysis of fish stocks [22]. The meaning of estimating the first-maturity-length is explained [23]. These authors suggest the decrease in the first-maturity-length may be related to a high level of pressure due to fishing, suffered by the reproductive population, the Matrices. This reinforces the importance of studies on the growth parameters of species in regional and global levels. The separation of stocks is tested based on reproductive biology and, recently, on the morphological and morphometric characteristics of *sagittae* otoliths too. Fast growth may also represent a philosophical advantage, since fish that reach larger sizes by the end of the summer's growth season usually have higher survival rates in their first winter [24]. Benefits of fast growth of juveniles include more variety of feeding resourcers [25]. Larger fish have an advantage in relation to predator size in before target prey [26]. Natural mortality of small individuals caused by predators may change the ratio between growth and reproduction of the Bluefish, where individuals dedicate more energy to the somatic growth according to a "Bigger-is-Better" strategy [27]. On the other hand, fishing shifts mortality to larger individuals, indirectly inducing more investment in reproduction and less energy dedicated to somatic growth, which results in a population that maximizes the adequacy of life in exploited environments according to the "Smaller-is-Better" strategy [28]. Thus maximizing foraging capacity (raise of the trophic level) and therefore the increase of inter-cohort competition for natural resources (possible "Bottleneck Theory" [29]); other than protection against predation. The "Growth-Mortality" hypothesis crosses the success in feeding with predation: as feeding increases, growth increases and the probability of mortality for starvation and/or predation decreases [30]; this is the "Growth Rate" mechanism (which can operate individually). In pelagic ecosystems, larger and faster growing larvae are more probably to survive. Recruitment dynamics in fish is defined as the survival of a cohort during the first year of life, can be highly variable, but is frequently positively correlated to the survival rates during winter [31]. Juvenile Bluefish probably look for depths above thermoclines as their swimming capacity improves.

The Bluefish is a key predator in many marine ecosystems regulating the food webs [26]. It is a population controller (top-down trophic control) of many species, especially of small teleost of lower tropic levels [32] [33]. It is an extremely voracious and potent coastal-oceanic, cosmopolitan-panmixe meso-predator (<1 m of length), abundant in regions of upwelling. The Bluefish shows a higher metabolic rate in comparison to its main competitors, especially during locomotion in foraging with temperature increase [34]. The Bluefish feeds on different teleosts, molluscs (nectonic cephalopods) and crustaceans. During the larval stage, it feeds mainly off of copepods [35]. The seasonal variation in the diet of the Bluefish is probably related to the availability of prey, varying according to bio-oceanographic conditions, which confirms the generalist-opportunistic behavior of the species, with no preference for prey and of diurnal and/or crepuscular habits (period of higher activity), which may or may not vary according to local temperature and to the photoperiod. The Bluefish probably prefers smaller or easier prey to capture in colder waters (regions of upwelling), due to a metabolic decrease. Although there is much information on how temperature physiologically limits the maximum consumption of fish, little is known on how ecologic processes affect feeding in lower temperatures [31]. The presence of organisms from all levels of the water column in stomach contents indicates a demersal-pelagic behavior, inshore or offshore, with more superficial action and high trophic adaptability [36]. The Bluefish is capable of eating double its weight per day, therefore resisting to long periods without food [37]. There are records of Bluefish who have regurgitated their food in order to attack again [38]. The energy obtained from small pelagic highly nutritious fish is necessary to maintain the very fast growth rates of the Bluefish [26].

From the compilation of all these informations it will be possible to develop a study on the age, the growth and the maturity of the Bluefish (*Pomatomus saltatrix* Linnaeus, 1766) along an upwelling area in the Southwestern Atlantic Ocean, the specific area of the *RESEX-Mar* of Arraial do Cabo - RJ.

The goal of our study is to describe the age estimate and the growth, from the comparison of results between readings of different structures of apposition: otoliths X scales and from the distribution of length frequency and the length-weight ratio of the Bluefish respectively; indicate the diet, from the analysis of stomach contents of this species in the region along an upwelling area in the Southwestern Atlantic Ocean; the first-maturity-age, from the determination of the lengths, Gonadosomatic Index (GSI) and of sex maturation stages (gonads) and the fecundity and, with that, provide more precise information for a better fishing management of this species. Considering that the region is an important kind of Marine Extractive Reserve (*RESEX-Mar*), a Conservation Unit of sustainable use [39]; the present study also aims to summarize information for the community on fishing activities and catches of the species. The data will be presented to local agencies with the intention of subsidizing a future, Legal and organized fishing management, due to the absence of studies.

2. Materials and Methods
2.1. Study Site

The *RESEX-Mar* area of Arraial do Cabo (Lat.23ºS - Long.42ºW) in **Figure 1**, is located on the east coast of the state of Rio de Janeiro. The area has an important characteristic: a unique projection of the coast in relation to the ocean, which makes it one of the places that advances the most towards the sea. The geographic and oceanographic aspect is determinant for the system of upwelling, which elevates cold and high in nutrients water from the Central Water of the South Atlantic (SACW/*ACAS*), with peaks during spring and summer [40]; local thermal threshold equal to ≤18ºC. This promotes a highly productive level (primary production) for the region and, therefore, rich in species of lower trophic levels that will possibly serve as prey to species of higher trophic levels, as is the case of the Bluefish. This enables extremely favorable conditions for fishing activities.

Figure 1. Location of the *RESEX-Mar* at Arraial do Cabo (Lat.23ºS – Long.42ºW), on the east coast of the state of Rio de Janeiro, southeastern Brazil [39]. The circled area corresponds to the area of highest Bluefish's fishing production. Source: https://marsemfim.com.br/resex-arraial-cabo/.

2.2. Fish Samples
2.2.1. Data and Processing

Collections were daily from March/2017 to March/2018 in fish markets, during fishing landings at the Marina dos Pescadores (Fishermen Harbor) in Praia dos Anjos and also from data provided by FIPAC; in Arraial do Cabo – RJ. Specimens were caught at the RESEX-Mar from the fishing activity that involved different fishing efforts, such as: hand lines, longlines, trawls, gillnets, beach nets (purse seines and/or waiting nets) and others. They were visually identified through their external morphology. For the full understanding of the different size classes, sexes and seeking the greatest sample N possible, samples from fishing were random. The specimens were collected from fragmented cohorts from the local stock according to monthly production and to availability for sale. *A priori* a primary biometry of the fresh specimens was carried out *in loco* (N=2,057), measuring total and standard lengths (Total Length (Lt), defined as the distance between the anterior end of the mandible and the upper end of the caudal fin in natural position slightly extended; and Standard Length (Ls), defined as the distance between the anterior end of the mandible and the caudal peduncle) both in millimeters and weight (Total Weight (Wt)) in grams.

For posterior dissection, bought specimens (N=202) were taken as fast as possible to the lab and frozen. The fish had their Total Length (Lt) determined in millimeters (mm), covering a range of 222 mm to 915 mm, and their Total Weight (Wt) determined with the approximation of 0.1 gram (g) on the electronic scale, Marte AC10k model the average of Wt was of 860.56 g (92,9 to 6000 g). All fish were eviscerated and sorted by sex, having their Gonadal Weight (Wg) and Liver Weight (Lw) recorded to the nearest of 0.001 g. The Gonadosomatic Index (GSI = 100 * (Wg / (Wt-Wg))) was calculated for all samples and used to analyze the periodicity of the gonadal development and of the local reproductive activity of the females [41]. In addition to these, the energy reserve rates, the Hepatosomatic Index (HSI = 100 * (Lw / Wt)) and Fulton's Condition Factor

(K), ($K = 100 * (Wt / Lt^b)$), where Lt^b is the Total Length under the "b" parameter (coefficient of physio-morphologic isometry), derived from the Length-Weight Relationship (LWR), equaled to 3, were used as indicators of monthly physiologic changes of the samples [22]. The K Condition Factor (Fulton's) is expected to be low during spawning periods (summer) and higher in the winter.

The sexual maturity was classified by the macroscopic examination of the gonads (observing the size relative to the abdominal cavity, shape, coloration and vascularization of the ovaries (elongated and tubular) and testes (elongated, flat, tubular and white)) in: stage A (immature), gonads of reduced size, translucid, located adjacent to the vertebral spine; stage B (in maturation), gonads occupying one third of the abdominal cavity with well-developed capillary network; stage C (mature), with turgid gonads, occupying most of the abdominal cavity (in females, oocytes are visible to the naked eye, while in males testicles are albescent); and stage D (spawned), with completely flaccid gonads with hemorrhagic aspect [42].

Biological data have the advantage of providing information on stages of sex maturity. On the other hand, research data have the advantage of providing more complete series of data on size and, therefore, there is the interest of combining both kinds of data. Biological data were used to determine the first-maturity-length (L_{50}), which is essential to determine the three retained indicators from data on size frequency.

The first-maturity-length (L_{50}) was defined as the average length in which 50% of all specimens were sexually mature [22]. The L_{50} was estimated and assumed from the analysis of gonadal maturation stages ("A", "B", "C" and "D"), where it was assumed that the mean of the Total Lengths (Lt) of the mature specimens, compared to the immature, corresponds to the L_{50} values (for grouped sexes and for separated sexes).

2.2.2. Preparation of Otoliths and Scales, Readings and Possible Interpretations

There are 3 types of otolith pairs (apposition structure). Otoliths are known as the "ear stones" of teleost. They are formed mainly by calcium carbonate (aragonite form), but also of protein and trace elements (ex: especially strontium (Sr) and barium (Ba), among others), elongated, of long sides and serrated edges, especially those of larger size, and are used for the reception of sound, maintenance of balance and processing of directional signals [43]. They are called as *sagittae*, *lapilli* and *asterisci* and vary considerably in size.

The used otolith pair was of the *sagittae* type. For each specimen, the otolith pair was removed from the auditory capsules (vestibular or semi-circular canals), had excess tissue removed with a tweezers, cleaned, weighed on a precision scale to the nearest 0.001 g and stored dry before the processing for age analysis. A total of 190 right otoliths were used for the interpretation of marginal increments (distance from the last age ring to the edge of the apposition structure). The otoliths of *lapilli* and *asterisci* types, of smaller sizes and poor readings, were not used. There is no statistical difference between right and left otoliths [44]. The right otolith was used. Therefore, the microstructure of the otolith provides the age, size, growth and development history of an individual.

