BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Article

FISHING IN THE LARGEST PERENE HYPERSALINE LAGOON IN SOUTH AMERICA, WITH NOTES ON CURRENT REGULATIONS

Márcio Luís Chagas MACEDO[1]
Sérgio Ricardo SANTOS[1]
Maurício Düppré de ABREU[2]
Hugo ZECCHIM[3]
Karina Annes KEUNECKE[4]
Geraldo TIMOTEO[5]
Marcelo VIANNA[1]*

[1] Universidade Federal do Rio de Janeiro - UFRJ, Instituto de Biologia, Departamento de Biologia Marinha, BioTecPesca. Av. Carlos Chagas Filho 373, Bl. A - Ilha do Fundão, 21.941-590, RJ, Brazil. mvianna@biologia.ufrj.br (*corresponding author).

[2] Cardume Socioambiental e Comunicação. Rua Constante Ramos, 35/202, Copacabana, 22.051-011, RJ, Brazil.

[3] Opus Socialis Soluções Socioambientais. Av. Alcebiades Sabino dos Santos, 353 , Sala 207, 28.895-658, Rio das Ostras, RJ, Brazil.

[4] Universidade Federal Rural do Rio de Janeiro - UFRRJ, Instituto de Ciências Biológicas e da Saúde, Departamento de Biologia Animal. BR 465, km 47, Seropédica, 23.890-00, RJ, Brazil.

[5] Universidade Estadual do Norte Fluminense - UENF, Laboratório de Estudos do Espaço Antrópico. Av. Alberto Lamego, 2000, 28.013-602, Campos dos Goytacazes, RJ, Brazil.

Received: April 30, 2021
Approved: November 26, 2021

ABSTRACT

Araruama Lagoon (Rio de Janeiro) is the largest hypersaline lagoon in South America. The aim of this study was to survey fishing landings, capture areas and production at this lagoon, in addition to analyzing data from the Pescarte Census. Fishing landings were monitored daily by community agents from March to August/2009, through the Petrobras Mosaico Program. Thirteen landing points were identified in five municipalities, totaling 8,096 recorded landings, and accumulating 469.1 tonnes. São Pedro da Aldeia (39.6%), Arraial do Cabo (27.7%) and areas in the central region (37.6%) and the south coast (29.1%) of the lagoon presented the highest landings and catch volumes. Twelve species were identified, mainly *Pogonias courbina* (48.9%) and *Penaeus* spp. (33.8%), and gillnets were the most important fishing gear. Very few studies have addressed fishing at Araruama Lagoon, leading to current planning measures supported by little data. We advocate a participatory review of current regulations, to better address gillnet fishing and the capture of different fish species. This study is the result of research financed by the Pescarte Environmental Education Project, a mitigation measure required by the Federal Environmental Licensing, conducted by IBAMA.

Keywords: Coastal lagoon; fishery production; fisheries management; participative management.

A PESCA NA MAIOR LAGOA HIPERSALINA PERENE DA AMÉRICA DO SUL, COM NOTAS SOBRE A REGULAMENTAÇÃO VIGENTE

RESUMO

A Lagoa de Araruama (Rio de Janeiro) é a maior lagoa hipersalina da América do Sul. O objetivo do estudo foi levantar os pontos de desembarque pesqueiro, áreas de captura e a produção da lagoa, além de analisar dados do Censo Pescarte. Por meio do Programa Petrobras Mosaico foi acompanhado o desembarque pesqueiro de março a agosto/2009, por agentes comunitários, com monitoramento diário da pesca. Foram identificados 13 pontos de desembarque, em cinco municípios, sendo registrados 8.096 desembarques, com 469,1 toneladas. São Pedro da Aldeia (39,6%), Arraial do Cabo (27,7%) e áreas da região central (37,6%) e litoral sul (29,1%) da lagoa apresentaram os maiores desembarques e capturas. Foram identificadas 12 espécies, sendo *Pogonias courbina* (48,9%) e *Penaeus* spp. (33,8%) as principais, com a rede de emalhar sendo o petrecho mais importante. Pouquíssimos estudos abordaram à pesca na Lagoa de Araruama; logo, as medidas de ordenamento vigentes estão respaldadas em poucos dados. Defendemos uma revisão participativa da regulamentação, de forma a abordar melhor a pesca de emalhe e a captura de peixes diversos. Este estudo é resultado de pesquisa financiada pelo Projeto de Educação Ambiental Pescarte, que é uma medida de mitigação exigida pelo Licenciamento Ambiental Federal, conduzido pelo IBAMA.