For age analysis, the *sagittae* otoliths were fixed, immersed with their concave surface facing down in a polyester resin, pre-heated with the use of a catalyzer; longitudinal sections, through focus, with a thickness between 0.1-0.3 mm, were obtained using a Buehler® IsoMet® low speed, high precision saw. After the cuts, the sections were sanded, cleaned in a solution of EDTA (at 5% for 2 minutes and a half, and rinsed), and fixated on slides using Canada balsam. The otolith sections were read under a Zeiss stereomicroscope, under transmitted light, with 5x to 100x amplification, photographed and measured by the ZEN 2011 program. The radius of the otolith (Ro) and the radius of the increments (Ri) were measured to the nearest 0.001 mm along the smallest axe (smallest scalar-numeric bias), from the otolith's nucleus to its edge. The type of edge (hyaline-translucid or opaque) was recorded, and increments, defined as the hyaline-translucid border (related to lower growth rates (winter)) and an opaque border (related to faster growth rates (summer)) combined (1 year) were counted from the second age ring, with only the 1^{st} ring discarded, called primordial ("age 0" – juvenile), an ontogeny mark; other than the distance from nucleus to most distal border along to the "*sulcus acusticus"*. Marks not considered complete were not counted or measured, unless the portion of the distal otolith was translucid. Readings were carried out by one unique reader and in random order, with no previous access to information on size, sex or period of sampling. In cases of probably redone and/or doubtful readings, an average was determined, or the otoliths were rejected. A strong relation between somatic growth of fish and growth of otoliths is expected.

An analysis of marginal increment was done to validate the periodicity in the formation of increments (biotic x abiotic factors) [45]. The marginal increment was calculated as: $Mi = (Ro - Rn) / Rn - (R_{n-1})$, where Ro is the radius of the otolith, Rn is the distance from the nucleus to the external increment, and R_{n-1} is the distance from the nucleus to the penultimate increment.

It is possible to affirm that the scales of the Bluefish are of ctenoid-cycloid type, thin and with their "*circuli"* arranged in parallel semi-circles in their front fields. The growth rings are marked in the front field as a zone where the "*circuli*" are closer to each other. In some cases, it is possible to observe these rings also in the posterior field, where they appear as interruptions in lines of ctenoids. The scales were removed (about 5 to 10 per specimen) from the axial region to the pectoral fin, below the lateral line, area with higher mechanical protection (lower regenerative rate and greater symmetry), as they seemed to be the most consistent or less regenerated and easiest to read. The scales were cleaned and mounted between two glass slides according to [42]; for a unique reading, interpretation of the number of growth marks and comparison. In the scales, an age ring was considered as a broadly spaced circle band, usually with interrupted circulation in the anterior field and/or lateral field, followed by a series of close circles (Circadian Cycle – daily age rings). Measurements were taken using a Zeiss magnifying glass (under variable amplifications) through photos taken with the ZEN 2011 program, from the focus along the smallest axe from the center of the anterior field to the distal border of the age rings and the scale border (marginal increment). The generalized criterion used for counting was to examine the patterns of discontinuity or agglomeration of the "*circuli"*. Many scales contained false rings (or anastomosis - crossing over), sometimes difficult to distinguish from true rings. A total of 199 pairs of scales were read by one unique reader and in random order, with no previous access to information on size, sex or period of sampling only for the count of age rings, aiming for a comparison in relation to the reading of the age rings from the otoliths, and the indication of which apposition structure enables a more accurate ages study to the studied species.

2.2.3. Diet

The stomachs of each Bluefish were extracted from the esophagus to the pylorus, with their ends tied with string to prevent their contents from being lost. These were then weighed using a precision scale (0.001 g), discounting the weight of the string, classified according to Degree of Repletion (0-3) and, then preserved in 10% formaldehyde. After this, the stomachs were placed on a *petri* dish, scraped with a scalpel to remove all their contents, the items were enumerated and the identification of these was carried out to the smallest possible *taxon*, with the support of specific literature. According to the Degree of Digestion, its content will be classified as: Fully Digested (FD); Partially Digested (PD) and Integer (I).

The Frequency of Occurrence (FI) was analyzed by adding the number of stomachs in which items were present, divided by the total number of stomachs analyzed, according to the formula: Fi = (ni x 100) / N, where ni = number of samples with food items and N = total number of samples.

The Relative Importance of each food item was evaluated using a classification index (% RI), which was calculated as: % RI = (% N +% F / 2), where % N is the average percentage by number of each item and % F is the percentage frequency of occurrence for each item.

The percentage of fish with empty stomachs (the Vacuity Index, I_v) was registered throughout the sampled year.

2.2.4. Fecundity

Gonads are paired organs that are attached to the peritoneum on either side of the swim bladder and run the length of the body cavity. The Absolute Fecundity was estimated using the average of three subsamples removed by scraping hydrated oocytes of the anterior, middle and posterior region of 10 mature gonads (ovaries in "B" and "C" stages) already maintained in Gilson's solution for the complete dissociation of hydrated oocytes. In this method, from a sieved mesh material of 250 μm and diluted in 2,000 ml of water, a 2 ml sub-sample was collected using a Stempel Pipette, and the number of hydrated oocytes was counted using a Dollfus Cube, extrapolating this count to the 2,000 ml of dilution. Relative Fertility (hydrated oocytes / kg of fish) was given through the general averages. The average diameter of the hydrated oocytes was measured per specimen (Zeiss magnifying glass, under variable amplification. Pictures and measurements were taken with the ZEN 2011 program). The average, standard deviation and coefficient of variation of the subsamples were also calculated.

2.2.5. Growth Parameters, Back-calculation and Statistical Analysis

Since small fish are usually discarded in fishing landings, we back-calculated all data from size by age using the relation between the otolith radius (Ro) and the fish size (Lt), in the model developed by [42] [46]. The length of the otolith was given by the measure of the axis measured between the focus and the distal edge of the otolith (Ro). The lengths of the otoliths (E (otolith radius (Ro)) and the Total Lengths of the fish (Lt) were plotted in graphs, to verify if there is a linear relationship between them, such data were adjusted to the linear equation Y = a + bX; where: X = length of the otolith (E = Ro); Y = Total fish length (Lt); a = intercept and; b = value of the coefficient (dependent variable); using the *least squares method: Lt = a + bE (X)*. Another way to performing the back-calculation uses the biological intercepts of the species [47]. Are considered 2.0 – 2.4 mm (the average length in hatching; Lo') and 0.0 mm (lowest average variation; Ro'), respectively, as the adopted values for the Bluefish [48] [49]. The biological intercept is defined as the point in which the relationship between the otolith radius and the length of the fish becomes linear, often at the very hatching. The most extreme change in the average may occur when all individuals below (or above) a determined length class (smaller, average (conditioning) or larger) are removed from the calculus. As the back-calculation interval increases, the overestimation of variance of the observed population will also tend to increase. Thus, the error in the average during back-calculation may not be explained only by the sampling process.

We compared the Growth Performance (ϕ') for *Pomatomus saltatrix* estimated by different authors using the phi-prime test: $\phi' = \log k + 2\log L\infty$ [50]. Since it has been suggested that phi-prime test values are similar for the same species and genera, this test provides an indication of the reliability of age estimates [50].

To verify the temporal variations between the analyzed parameters the Kruskal-Wallis test (*H*) and Tukey's test *T* (*F*) were used. To determine the sex-ratio between females and males (F: M) and unsexed, the chi-squared test ($\chi 2$) was applied. Tukey's test being used to determine which means differed. The correlation coefficient between the regressions was tested using the One-way ANOVA. The degree of association (correlation) among the variables was calculated by the Coefficient of Correlation of R^2 (0-1). All were compared at the significance level of $p \leq 0.05$. Statistical analyzis used [51].

The descriptive statistics derived from the use of statistic functions of MICROSOFT EXCEL® 2007 and of STATISTICA™.

3. Results

3.1. Age and Growth

3.1.1. From otoliths

Regarding the abundance of ages by lengths, **Figure 2** showed samples from 1+ to 12+ years (grouped sexes); 1+ to 12+ years (females); 1+ to 10+ years (males) and; 1+ to 7+ years (unsexed). The mean age was between 2-5+ years (N=202). Frequencies of occurrence: 2+ years (14.85%); 3+ years (25.74%); 4+ years (23.26%) and 5+ years (13.36%). For the length-age ratio see [52]. The ages (number of age rings) varied from 1+ to 12+, with a maximum observed age of 12+ years, 915 mm and 6 kg from a female (September/2017).

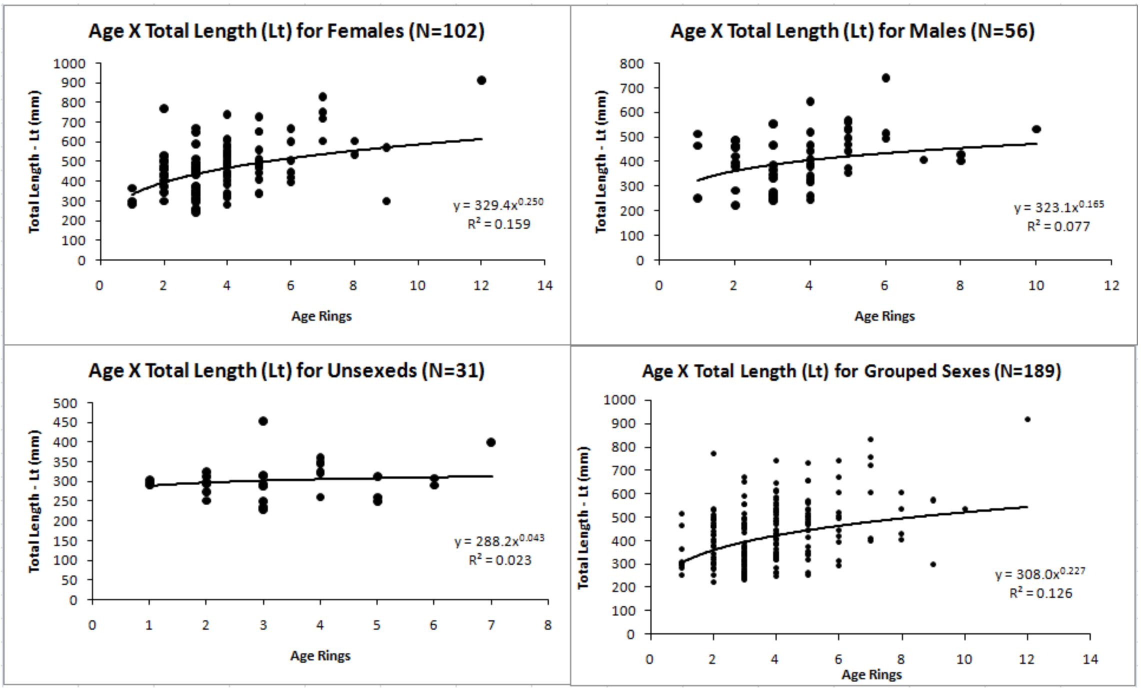

Figure 2. General relationship between the Age Rings (+) of the Bluefish from the present area, as a function of their Total Length (Lt) in mm.