Palavras-chave: Lagoa costeira; produção pesqueira; manejo pesqueiro; manejo participativo

INTRODUCTION

Hypersaline aquatic environments result from partial marine water trapping close to the coastal zone in areas presenting reduced rainfall rates and small drainage basins. This leads to an imbalance between evaporation and water input, gradually increasing salinity levels. These peculiar ecosystems, although extremely interesting, still in-depth studies (Sales et al., 2018).

Coastal lagoons in the state of Rio de Janeiro, southeastern Brazil, were formed during the recent Quaternary, due to depositional processes derived from isostatic sea

movements (Lima et al., 2001). Many these lagoons are located in the Região dos Lagos (Lakes Region) area, which extends from the municipality of Maricá to Barra do Furado, between the municipalities of Macaé and Quissamã.

Araruama Lagoon is one of the largest lagoons in this area, unique due to a permanent hypersalinity condition (Kjerfve et al., 1996; Bidegain and Bezerril, 2002). In the 1950s, it consisted in the main fish supplier to the metropolitan Rio de Janeiro region (Bernardes and Bernardes, 1950). It is currently an important fishing area, but although studies are still lacking. Araruama Lagoon fishery activities are directed at shrimp (Slack-Smith, 1974; D'Incao et al., 2002; Gomes et al., 2013) and mullet (Barroso and Fabiano, 1995; Saad, 2003), although fish landing data are sporadic and inaccurate. The first study concerning fishing at Araruama Lagoon was performed by Bernardes and Bernardes (1950), who reported that certain fisheries requiring larger boats are impossible due to the lagoon's reduced bathymetry. Fishing gear is usually manually operated by fishers and/or remains fixed in the environment (Barroso and Fabiano, 1995). Bidegain and Bezerril (2002) compiled several studies concerning Araruama Lagoon, addressing different knowledge areas and presented some fishing data. Saad (2003) described the Lagoon's spatial distribution and fish assemblages and generated data concerning fishing statistics for corrals and seine fishing. D'Incao et al. (2002) pointed out the problem of lack of fisheries production data for estuarine and lagoon waters in general, and especially for Araruama Lagoon, due to intense fishing activities, subsequently corroborated by Gomes et al. (2013).

Regardless of practiced fishing activities and despite its ecological particularities and economic and social importance, the ichthyofauna at Araruama Lagoon still has been the object of studies. Almeida-Silva et al. (2015) studied the dietary ecology of local fish species and concluded that, despite the lagoon's hypersalinity, the dietary habits of local species do not differ from their coastal zone diets. Cruz et al. (2018) concluded that cyclical salinization and desalination events alter the trophic fish structure at this lagoon. Furthermore, the ecological relevance of Brazilian hypersaline habitats is also addressed in very few studies. Sales et al. (2016), when studying a hypersaline estuary in northeastern Brazil, reported that the site serves as a nursery area for several fish species, with an emphasis on the Gerreidae family, of significant fishing importance. Sales et al. (2018), assessing the same region, confirmed the nursery role of this estuary and highlighted the importance of different habitats in ichthyofauna structuring. By demonstrating the nursery role of a hypersaline ecosystem, these studies alert to the need for fisheries management measures. The risk of poorly managed fishing activities resulting in overfishing is very high, due to the predominance of juvenile biota and the fact that this is a growth zone.

In this context, the aim of this study was to characterize commercial fisheries at Araruama Lagoon, Rio de Janeiro, southeastern Brazil, generating information to contribute to the discussion of the adequacy of current fishing regulations, the sustainable use of fishing resources and the local reality.

MATERIAL AND METHODS

Study area

Araruama Lagoon, located in Rio de Janeiro, southeastern Brazil, presents sandy strands of a marine origin and intercrossing depressions. Araruama is one of the largest permanent hypersaline lagoons in the world, comprising about 220 km^2, with a 190 km perimeter. Its greatest width is of 13 km between São Pedro da Aldeia Beach and Monte Alto, and its maximum length, not considering the Itajurú Canal, is of 39 km, with a maximum depth of 12 m (Kjerfve et al., 1996; Bidegain and Bezerril, 2002). Salinity is always higher than in the adjacent coastal zone, varying in the east-west direction and with average values above 50 (Kjerfve et al., 1996). It is surrounded by the municipalities of Araruama, Iguaba Grande, São Pedro da Aldeia, Cabo Frio, Arraial do Cabo and Saquarema (Figure 1). The hydrographic Araruama Lagoon basin covers about 400 km^2, totaling 60 km^2 of salt pans and 6 km^2 of peripheral lagoons, with only two perennial lagoons, Moça and Maturana (Kjerfve et al., 1996). The local climate is semi-arid in the Cabo Frio and Arraial do Cabo portion and part of Araruama, and tropical in the Araruama, Iguaba Grande and São Pedro da Aldeia areas (Kjerfve et al., 1996; Bidegain and Bezerril, 2002).