Within the same probable cohort, a high variety of length classes occurred. There were no samples of extreme large (Lt >915 mm) and small (Lt <222 mm) classes. For information on the relationship between somatic growth and otologic growth see [53]. The Growth Performance (ϕ ′), for *Pomatomus saltatrix* in local waters (2.85) was closer than in other localities around the globe: 3.17 [54]; 3.30 [55]; 2.67 [56]; 2.78 [57]; 2.30 [58] and; 3.28 [59].

3.1.2. From scales (only for comparison)

The number of age rings in scales varied from 1 to 13. The variation in the number of age rings counted by the scales was, on average, 1-2 times greater than found in the otoliths. The **Figure 3** shows the variation on average count of age rings between otoliths and scales during the months. It has been frequently observed that, immediately after the marking of the first annual rings, a new "*radii*" appear in the lateral fields of the scales. The appearance of a new "*radii*" is a useful criterion for the identification of true rings in the scales.

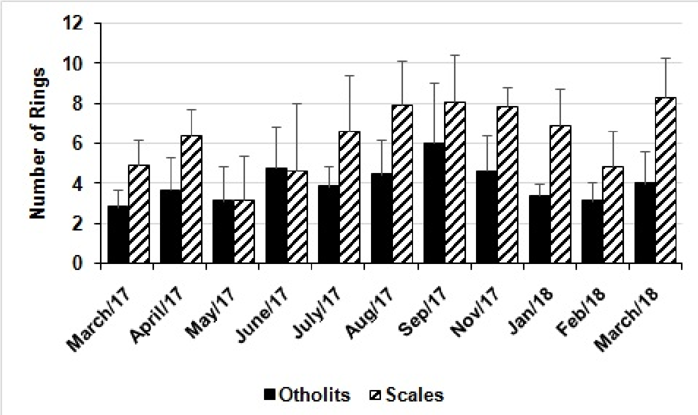

Figure 3. The variation on average count of age Rings between all Otoliths (N=190) and all Scales (N=199) from the Bluefish during the months. Significant differences between readings were found ($p \leq 0.05$).

3.2. Diet

For feeding studies, the stomachs of 202 specimens of Bluefish were examined, of which 14.40% presented content (Frequency of Occurrence (FI) - %) and all with the Degree of Stomach Repletion (0-3) ≥1. A total of 3 different food items were found in the stomach contents examined (small pelagic teleosts, squid and organic matter). The most frequent items found in the stomach were small pelagic teleosts. At the species level, the items with the highest food frequency were small pelagic teleosts (>83.00%), followed by *Loligo sp* (>8.30%).

The Degrees of Digestion presented: Fully Digested (FD) = 9.37%; Partially Digested (PD) = 78.12% and Integer (I) = 12.50%.

The Relative Importance (%) of each food item was: *Anchoviella lepidentostole* (31.25%); *Sardinella brasiliensis* (25.00%); *Mugil curema* (21.88%); *Loligo vulgaris* (6.25%); *Dactylopterus volitans* (3.13%); *Haemulon* sp. (3.13%); *Scomber* sp. (3.13%) and Organic matter (6.25%).

The percentage of fish with empty stomachs (the Vacuity Index, I_v) registered throughout the sampled year was 85.60%.

Analyzing the data by seasons of the year it can be affirmed that there is a low variation through the months of the year. Only fish were found in all of the specimens' stomachs. Many stomachs could not have all the food items identified because of the advanced digestion process they were in. Items identified as possible bait were excluded from the analyzes.

Results confirmed that *Pomatomus saltatrix* is a species of carnivorous habit with generalist-opportunistic and demersal-pelagic behavior, feeding mainly off of small fish and mainly oriented by vision, according to the offer of food during the day on the surface near the coast, at night in offshore and deeper waters [5].

3.3. Fecundity

The Absolute Fecundity per mature ovarian ("B" and "C" stages) showed: average on 696,074 hydrated oocytes, ± of 105,690.41 and the coefficient of average-general variation (%) of 16.30. A higher number of hydrated oocytes and greater average diameter, in stages “B” and "C" of maturation respectively (macroscopic examination (observing the size relative to the abdominal cavity, shape, coloration and vascularization of the ovaries (elongated and tubular) and testes (elongated, flat, tubular and white))) in August/2017 and September/2017 suggesting the occurrence of two probably main reproductive periods for the species in the region of Arraial do Cabo - RJ (bimodal event). The Relative Fecundity per mature ovarian ("B" and "C" stages) / kg of fish) was equal to 305,381.34 hydrated oocytes. The mean diameter of the hydrated oocytes measured (N=86) was 1005.08 μm (± 325.91 & general average variation coefficient was equal to 23.02%). In all seasons there was the occurrence of all gonadal stages. As spawning intensity is high, split spawning and the survival of offspring are probably confounded, a bimodal pattern of larvae and juvenile abundance may occur. The total number of hydrated oocytes that form the highest mode (upwelling area (local thermal threshold equal to ≤18ºC) with the average temperature between 20ºC and 25ºC) was considered as the spawning lot.

A study listed nematode parasites in fish in Brazil, and cited species of *Philometra* parasitizing marine fish, such as the Bluefish gonads [60]. The *Philometra saltatrix* is a specific parasite for the Bluefish along its entire distribution [61]. Fortunately, during our study, no parasite was found in the gonads (ovaries or testicles).

3.4. Somatic and Otolith Growth Relationship

Of the total analyzed otoliths pairs (N=190), 189 were used for the back-calculation of length per age. The back-calculated expresses the relation between the radius of the otoliths (Ro) and the Total Length (Lt) of the specimens during capture (L_c). Linear regressions (Lt = a + bX) between otolith ratios and total fish lengths were adjusted to grouped sexes (y = 192.2x + 349.4; $R^2 = 0.060$; $p \leq 0.05$), N=189, in **Figure 4**.

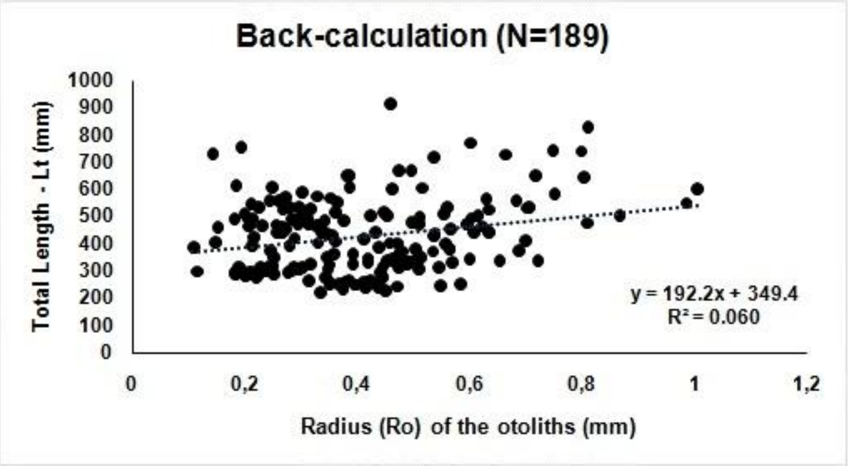

Figure 4. Back-calculation - Relation between measurements of the Radius (Ro or E) and the Total Length (Lt) data of the collected specimens of the Bluefish from the present area. The trend line represents the average of the back-calculeted radius ($p \leq 0.05$).

3.4.1. Using the general average values of Marginal Increment (MI) as the Validation

The variations in the average values of Marginal Increment (MI) were significant throughout the year (F = 2.2374; p = 0.0176; KW-H = 29.3098 and; p = 0.0011). The lowest average of monthly MI in all otoliths of *Pomatomus saltatrix* (N=190) was observed in March/2018 (MI = “-0.69” (mean)). As the number of individuals sampled with translucent borders was maximized in the same months, an annual pattern could be evidenced.

Physiological changes (K and HSI) correspond to the evolution of MI. Significant different monthly averages were observed in K (**Figure 5** and **Figure 6**) and in the HSI (**Figure 7** and **Figure 8**).

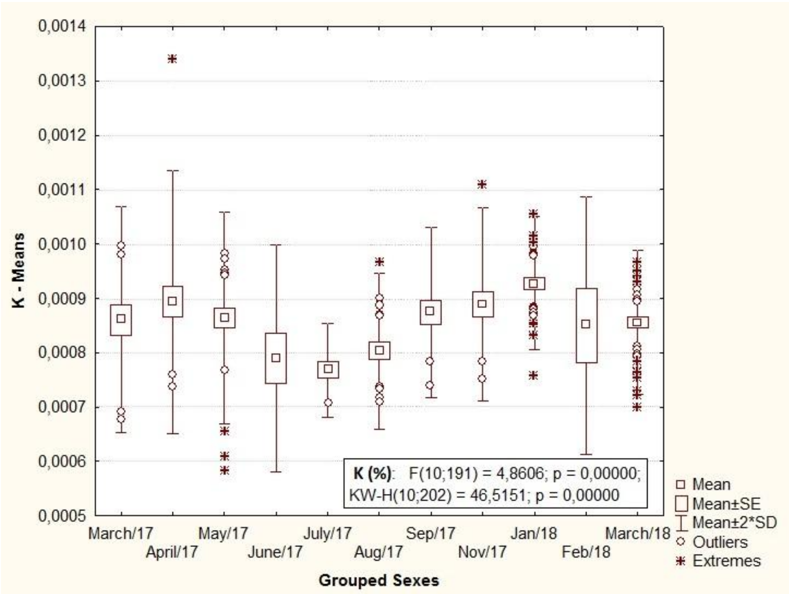

Figure 5. Tests: Tukey-F/T (parametric) and Kruskal-Wallis-H (non-parametric); mean values and significant differences ($p \leq 0.05$) for the K parameter of the Grouped Sexes (subtle variations over the months) for the Bluefish of the present area. Higher average/means increases from July/2017 to January/2018.

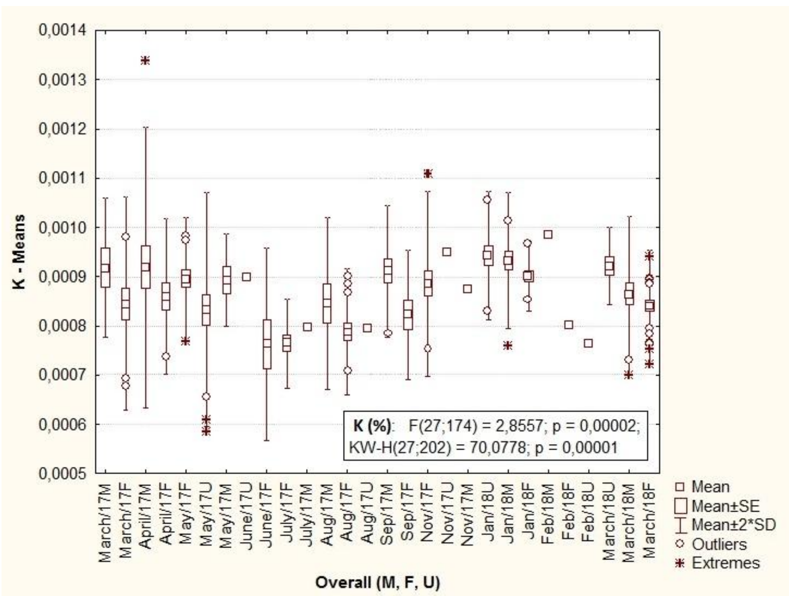

Figure 6. Tests: Tukey-F/T (parametric) and Kruskal-Wallis-H (non-parametric); mean values and significant differences ($p \leq 0.05$) for the K parameter for Overall: M, F, U (subtle variations over the months) for the Bluefish of the present area. Higher average/means increases from July/2017 to January/2018.

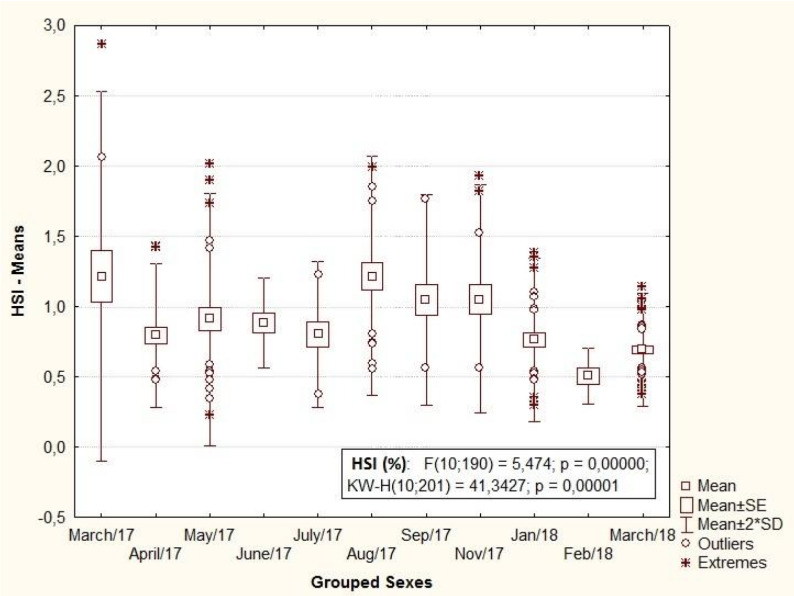

Figure 7. Tests: Tukey-F/T (parametric) and Kruskal-Wallis-H (non-parametric); mean values and significant differences (p ≤ 0.05) for the HSI parameter for Grouped Sexes (subtle variations over the months) for the Bluefish of the present area. Higher average/means increases from July/2017 to August/2017. Four medium peaks were found: March/2017; August/2017; September/2017 and November/2017.

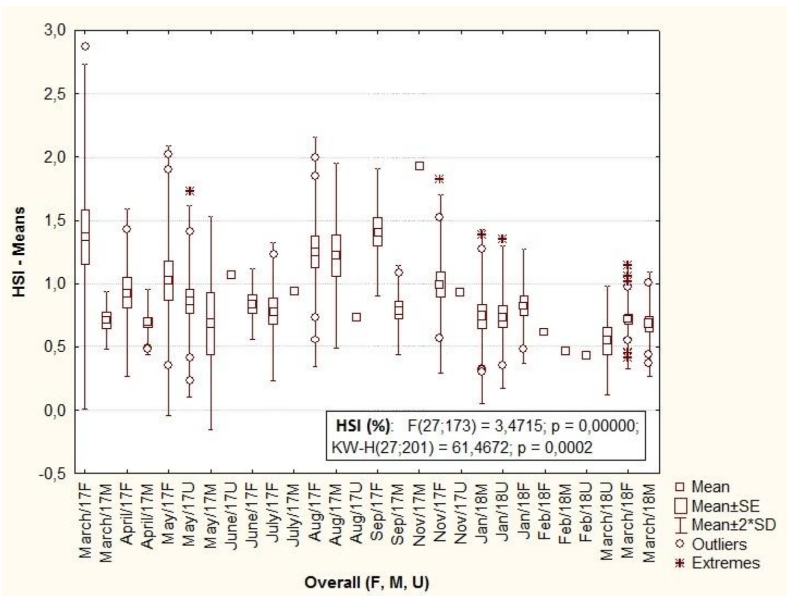

Figure 8. Tests: Tukey-F/T (parametric) and Kruskal-Wallis-H (non-parametric); mean values and significant differences (p ≤ 0.05) for the HSI parameter for Overall: F, M, U (subtle variations over the months) for the Bluefish of the present area. Higher average/means increases from July/2017 to August/2017. Four medium peaks were found: March/2017/F; August/2017/F; August/2017/M and September/2017/F.

3.5. Sex Ratio and Size Distribution

Females (N=109 / 53.9%) prevailed over males (N=59 / 29.2%), being 1.84: 1 the ratio between sexes ("*sex ratio"* - F: M); and on specimens of undetermined sex/unsexed (N=34 / 16.8%) for N=202. The term "unsexed" refers to those specimens, which could not have their sex identified by the authors only from the macroscopic analysis of the gonads, because they are extremely filamentous, making it difficult to differentiate them. Females tended to be larger and more abundant between the sexes and all size classes. The minimum and maximum total lengths (Lt) of the Bluefish varied from 201 mm in February/2018 to 915 mm in September/2017, respectively (N=2,057). Length classes <250 mm Lt were underrepresented in both sexes. The average Lt was 541 mm and the average of Total Weight (Wt) values was 1,428.5 g. Females ranged from 241 mm to 915 mm Lt with the mode at 418 mm; males ranged from 222 mm to 741 mm Lt with the mode at 465 mm and unsexed ranged from 230 mm to 780 mm Lt with the mode at 300 mm. The average lengths of 472 mm and 415 mm Lt were determined for females and males, respectively, and for unsexed the average length was 333 mm Lt.

The distributions of the Lt (mm) Classes for Bluefish showed, for the most part, a normal growth curve, the proportion between females and males being inverse, with females becoming increasingly more abundant, corroborating with the expected and with the description in references [39]; in **Figure 9**.

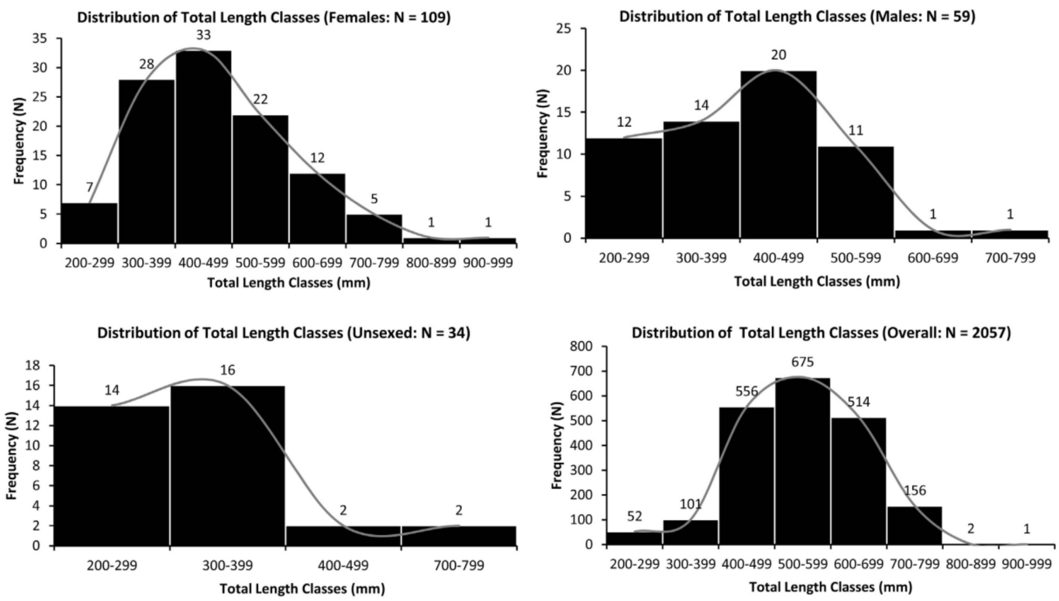

Figure 9. The general distribution of Total Length Classes of the Bluefish from the present area [39].

The results of the averages for Lt and for Wt, for overall, showed that the months of May (autumn) of 2017 and February (summer) of 2018 had records of the highest (627 mm and 2,061.3 g) and lowest (435 mm and 822.6 g) results, respectively. When separated by sex, the highest averages (556 mm and 1,569.2 g) were registered in June (winter) of 2017, and the lowest averages (274 mm and 289.5 g) also in February (summer) of 2018. Distribution of the length classes also varied between months. The monthly distribution of TL Classes (mm) for the separated sex, according to production and the availability of copies for sale, presented smaller difference and standard deviation among the means as expected, probably, caused by the lower number of samples (N) [39]; in **Figure 10**.