Field methodology

The research was divided into two stages. The first began on November 24th, 2008, with a prospective trip to surrounding Araruama Lagoon fishing communities, in order to identify and a map of the most relevant fishery landing sites and meet with fishing community leaders. A new campaign was performed in December 2008, when the lagoon was once again visited and the same assessments carried out, in addition to answering any open questions and increasing biological material sampling for landed fish identification and photography. After defining the monitoring sites (Figure 1) and following a communication and registration period, tests were carried out at each location in January 2009, followed by interviews, to select the field agents, facilitating information access and greater community integration.

After the selection, the field agents underwent a one-week training and leveling course, when they were introduced to the research tools that they would use during fishing landing monitoring, such as the field questionnaire applied to the fleet survey, items and landing data, and the map used in fishery landing spatialization. They also learned to use a pictorial field guide for fish identification, containing fish species images and diagnoses. This guide was created to simply distinguish between the most common species landed at Araruama Lagoon. In parallel, the study area was georeferenced and divided into quadrants, according to 5 km x 5 km (Figure 1).

Fishery landing monitoring began in March 2009, after a January fish mortality event (Ecodebate, 2009), and was completed in August 2009, following the end of the fishing season and conclusion of the Petrobrás Mozaico project financing contract, totaling 181 data collection days. Fishery landings were monitored daily, and the completed questionnaires were collected weekly from the field agents in each assessed municipality, completing an entire Araruama Lagoon tour. Any agents' doubts were made clear during the questionnaire collections, and relevant observations were

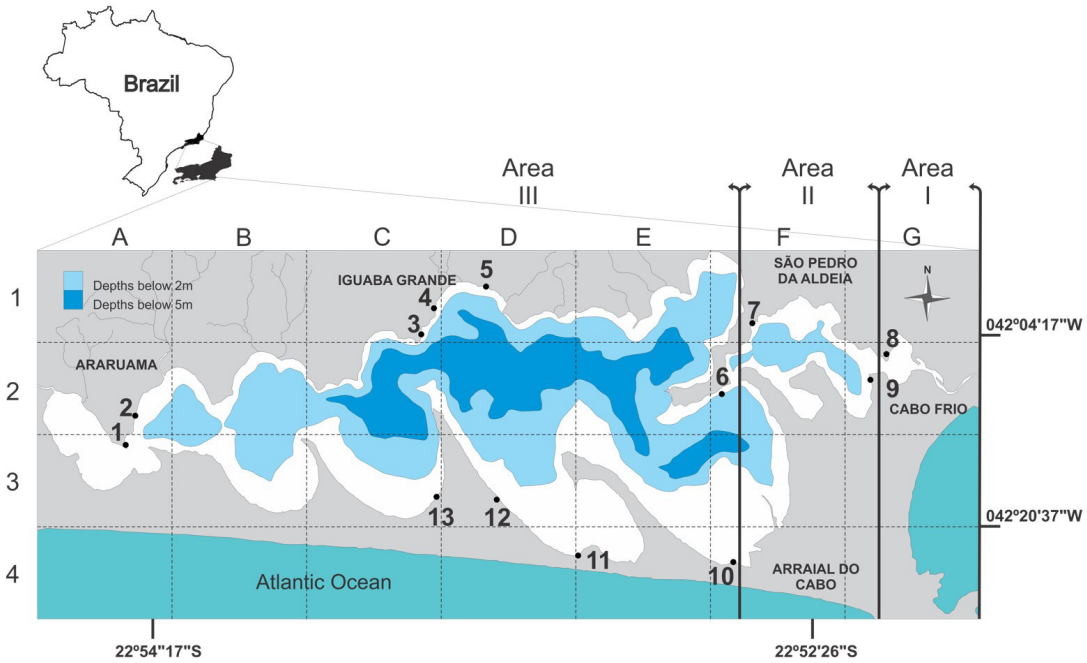

Figure 1. Araruama Lagoon, Rio de Janeiro, southeastern Brazil. The municipalities and fishery landings monitored in 2009 during this study are highlighted as follows: Areal (1), Praia do Hospício (2), Túnel (3), Popeye (4), Pedra (5), Praia da Baleia (6), Camerum (7), Ponta do Ambrósio (8), Praia do Siqueira (9), Monte Alto (10), Figueira (11), Acaíra (12), Caiçara (13).

noted. This aided in the addition or removal of any monitoring points and in the inclusion of fish size categories, adapting the questionnaire language to that used by fishery. After elucidating possible doubts, the questionnaires were validated and sent to the laboratory for typing and tabulation.

The second stage corresponded to a data analysis of the 2016 Pescarte Census, referring to a block of questions concerning the Work and Professional Trajectory of Artisanal Fishers. This project is an environmental mitigation measure carried out by a federal licensing of the oil and gas industry, developed through shared management between Petrobrás and the State University of the North Fluminense, under CGMAC/IBAMA supervision. In total, 4,331 fishermen were interviewed, from a total of 3,334 families. The fisher data from the selected Araruama Lagoon locations were then processed.

Information analyses

At the laboratory, field questionnaires were typed on an electronic spreadsheet. Biota landed in the fisheries but not included in the pictorial guide were identified considering their lowest possible taxonomic level with the aid of specific bibliography. (Costa et al., 2003). The organisms were then fixed and deposited at the Biology and Fisheries Technology Laboratory (BioTecPesca/IB/UFRJ) and the National Museum of Rio de Janeiro zoological collections. Subsequently, depending on the landing occurrence frequencies, the species was inserted in the field form for subsequent measurement and occurrence records.

The study area was georeferenced using the Corel X5 and Quantum GIS softwares to vectorize the Araruama Lagoon map. The entire landed fishery production was positioned at the central point of each quadrant (centroid).

RESULTS

In 2009, the 13 most important fishing landmarks at Araruama Lagoon were identified, distributed in five surrounding municipalities. Of these, only seven presented constant landings and were proven to be indeed commercially important and, thus, monitored, as follows: Areal, Pedra (or Iguaba), Praia da Baleia, Camerum, Ponta do Ambrósio, Praia do Siqueira and Figueira (Figure 1). A total of 8,096 questionnaires were completed and validated during the 181-day study period (Table 1), corresponding to the daily production of each fishing boat, per lagoon location and quadrant.

Table 1. Fishery landing monitoring activities carried out in 2009 at Araruama Lagoon, Rio de Janeiro, southeastern Brazil, per municipality, location and number of filled questionnaires.

Municipalities	Locality	Filled questionnaires
Araruama	Areal	517
Iguaba Grande	Pedra	1,607
São Pedro da Aldeia	Ponta do Ambrósio	2,000
São Pedro da Aldeia	Baleia	1,610
Cabo Frio	Siqueira	1,668
Arraial do Cabo	Figueira	694
Total spreadsheets		8,096

Among the eight different types of gear used by fishers, gillnets were the most frequent, both concerning location and operation area distribution (Table 2 and Figure 2). This gear can be operated both with a single type of mesh along its entire length, or with a set of several netting panels, forming sections comprising different meshes in a single net. The most frequent mesh used measured 45 mm between adjacent nodes. The sets were performed once a day, and each one lasted 12 hours between the time of deployment and retrieval. The most common combined nets, on the other hand, comprised 45/50/60/70 mm or 50/55/60/70 mm mesh sets between adjacent nodes, used mainly at Arraial do Cabo. One gillnet characteristic is the possibility of working with different configurations, allowing for fishing in different locations and at greater depths (Figure 2 and Table 3) for specific and different types of fish.

Different uses of Araruama Lagoon fishing resources between the different communities and areas of the lagoon were observed. Fishing at Praia do Siqueira (Cabo Frio) uses mainly "troia" fishing (manual trawling), aimed at catching shrimp. Araruama, Iguaba, São Pedro da Aldeia (Praia da Baleia) and Arraial do Cabo (Figueira) use mainly gillnets to catch mostly fish. Ponta do Ambrósio (São Pedro da Aldeia), on the other hand, was characterized by different fishing gears, although focused mainly on shrimp (Table 2). Both trawl nets and "troia" nets present a mesh size between 8 and 13 mm between adjacent nodes, with restricted distribution (Figure 3). "Troia" fishing data at Camerum (São Pedro da Aldeia), an important fishing area that uses this type of gear, were not obtained due, to the field agent's dismissal. The longline, dip net and net gears were less used compared to the other gear (Figure 4). Shrimp fisheries are concentrated in the shallowest areas nearest to the sea (Table 3).