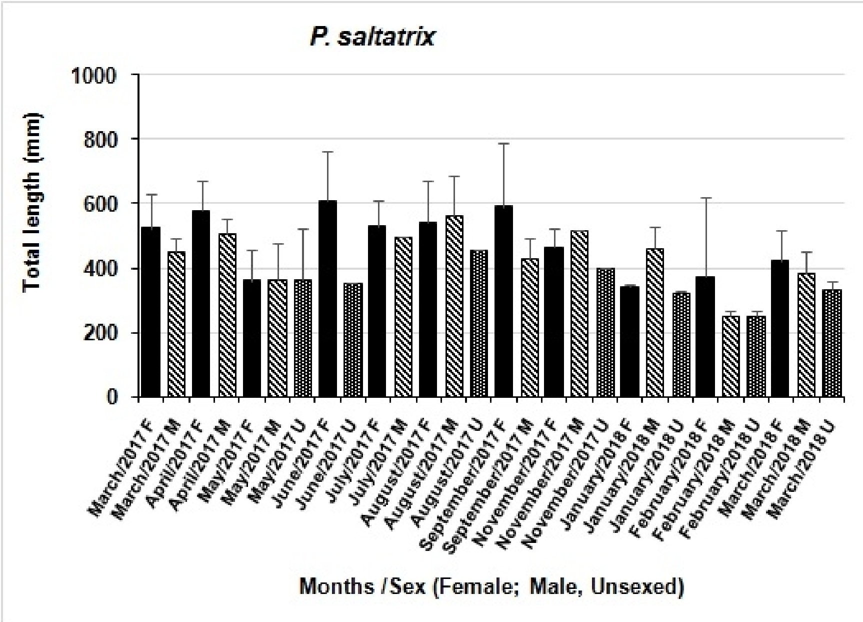

Figure 10. The monthly distribution of Total Length Classes (mm) for the separated sexes (Female; Male, Unsexed) of the Bluefish from the present area [39].

3.6. Maturity

The assumed estimates of the average length-at-first-maturation (L_{50}) were in average of 452 mm Lt for grouped sexes (1-12+ years); 472 mm Lt for females (1-12+ years); 415 mm Lt for males (1-10+ years). From these average lengths, all specimens were considered as mature individuals (L_{100}) and therefore, active participants in the reproductive processes.

Months tendencies in gonadal maturation growth were observed for grouped sexes in **Figure 11**, although they were less significant in males in **Figure 12**. In males, GSI values lower to 7.53% (September/2017) occurred during the entire year. The spawning of Bluefish is split, with the most representative periods being the beginning of autumn and the beginning of spring-summer (bimodal event). Specimens with mature gonads ("B", "C" and "D") were found during all the sampled year. The highest GSI values (GSI = 9.18% (from a female), April/2017) matched the macroscopic analysis of the gonads in stages "B" and "C" (in maturation and mature respectively) of gonadal development, but the Absolute Fecundity was not so high, perhaps due to the small size of the specimens captured at this time. As for Fulton's Condition Factors (K), there was no interference related to the weight of the gonads, which showed some variations.

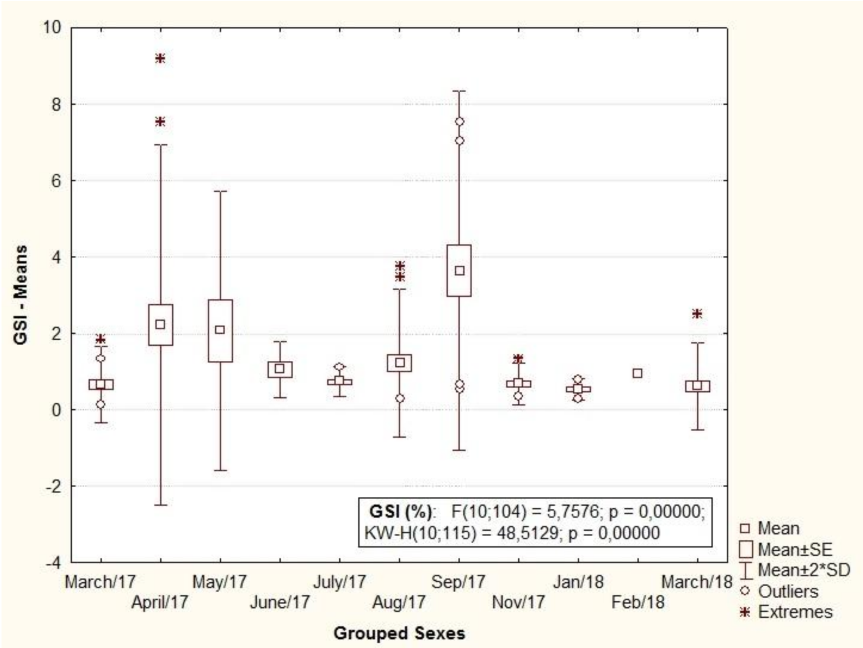

Figure 11. Tests: Tukey-F/T (parametric) and Kruskal-Wallis-H (non-parametric); mean values and significant differences ($p \leq 0.05$) for the GSI parameter for the Grouped Sexes (subtle variations over the months) for the Bluefish of the present area. Average monthly tendency of gonadal development (maturation). Average increases more pronounced from July/2017 to September/2017.

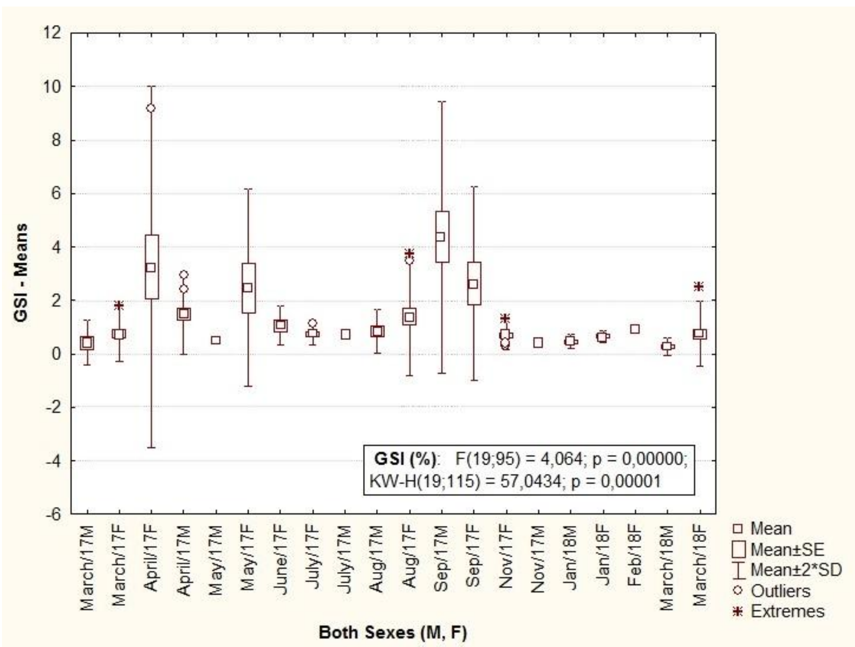

Figure 12. Tests: Tukey-F/T (parametric) and Kruskal-Wallis-H (non-parametric); mean values and significant differences ($p \leq 0.05$) for the GSI parameter for the Both Sexes: M, F (subtle variations over the months) for the Bluefish of the present area. Average monthly tendency of gonadal development (maturation). Maximum mean value for males in September/2017 and minimum mean value for females in January/2018.

The percentage and quantity of gonadal maturation stages throughout the sampled year (March/2017 to March/2018) are indicated by **Figure 13** and **Figure 14**, respectively.

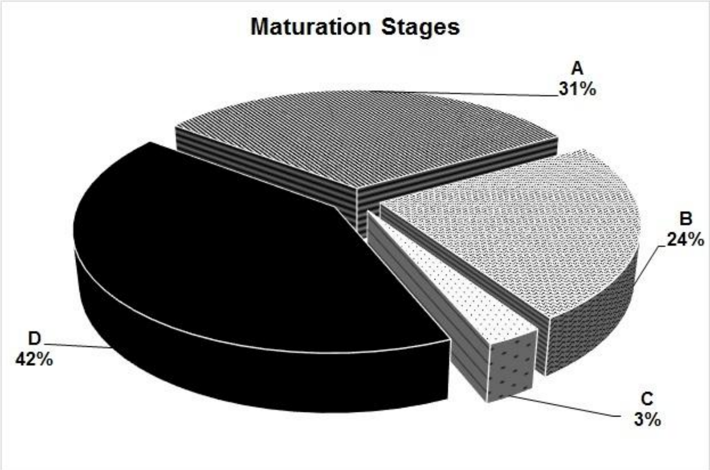

Figure 13. The percentage of the gonadal Maturation Stages ("A" (immature); "B" (in maturation); "C" (mature) and "D" (spawned)) throughout the sampled year (March/2017 to March/2018).

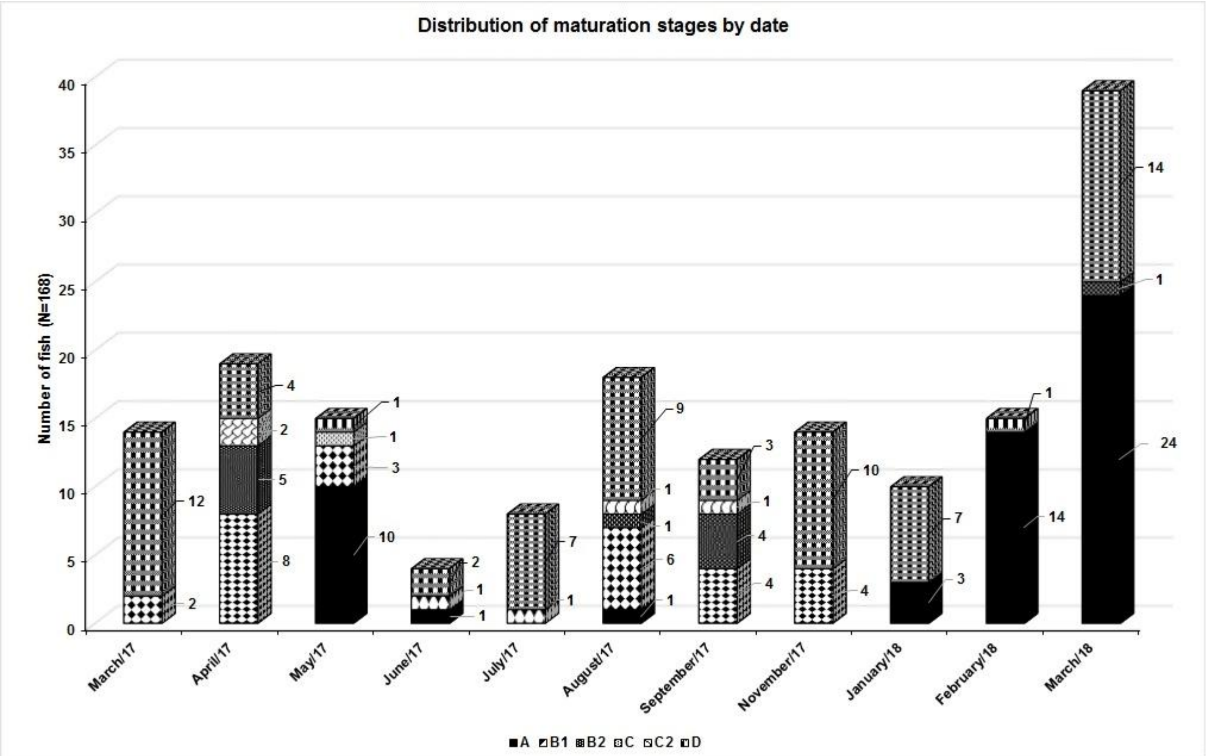

Figure 14. The quantity and distribution of gonadal maturation stages ("A" (immature); "B1 and B2" (in maturation); "C and C2" (mature) and "D" (spawned)) throughout the months of the sampled year (March/2017 to March/2018).