The minimum fishing depth was 0.7 m (dip net) and the maximum, 12.0 m (gillnet). The other gear types, despite working at a maximum depth of 6 m (trawl net) and 4 m (hookline), were exceptions. In most cases, fishing was carried out in shallow areas from 1.5 to 2.0 m in depth (Table 3).

The total monitored fishing landing volume was of 469.1 t, recorded between the second half of March and the first half

Table 2. Percentage (%) of fishing gear used in 2009 in each location and municipality, at Araruama Lagoon, Rio de Janeiro, southeastern Brazil.

Gear	Araruama		Iguaba Grande			São Pedro da Aldeia		Cabo Frio	Arraial do Cabo
	Areal	Praia do Hospício	Pedra	Popeye	Túnel	Praia da Baleia	Pta. do Ambrósio	Praia do Siqueira	Figueira
Hookline	22	-	-	-	-	3.9	-	-	-
Gillnet	72.4	100	100	100	100	96.0	1.5	-	100
Troia	5,6	-	-	-	-	-	30.6	95.6	-
Longline	-	-	-	-	-	0.1	-	-	-
Trawling	-	-	-	-	-	-	35.7	3.8	-
Staked	-	-	-	-	-	-	30.8	0.6	-
Net	-	-	-	-	-	-	0.7	-	-
Tarqueta	-	-	-	-	-	-	0.8	-	-

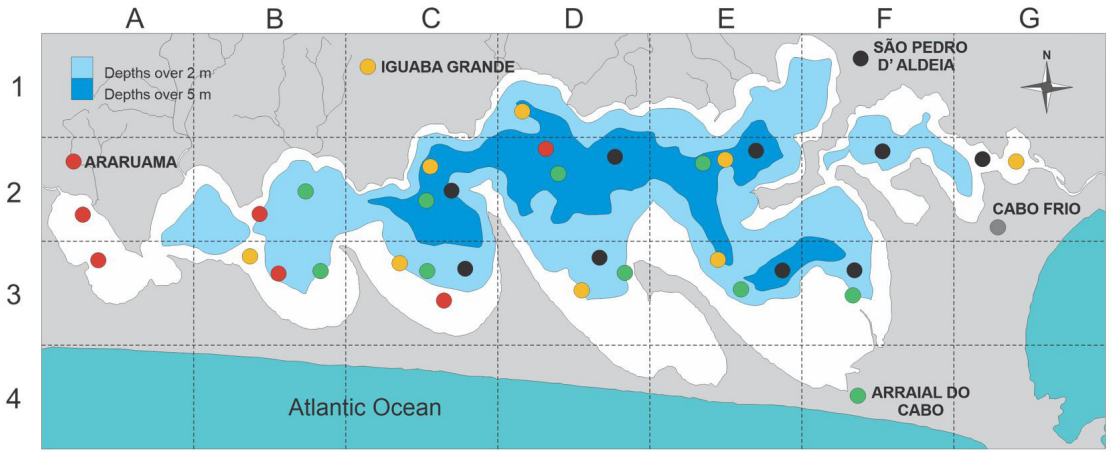

Figure 2. Gillnet fishery operation locations (small circles) in 2009 at Araruama Lagoon, Rio de Janeiro, southeastern Brazil. The different colors indicate the municipalities of the origin of the fishermans.

Table 3. Fishing gear recorded in 2009 at Araruama Lagoon, Rio de Janeiro, southeastern Brazil, with minimum, maximum, and modal depths, in meters.

Gear	Minimum depth (m)	Maximum depth (m)	Mode (m)
Trawl net	1.0	6.0	1.5
Staked	1.0	2.5	2.0
Hookline	1.0	4.0	1.0
Gillnet	1.0	12.0	6.0
Dip net	0.7	1.0	0.7
Troia	0.5	3.0	1.5
Tarqueta	1.0	1.5	1.5

of August (Table 4). It is important to note that São Pedro da Aldeia results are underestimated due to lack of information from Camerum, as stated previously, and in Arraial do Cabo, where some spreadsheets were lost. Even so, São Pedro da Aldeia was responsible for the highest production volume (218.3 t) and Cabo Frio, the lowest value (13.4 t).

The most fished areas at Araruama Lagoon were quadrants C3, D2, F3 and E3 (Table 5 and Figure 5), responsible for 66.9% of the total fishery production at the lagoon during the monitoring period, totaling 369.9 t of fish, mainly black drum (*Pogonias courbina*), by gillnet fisheries.

A total of 13 commercial landed categories landed were identified, as follows: shrimp (*Penaeus paulensis*, *P. brasiliensis*),

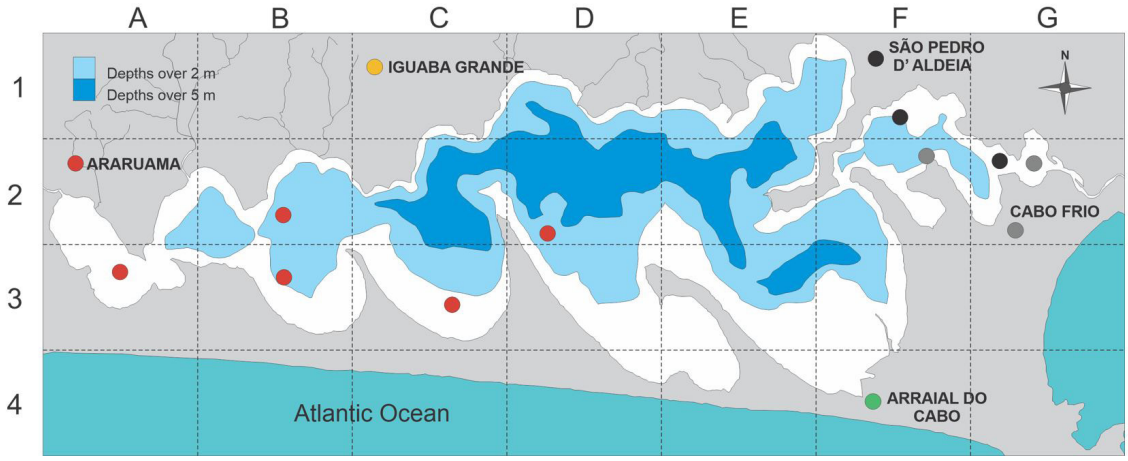

Figure 3. "Troia" fishery operation locations (small circles) in 2009 at Araruama Lagoon, Rio de Janeiro, southeastern Brazil. The different colors indicate the municipalities of the origin of the fishermans.

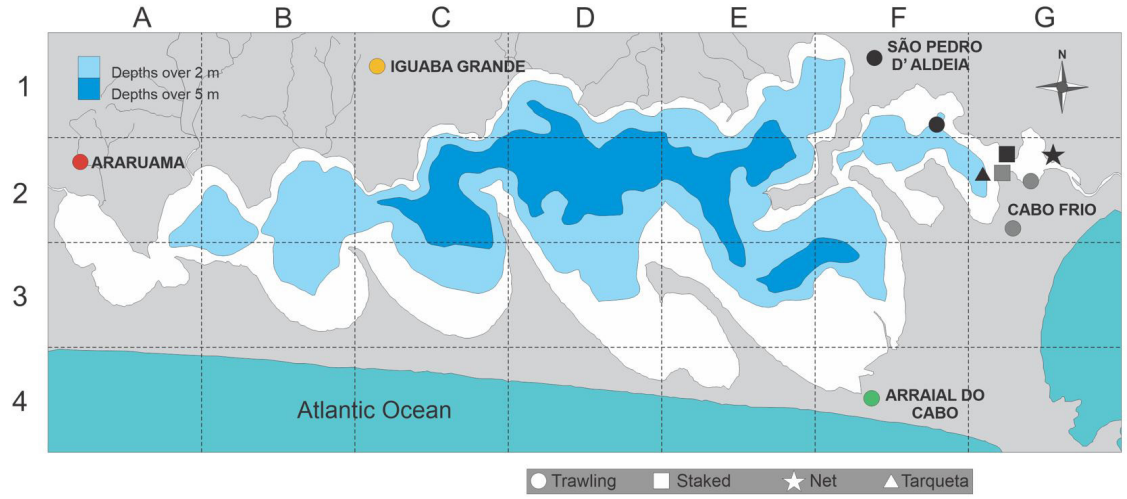

Figure 4. Trawling, staked, net and "tarqueta" fishery operation locations (small circles) in 2009 at Araruama Lagoon, Rio de Janeiro, southeastern Brazil. The different colors indicate the municipalities of the origin of the Fishermans.