4. Discussion

It was presumed that the analyzed fish represent the Brazilian stock of the Bluefish. The *Pomatomus saltatrix* specimens of Brazil and Argentina seem to belong to a unique stock, and the observed patterns of migration show similarities to other regions: movement toward lower latitudes in winter, when surface temperatures drop, and toward higher latitudes in the end of spring and in the summer. Adults moving south in the end of spring and in summer seem to be following the movement of warm waters of the Brazilian Current [12]. Little is known on the specific stock of Bluefish captured in the State of Rio de Janeiro. They may also belong to a separate stock, directly associated to the upwelling of Arraial do Cabo – RJ (an upwelling area (local thermal threshold equal to ≤18ºC) with the average temperature between 20ºC and 25ºC and minimum average of 14-16ºC) in the Southwestern Atlantic Ocean).

A method called back-calculation is constantly employed to estimate the size of uncaptured fish at a certain age, using daily or annual increments from the otoliths. The otoliths may be used in a trustworthy way to calculate the size-age ratio after the validation of the predicted formation of the age rings that are formed on these apposition structures, the length of the fish and the otolith ratios have a functional correlation [47]. When data from direct observation of the distribution of class sizes of a previous cohort is not available, back-calculation enables a valuable estimate of average size in previous ages. In addition, when compared to the direct observation of sizes through time, back-calculated sizes provide a valuable temporal series.

Otoliths have shown to be better for aging Bluefish than scales [62]. The Bluefish, according to the largest number of published data, lives on average, between 6.3 (males) and 7.8 (females) years of age, with females being more present in the various age groups and length classes described. In its "Age Zero" (hypothetical) it has its total length ≤250 mm and they usually come from specimens found in estuaries or in offshore waters [12] [20]. The oldest fish found in this study was 12+ years old (a female). The maximum recorded age is of 14 years at Chesapeake Bay region [21]. The maximum age in this study was close to fish from other studies, of 11 years [63]; 12 years [64] and [55] and, 13 years [59]. Some specimens of this study probably did not experience the same habitat, contributing to the presence of older individuals with otoliths of higher or faster growth. This greater longevity may explain the lower rates of Fulton's Condition Factors (K) (unsexed specimen, K = 0.000583, May/2017) and higher asymptotic sizes ($L\infty$) of *Pomatomus saltatrix* registered in this study (assumed as $L\infty$ = 915 mm). The great length variety observed within one unique cohort may be attributed to its reproductive pattern: it is a species of split spawning and high PLD (1-8 days; [16]). The 1 or 2-year-old fish captured in offshore waters may be mature fish that have not yet gone back for spawning in inshore waters [65]. The occurrence of samples with more than 3 years of age in inshore waters probably represents the group of samples who have gone back, after spawning, for feeding [66]. However, since the otolith formation happens during the first stages of the egg (from 0 to 24 hours), it would be complicated to obtain an exact length average in the moment of formation [49]. Given that, this measurement is probably lower than the hatch size of 2.0 mm to 2.4 mm [48]; and that the growth of the otolith in relation to the somatic growth is linear, forcing an intercept of zero must provide reasonably precise length estimates [48] [49]. The presence of a narrow hyaline zone near the core of the otoliths characterizes the occurrence of a disturbance in the growth rhythm during initial stages of development of the Bluefish. The mark of this zone may be associated to dietary habits, habitat or even to exogenous variables that slow down growth for a short period of time [67]. The visualization of the rings in the beginning of summer probably happens due to the resumption of growth after spawning.

The analysis of seasonal feeding habits and the change in trophic habitat observed during the sampling periods provide evidence for a more complete coastal evaluation of the diet of the Bluefish [also see 68]. Engraulids and atherinids are important sources of food. Regarding recent inter-cohort feeding, a restriction of available prey would be of particular importance to the summer cohort, which already experiences a narrower range of potential prey due to its smaller size [25]. Adults have their diet mainly dominated by pelagic fish [69]. Juveniles have their diet mainly dominated by small specimens, mainly engraulids and atherinids [20]. Stomachs with different kinds of items usually had the same type of prey and stage of digestion, which shows an extremely voracious predatory behavior. The seasonal variation showed to be of low importance in relation to their most common eating habits (small pelagic fish). Predation tends to be based on size rather than species, resulting in different diets, but in relationships similar to predator size. Variations in the relative growth rate of predators and prey, predator size preferences, and timing of the change to piscivorous diets are probably the most important variables affecting the outcome of interactions between predator and prey populations (Top-Down trophic controls).

Upwelling events along the southeastern Brazilian, more frequent during spring-summer [70]; generate spawning benefits for local species (mainly during these peaks (summer)). The Hepatosomatic Index and the Condition Index increased especially during the winter-summer and autumn-summer respectively, reaching maximum values by the end of the summer and spring respectively, before the start of a new spawning period, in this study may have resulted from the energy accumulated during the peaks of the upwelling and even confirms the results of marginal increment. There is a positive relationship between the size and lipid content of the Bluefish during winter for individuals born in spring [71]. The juveniles depend on multiple deposit tissues (liver, viscera, skin, and others) for lipid storage and mobilization, for metabolism during winter and for the cohorts [72]. Seasonal patterns of energy depletion observed in fish in natural environments also support these arguments [73]. The mortality rate of fish during periods of stress caused by the cold has been related to size.

Smaller individuals show higher mortality rates since larger fish usually have larger reserves of energy [31]. The dynamics of lipid accumulation may not be as dependent on size as previously assumed, and there may be a trade-off or specific physiological restriction to the cohort between growth and energy use in juveniles [74].

Fecundity rates are important for management and almost inexistent for the Bluefish. The low Gonadosomatic Index (GSI) described for the Bluefish is typical of split spawning [64]. If so, then the fecundity estimates of the Bluefish may be biased, potentially underestimating the productivity of the Bluefish. In other studies, showed that Bluefish in Africa and in Brazil, respectively, have split spawning [12] [75].

Bluefish eggs have a spherical smooth membrane and range from 0.90 mm to 1.20 mm (average of 1.00 mm), and the oil globule was smaller, varying from 0.22 mm to 0.30 mm (average of 0.25 mm) with pigmented appearance, one only oil globe of around 0.2 mm of diameter and lined-up melanophores in the embryo [16]. After fertilization, the egg capsule is transparent, colorless, thin but tough, the amber yolk is pale and the only oil globule is large, a deeper amber. In preserved tissues, the blastoderm tissue is white, more opaque and slightly granular. The perivitelline width is approximately one-sixth of the radius of the egg. Bluefish eggs hatch from 46 to 48 hours. The yolk is almost consumed 2 days after hatching. In addition, the evidence of multiple spawning is that the number of vitellogenic oocytes maturing in the ovaries did not decrease during spawning times, indicating continuous oocyte recruitment. There is considerable overlap in oocyte diameter between stages, with no distinct modes, except between oocytes with oil layers and hydrated, indicating that the fecundity/fertility of the Bluefish is undetermined. The presence of hydrated oocytes in advanced stages indicates that fish are able to spawn several times in a single season. Some ovaries can show some early atresia (α-atresia) with healthy and surrounding oocytes. There are records of many healthy oocytes, along with atreic oocytes, which did not mean complete reabsorption. The development of the gonad and the beginning of the spawning were probably asynchronous. The larvae grow slowly, showing rapid growth only on the first day, and probably die from the eighth day after hatching [16]. The size of the egg varies on many scales: within a spawning season, egg size usually decreases as the season progresses; larger females generally produce larger eggs; environmental factors (e.g. salinity, temperature) may affect the size and quality of the egg [76]. Analysis of the development stages of Bluefish eggs suggested that spawning activity peaks early in the evening near sunset [13]. Fecundity estimates by size showed the variability observed among the size ranges [75]. The lack of a strong relationship between fecundity and somatic length or weight is probably explained by both the scarcity of large fish and the nature of the reproductive biology of the Bluefish (split spawning). If spring and summer spawning seasons represent distinct stocks, spawned adults caught in the spring should be large in size back-calculated to the 1st year, due to a shorter growing season [64].

The marginal increment analysis indicated that the rings were established during winter. The pattern of incremental formation at the same time in juveniles and adults suggests that the regulatory mechanism cannot be related only to somatic growth or reproductive activity [77]. The increment formation is an independent physiological process, more directly responsive to environmental variations [78]. For further information on the possible asymmetries present in the apposition structures, here focusing on otoliths, the reading of the work [79] [80] is indicated; of which one of the focuses is sclerochronology (study of physical-chemical variations in the formation of rigid structures of organisms in the context of their formation). Ring formation occurs in winter (June to September) and is associated to lower water temperature [12]. Rings do not become visible until growth restarts in January or February. During the peak of spawning, January-February-March, the true age of individuals with a ring is 7 months on average [20]. Growth increments are possibly annual. The back-calculation should be restricted to the most recent ring to avoid sampling bias [81]. The importance of initial growth (recruits) for classification supports methods in which early incremental growth is used to separate stocks. The spatial distribution of sex ratio is mainly dependent on local reproductive activity. A fish born in spring are reproductively active in the summer [64].