Table 4. Total fishery landings monitored in 2009 at Araruama Lagoon, Rio de Janeiro, southeastern Brazil, per municipality and locality, in tons.

Municipalities	Locality	Landings (t)
Araruama	Areal	41.4
Iguaba Grande	Pedra	81.3
São Pedro da Aldeia	Ambrósio/Baleia	218.3
Cabo Frio	Siqueira	13.4
Arraial do Cabo	Figueira	114.7
Total		469.1

Table 5. Total landed fish catches monitored in 2009, at Araruama Lagoon, Rio de Janeiro, southeastern Brazil, per quadrant.

Quadrant	Total landing volume (kg)	Percentage (%)
C 3	88,241.7	19.01
D 2	86,088.9	18.55
E 3	73,779.4	15.90
F 3	62,561.4	13.18
G 2	42,221.3	8.67
D 3	37,245.6	8.00
E 2	36,902.1	7.69
F 2	11,548.7	2.49
C 2	10,984.9	2.32
B 2	9,395.9	2.02
A 3	6,185.9	1.33
B 3	3,348.5	0.72
A 2	525.2	0.09
D 1	91.0	0.02

swimming crab (*Callinectes* spp.), fat snook (*Centropomus parallelus),* common snook (*Centropomus undecimalis*), silver mojarra (*Eucinostomus* spp.), caitipa mojarra (*Diapterus* spp.), Brazilian mojarra (*Eugerres brasilianus*), Atlantic thread herring (*Opisthonema oglinum*), Lebranche mullet and white mullet (*Mugil liza*, *M. curema*), whitemouth croaker (*Micropogonias furnieri*), black drum (*Pogonias courbina*), common halfbeak (*Hyporhamphus unifasciatus*) and mixed (varied fish) (Table 6). In addition to taxonomic separation, the landed black drum were also separated by size: very small (vs): 250 to 300 g; small (s): 301 to 600 g; medium (m): 601 to 900 g; large (l): 901 to 1,500 g; and very large (vl): 1,501 g or bigger.

Of the total fisheries production landed Araruama Lagoon, black drum was the most commercially important species, corresponding to 48.9%, widely distributed throughout the lagoon. Shrimp was the second most important category, accounting for 33.8% of all monitored landings. The mullet category and Brazilian mojarra complete the most important fish in the region. The total landed biomass reached the highest values between April and May, followed by March and July, with the lowest catches in August. Shrimp landings increased in April, May and June, while the mullet category increased in April and May and decreased in July, confirming the end of the fishing season at the lagoon. Black drum presented the highest catch rates from March to June, peaking in May and decreasing in August. Brazilian mojarra presented biomass similar to that of the mullet category in March, followed by declines in the following months (Table 6). It is important to note that only half of March and of August were monitored during this study.

The Pescarte Census results are quite relevant for this assessment, as they partially contextualize the Araruama lagoon fishing community (Cabo Frio and Arraial do Cabo) in a more recent scenario (2016) compared to the data from the first stage of the study (2009). According to the questionnaires filled out by 320 respondents, fishing is in fact an important economic activity