The bio-ecological growth parameters in the present study indicate sexual dimorphism in length in *Pomatomus saltatrix*. Females reach a larger size (unimodal data) and live longer than males, as also reported [12]. This results in different growth rates between females and males, with environmental factors being a major stress generator influencing this growth. The L_{50}, for grouped sexes, of 452 mm Lt determined for the *Pomatomus saltatrix* is relatively close to that determined on the east coast of the USA (480 mm Lt) [59]. On the other hand, it is superior to the L_{50} of 250 mm Lt in South Africa [82]; of 430 mm Lt, obtained in the Senegal-Mauritanian coast by [83]; in the south of Brazil, the Bluefish length at the first maturity is from 350 mm to 400 mm Lt [20] and this stock is considered to be relatively fast growing; it is 334 mm for females and 339 mm for males [55] and it was 254 mm (Fork Length) [57]. A maximum of Bluefish's length of 672 mm was registered in purse seine samples in the south of Brazil [54]. During the main spawning period of the species, these differences can be explained by the variation in the methods to determine such parameter. The presented study determined, for the area of the *RESEX-Mar* of Arraial do Cabo – RJ, the L_{∞} = 915 mm, on the northwest coast of

Africa, the L_∞ = 1,044 mm Lt [83] and in the Atlantic Ocean, the L_∞ = 1,019 mm Lt [84].

Species distributed in large areas often show very evident growth differences considering the high variation in latitude [85]. These variations can be attributed to different food supply conditions and temperatures prevailing in these areas [86]. Cold waters (the study area presents upwelling) tend to produce larger, longer-lived and late maturing individuals (slower metabolism). Bluefish generated in summer are larger in body size at a certain age compared to the Bluefish born in spring, which is partially due to the rapid growth of spawned fish in the summer. On the other hand, the characteristics of the life history of the Bluefish born in the summer will probably cause a selective disadvantage, since this cohort experiences an increase in size-dependent mortality during seasonal migrations and winter periods [24]. Bluefish born in the spring have historically dominated the annual class and, therefore, presumably determines the dynamics of the adult population [87]. It is plausible affirm that the body size discrepancy between spring and summer at the beginning of autumn migrations and winter periods is a key factor that regulates the recruitment dynamics of this species [88]. Recruitment size was defined as between 40 mm and 70 mm [89].

The average Length-in-capture (Lc) regarding L_{50} has been suggested as a potential indicator of fishing pressure on the stocks. If Lc exceeds L_{50}, the biomass of a mature stock is probably higher than what may produce a maximum sustainable yield, implying that fishing is probably to be sustainable [90]. The average of overall Lc value (Lc = 541 mm) assumed in our study is above to the estimates average of L_{50} (L_{50} = 452 mm), nevertheless reinforcing the need for adequate management of this stock (even though it appears to be within a sustainable fishing situation). Our estimates of L_{50} could contribute to the future implementation of a minimum size for capture of the species in the Rio de Janeiro State. The growth rates of fish born in the summer would be higher than of those born in the winter of the same cohort [91].

A study compared the age-length relationships among global populations of *Pomatomus saltatrix* [26]. Three clusters were apparent. The fast-growing group included the northeast of the North America [92]; and populations from northwestern of the Africa [83]. The intermediate growth group included the Black Sea [93]; eastern South America [94]; probably as the group of the present study. The slow-growing group included the South African [82]; Mediterranean [95] and Australian populations [38]. These various growth groups were related to size at maturity: faster growing populations have larger sizes at maturity [26].

Morphometric variation studies and meristic analyzes among populations continue to play an important role in the identification of different rates of growth, mortality or reproduction that are relevant to the definition of fish stocks [96]. Examples of the main meristic variations are: vertebrae numbers, gill rakers, dorsal fin rays, anal fin rays, second dorsal fin rays and lateral line scales. The morphological variation between fish populations is influenced by a mix of environmental external factors that include, but are not limited to, hydrography, geography, temperature (main element), salinity, radiation (photoperiod), dissolved oxygen, water depth, bio-oceanographic and biogeographical barriers, current flows and different larvae transportation mechanisms, seasonality, food offering and predation; and endogenous factors as: size, different habitats, reproductive isolation, physiologic changes (metabolism), allometric growth and diet, as it is also partly quoted by [97].

The Bluefish is currently considered as vulnerable [98] [99]. In this case, the monitoring of the *RESEX-Mar* of Arraial do Cabo - RJ must have a more preventive function [100]. The conservation measures include: the reduction of fishing efforts with purse seines and a limit of juvenile captures [101]; the official determination of a defense period, of 4 months (December 1st to March 31), during spawning summer-autumn peaks and upwelling peaks, as well as the establishment of a minimum capture size of 350 mm, possibly mature specimens already having their first spawning [3]. Through these, the capture of new recruits would probably be avoided. The Rio de Janeiro State (BR) still does not have a specific defense period or official norms for the correct capture of the Bluefish [3].

5. Conclusions

The present study identified the months of November and December (spring and summer) of 2017; January, February, and March (summer and summer-fall) of 2017 and 2018 as the reproductive peaks of older adults (spawning peaks) and the months of March (summer-fall) of 2017 and February (summer) of 2018 as the most fishing productive, periods that coincide with the peaks of the local upwelling. The increase in Bluefish abundance may have been caused mainly by increased recruitment during spawning periods, leading to a change in the contributions relative to fish born throughout the year and because of high local productivity.

Stocks harvested in the region may be formed by a single resident and/or transitory cohort that during its growth period, changes the spawning season or site. Further investigation is needed to quantify the impact on population dynamics and recruitment patterns of Bluefish in the region. In fact, it is important to let juveniles grow to the ideal size and focus on capturing older or mature individuals. This would increase fishermen's productivity and yield, leaving the stock healthy.

The upwelling oceanic waters, rich in nutrients, are important for this species during the winter period. The absence of food in the winter is probably responsible for the decrease of recruitment of the summer cohort to the local stock. One of the major research goals in marine ecology is to understand all the processes that cause variation in recruitment. Clearly, there is an urgent need to incorporate biotic interactions in predicting the impacts of climate change. Understanding trophic adaptability is a step in this direction.

The Bluefish has difficulty catching and ingesting live prey during the winter. This would lead to a greater energetic expense during this season and would also increase the vulnerability of the Bluefish to predators. In addition, relatively large prey becomes increasingly difficult to ingest as temperature drops, due to metabolic decrease. This suggests that the reason for which the Bluefish shows an adaptation to energy conservation during the winter may result in a consistent limitation of prey during winter. The abundance of prey in large scale may have important implications on survival during this period. The distribution of prey size is also important.

The reading of otoliths seems to be better and more precise than the reading of scales. The formation of age rings in otoliths tends to be a mainly annual process, probably occurring in winter, and seems to be associated to the low temperature of water, to energetic expense and to the reduction of feeding activity during migratory movements, which eases its measurement and related analysis. On the other hand, scales have a clearer presence of daily age rings (Circadian Cycle), which, in many cases, may lead to an extrapolation in the determination of annual rings due to counting errors.

For a better fishing management, it is advisable to recalculate the CPUE and establish lower levels of exploitation due to imprecise calculations of the Maximum Sustainable Yield (MSY), obtained when the instant mortality rate by fishing is approximately equal to the natural mortality rate, where values and abiotic variables in the reproductive and growth processes are not yet well-known. They are also due to calculating rates of: Total Mortality (Z); Natural Mortality (M); Fishing Mortality (F) and Exploitation/Exploration (E) and the longevity of the species especially for the region. To better understand the fecundity/fertility, the histological study of the gonads is advisable. For future studies on displacement, migration and foraging the employment of TAG’s is recommended, as well as abiotic studies (anthropic pollutants and others) and local oceanography.

Considering that the region has an important *RESEX-Mar* for sustainable use, collecting more information on fishing activities and on the condition of the stock of Bluefish is really necessary. Providing all this data to local agencies to subsidize a better future and better fishing management, considering that there are few related studies, is fundamental. The present study also demonstrates the need to monitor and manage the fishing production of the Bluefish on an even broader geographic scale.

8 Steps for the Sustainable Fishing Management of the Local Stock (*RESEX-Mar* of Arraial do Cabo - RJ) of the Bluefish:

1- The official determination of a defense period of 4 months (from December 1 to March 31);
2- The active-Legal monitoring of fishing efforts and used gadgets (hooks and such);
3- The establishment of a minimum size for capture (>350 mm (non-recruits), (L_{50}));
4- The determination of fishing spatial and temporal quotas (temporal calculations of CPUE);
5- The sustainable exploitation of the resource (ideal size for catch: ≥580 mm to ≤710 mm);
6- The preservation of the Matrices (prohibit the capture of specimens above ≥710 mm of length);
7- The adequation of mesh for the nets: beach trawls = 50 mm and waiting nets = 25-45 mm. To avoid juvenile capture (recruits) which, on the contrary, may compromise the renewal capacity of the stock, and;
8- The realization of periodic campaigns to inform fishermen about current fishing regulations and the most appropriate types of gadgets to be used, as well as the correct handling methods and the freeing of inappropriate catches to minimize the fishing mortality rates of the species.

These mentioned regulations will probably create a stronger bond between bioecological processes for the species in focus, local social processes and management regulations, therefore reducing conflicts between stakeholders.

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6. CONCLUSÕES GERAIS

- A atividade pesqueira em Arraial do Cabo - RJ, fonte pioneira de renda dos pescadores tradicionais, possui características das pescarias artesanais ao longo da costa brasileira, apresentando, principalmente, uma frota pesqueira de pequeno porte, com pouca autonomia de mar e atuando, normalmente próximo à costa (águas *inshore*). A frota pesqueira artesanal em Arraial do Cabo é caracterizada principalmente por três tipos de embarcações (traineira, bote de "boca aberta" e canoa) que realizam as pescarias de cerco; de arrasto de praia; de rede de espera; de linha de mão e; de espinhel (superfície, meia água e fundo). Atualmente em Arraial do Cabo a embarcação "boca aberta" (bote) tem a preferência dos pescadores, por ser uma embarcação relativamente barata, de pequeno porte e por possuir grande mobilidade. A produção pesqueira tende a apresentar o seu pico no verão, período este coincidente ao pico da ressurgência (maior produtividade primária);
- A produção pesqueira da Enchova no estado do Rio de Janeiro é tida como homogênea. Mas, de acordo com relatos de pescadores locais (RESEX-Mar de Arraial do Cabo - RJ), a produção parece estar em queda;
- Na região, a pescaria é considerada constante e anual (contínua);
- O estoque local explorado parece ser formado por uma única coorte que, durante seu período de crescimento, muda o seu local de desova; ou por subpopulações diferentes. Pouco se sabe sobre o estoque específico da Enchova pescado no estado do Rio de Janeiro. Os peixes coletados e analisados, também podem pertencer a outro estoque separado e específico, associado diretamente à ressurgência de Arraial do Cabo (recomendação: a realização de estudos genéticos (metagenômica));
- Segundo os dados cedidos pela Fundação Instituto de Pesca de Arraial do Cabo (FIPAC), a captura total mensal da Enchova, resultante da soma produtiva entre todos os diferentes esforços de pesca empregados, de janeiro/2017 a fevereiro/2018, variou de 8.559 kg a 14.326 kg, apresentando a menor captura de 2.361 kg em setembro/2017 e a maior, correspondente a

14.326 kg, em fevereiro/2018. Em relação à sua produção anual, há flutuações que podem ser devidas ao fato dessa espécie ser migratória e cosmopolita-panmixa;

- O período de novembro/2017 a março/2018 apresentou a maior produção pesqueira (pico da ressurgência local);
- As classes de tamanho mais frequentes foram (N=2.057): fêmeas - 400 a 499 mm; machos - 400 a 499 mm; sexo indeterminado - 300 a 399 mm e; sexos agrupados - 500 a 599 mm, cobrindo uma amplitude de 201 mm a 915 mm;
- Ao longo do ano, foram obtidos espécimes (N=2.057) abrangendo as três classes de crescimento: recrutas/juvenís (≤350 mm); maduros/adultos (≥350 mm e ≤710 mm) e Matrizes (≥710 mm);
- As fêmeas apresentaram crescimento e peso gerais maiores do que os machos;
- Os parâmetros de crescimento estimados a partir dos métodos diretos (estruturas de aposição) apresentaram melhor ajuste com os dados da literatura do que aqueles estimados a partir do método indireto (RCP (*LWR*), frequências e classes de comprimento). Todavia, estimativas derivadas dos métodos indiretos não devem ser excluídas, visto que os dados de distribuição das frequências de classes de comprimento ao longo dos anos podem ser mais facilmente obtidos do que os dados provenientes dos métodos diretos;
- A média de idade ficou entre os 2-5 anos (N=202). Frequências de ocorrência: 2 anos (14,85%); 3 anos (25,74%); 4 anos (23,26%) e 5 anos (13,36%). O espécime mais velho foi uma fêmea com 12+ anos, 915 mm (Comprimento Total - CT) e 6 kg e, o espécime macho mais velho apresentou 10+ anos, 532 mm (CT) e 1.181,5 kg;
- O número de anéis de crescimento dos espécimes dissecados (N=202) variou de 1 a 12. Apresentando, em média de 2 (14,85%) a 5 (13,36%) anéis etários, para peixes com CT variando de 222 mm (macho <) a 915 mm (fêmea >);
- A determinação de idade da Enchova foi possível porque os otólitos

apresentam anéis etários bem definidos (maior legibilidade frente às escamas (Ciclo Circadiano)) que se formam com uma periodicidade anual;

- Os incrementos marginais demonstram que a principal fase de crescimento ocorre até a marcação do segundo anel etário;
- Foi observado que a zona hialina (translúcida) provavelmente se forma quando o crescimento das escamas já foi reiniciado. É assumido, através do presente estudo e das muitas referências bibliográficas consultadas, que a época de formação das marcas de crescimento (anéis etários) nos otólitos (anual) é provavelmente posterior à das escamas (diária: Ciclo Circadiano);
- A formação dos anéis etários parece ocorrer no inverno e pode estar associada à redução metabólica;
- Possivelmente a marcação do primeiro anel etário ocorre antes da primeira maturação sexual (L_{50});
- O estudo de validação da formação dos anéis etários foi fundamental para a melhor determinação e identificação dos padrões de crescimento, a ponto de serem utilizados nos modelos indiretos tornando-os ainda mais precisos;
- A partir das análises qualitativas e quantitativas do conteúdo estomacal, foi possível afirmar que a atividade alimentar da Enchova na região é constante ao longo do ano. Sua dieta está baseada principalmente em teleósteos (87,5%). Possui um comportamento alimentar claramente generalista-oportunista e de hábito demersal-pelágico, contudo há a preferência por pequenas espécies pelágicas de teleósteos;
- Não houve a presença de estômago evaginado (regurgitado) e poucos espécimes apresentaram alimentos ainda na cavidade faríngea;
- A variação dos Índices Gonadossomático (IGS) e dos estádios macroscópicos de desenvolvimento gonadal apresentaram-se como bons indicadores do desenvolvimento sexual e dos períodos reprodutivos da Enchova, onde o período reprodutivo é determinado principalmente pelas fêmeas (filopatria);
- A distribuição dos estádios de maturação entre os espécimes analisados evidenciou a presença de exemplares maduros (“B”, “C” e “D”) ao longo de todos os meses do ano amostrado (março/2017 a março/2018);
- Na região de estudo, a Enchova apresentou um padrão reprodutivo

semelhante ao de outras populações, com características típicas de desova parcelada e fecundidade/fertilidade contínua ou indeterminada, com o desenvolvimento de ovócitos de forma assincrônica, confirmado por uma sobreposição considerável no diâmetro médio dos ovócitos hidratados;

- Um longo período reprodutivo foi observado;
- Foi possível afirmar que a desova da Enchova (*Pomatomus saltatrix*) na região de Arraial do Cabo está concentrada principalmente na primavera-verão e menos no inverno, mais especificamente entre os meses de agosto, setembro e abril, coincidindo com os meses de maior intensidade da ressurgência. Coincidindo com os maiores Índices Gonadossomáticos (IGS), as maiores taxas de fecundidade e a maior média de raio de ovócitos hidratados em gônadas no estádio "C" de maturação (maduras);
- Os valores do Fator de Condição Fisiológica de Fulton (K, crescimento) e do Índice Hepatossomático (IHS) se mostraram como bons parâmetros para a confirmação do período de maior atividade reprodutiva da espécie, apresentando um padrão relativamente semelhante ao verificado no IGS;
- As fêmeas atingiram o Comprimento Médio de Primeira Maturação Sexual (L_{50}) em aproximadamente 472 mm (CT) e os machos em aproximadamente 415 mm (CT), a partir destes comprimentos todos os espécimes foram considerados como indivíduos maduros (L_{100}) e, portanto, participantes ativos nos processos reprodutivos;
- Em relação à desova, à fecundidade e fertilidade os resultados podem variar, frente às diversas variáveis bio-oceanográficas, de região para região;
- Distinções observadas nos parâmetros bio-ecológicos gerais de crescimento entre as regiões podem ser atribuídas a diversos eventos durante as etapas ontogênicas, tais como: reprodução, suprimento alimentar, pressão pesqueira, entre outros;
- Investigações adicionais são necessárias para quantificar o impacto pesqueiro sobre a dinâmica populacional e os padrões de recrutamento das Enchovas na região. De fato, é importante deixar os juvenís crescerem até o tamanho mínimo ideal (>350 mm) e focar na captura de indivíduos maiores

ou já maduros. Isso aumentaria a produtividade e a renda dos pescadores, deixando o estoque ainda mais saudável;

- Para efeitos de uma futura e melhor gestão pesqueira, aconselha-se recalcular a CPUE e estabelecer níveis de exploração mais baixos em razão dos cálculos imprecisos do Rendimento Máximo Sustentável (MSY), obtidos quando a taxa instantânea de mortalidade por pesca é aproximadamente igual à taxa de mortalidade natural, onde, os valores e as variáveis abióticas nos processos de reprodução e crescimento, ainda não são bem conhecidos. As taxas de: Mortalidade Total (Z); Mortalidade Natural (M); Mortalidade por Pesca (F), a de Explotação/Exploração (E) e; a longevidade da espécie também devem ser recalculadas para o (s) estoque (s) específico (s) pertinente (s) à área da RESEX-Mar de Arraial do Cabo - RJ. Para um melhor entendimento sobre a fecundidade e a fertilidade, aconselham-se novos estudos histológicos das gônadas. Para estudos futuros sobre o seu deslocamento, a sua migração e forrageamento, recomendam-se o emprego de *TAG’*s (acústicos ou via marcação por satélites). Assim como, a realização de estudos abióticos (poluentes antrópicos, entre outros) e oceanográficos locais e;
- O presente estudo fornece informações importantes sobre os parâmetros bio-ecológicos da Enchova na região, podendo contribuir para com a elaboração de políticas públicas voltadas para o seu manejo e conservação pesqueira, visando o ordenamento sustentável do estoque. Recomenda-se a continuidade do monitoramento pesqueiro e estatístico da Enchova. Com isso, será possível realizar uma avaliação mais precisa do ciclo de vida desta espécie como subsídio ao processo de futuro manejo pesqueiro. O mesmo também demonstra a necessidade de se monitorar e gerenciar a produção pesqueira da Enchova em uma escala geográfica ainda mais ampla.

<u>APLICAÇÃO BIOTECNOLÓGICA MARINHA</u>: 8 Passos para o Manejo Pesqueiro Sustentável do Estoque Local (RESEX-Mar de Arraial do Cabo - RJ) da Enchova

1. A determinação oficial de um período de defeso, de 04 meses (01 de dezembro a 31 de março, pico reprodutivo);
2. O monitoramento permanente e ativo-Legal dos esforços de pesca e petrechos utilizados (anzóis e afins);
3. A implementação de um tamanho mínimo para a captura (>350 mm (não-recrutas); (L_{50}));
4. A determinação de cotas pesqueiras (cálculos temporais e espaciais de CPUE);
5. A exploração sustentável do recurso (tamanho ideal para captura: ≥580 mm a ≤710 mm);
6. A preservação das Matrizes (proibir a captura de espécimes acima dos ≥710 mm de comprimento);
7. A adequação das malhas para as redes: de arrasto de praia = 50 mm e de emalhe (espera) = 25-45 mm. Visando impedir a captura de juvenís (recrutas) o que, caso contrário, pode comprometer a capacidade de renovação do estoque e;
8. A realização periódica de reuniões para informar aos pescadores as atuais regulamentações pesqueiras vigentes e os tipos de petrechos mais adequados a serem empregados, assim como os corretos métodos de manuseio e de soltura dos exemplares fora dos padrões acima propostos, a fim de minimizar as altas taxas de mortalidade da espécie causadas pela pesca.

Os dados deverão ser apresentados ao ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade), Órgão Federal gestor da RESEX-Mar (Reserva Extrativista Marinha) de Arraial do Cabo - RJ.

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