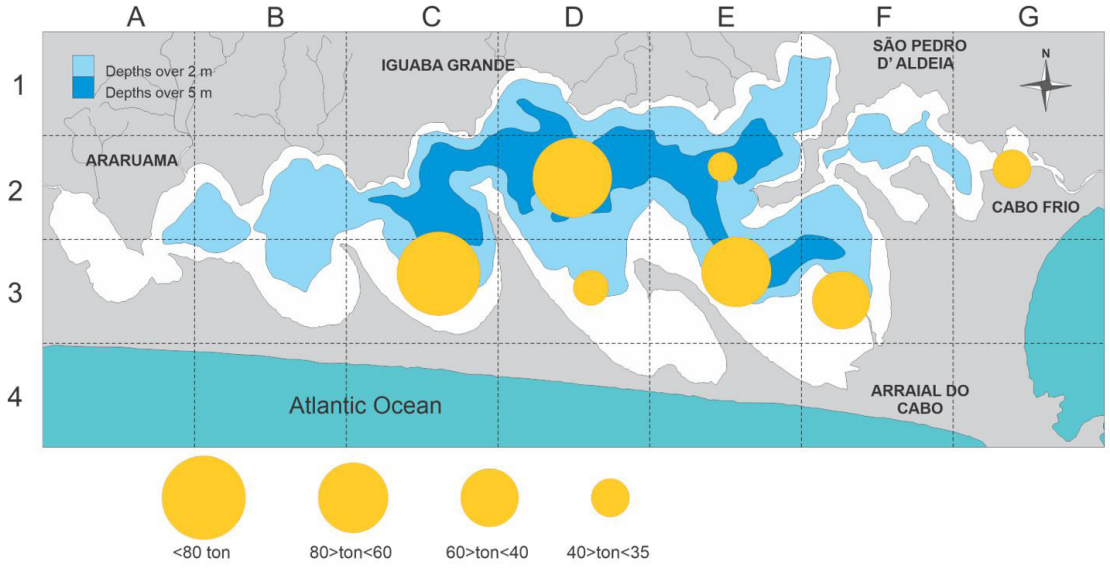

Figure 5. Distribution of fish catch areas per quadrant in 2009, at Araruama Lagoon, Rio de Janeiro, southeastern Brazil.

Table 6. Monthly and total biomass (kg; %) of the fish categories landed from March to August 2009 at Araruama Lagoon, Rio de Janeiro, southeastern Brazil.

Categorie	Month						Total (kg)	%
	March	April	May	June	July	August		
Fishes								
Common halfbeak	0	9	6	0	0	0	15	0.003
Brazilian mojarra	8,943	3,877	3,552	2,363	1,342	702	20,779	4.43
Silver mojara	51	132	142	3	2	0	330	0.07
Caitipa mojarra	12	5	0	0	0	0	17	0.004
Whitemouth croaker	0	28	33	0	0	0	61	0.01
Mixed	0	28	0	0	0	0	28	0.01
Mullets	6,113	12,664	11,479	3,126	843	332	34,557	7.37
Black drum	10,025	35,275	74,314	6,642	1,182	0	127,438	27.17
Black drum (vs)*	20	3,434	6,558	3,290	195	50	13,547	2.89
Black drum (s)*	1,750	11,369	5,380	8,020	3,642	566	30,727	6.55
Black drum (m)*	39,791	21,078	24,238	22,651	8,252	732	116,742	24.89
Black drum (l)*	640	12,488	12,740	36,064	16,707	450	79,089	16.86
Black drum (vl)*	0	1,957	476	328	0	0	2,761	0.59
Common snook	5	376	15	85	3	0	484	0.10
Fat snook	4	2	4	1	30	0	41	0.01
Atlantic thread herring	0	3	32	10	0	0	45	0.01
Crustaceans								
Shrimp	3,886	6,378	8,675	10,638	9,066	3,245	41,888	8.9
Swimming crab	0	59	207	228	73	0	567	0.12
General total	71,240	109,162	147,851	93,449	41,337	6,077	469,115	100

* Size categories used by fishers during landings: very small (vs): 250 to 300 g; small (s): 301 to 600 g; medium (m): 601 to 900 g; large (l): 901 to 1,500 g; and very large (vl): 1,501 g or bigger.

for most of participants. Over 70% of participants fish for five days or more during the week; about 80% of the respondents fish near their homes, as they come and go on the same day; over 80% only stop fishing during the closed fishing season or when the weather does not allow it; and almost 60% always fish with the same group. About 60% of the interviewed fishers change their gear type during the year, corroborated by the main reported fish landing data, which are neither shrimp nor mullet, but different fish species. Furthermore, almost 65% of all fishers received over R$ 100.00 in their last fishing trip (Table 7).

Table 7. Answers obtained during the Pescarte Census carried out in 2016, at Araruama Lagoon, Rio de Janeiro, southeastern Brazil.

Questions	Answers (%)		
How often do you perform your fishing routine (in the summer)?	7 days a week (39.4)	5 days a week (31.0)	Others (29.6)
Do you fish every month?	Yes (75.5)	No (24.5)	-
Why do you stop fishing during this period?	Adverse natural conditions (45.0)	Because it is closed season (34.9)	Others (20.1)
Do you always fish with the same group of people?	Yes (64.2)	No (35.8)	-
Do you alternate fishing gear during the year?	Yes (59.0)	No (41.0)	-
What are the most fished species?	Shrimp (20.5)	Mullet (11.2)	Others (68.3)
How much did you receive in cash in your last fishing trip?	Above R$ 200.00 (43.4)	Between R$ 101.00 and R$ 200.00 (19.4)	Up to R$ 100.00 (37.2)

DISCUSSION

Coastal transition ecosystems, such as lagoons, are subject to anthropic impacts since high population densities usually occupy their surroundings (Ajemian et al., 2018). This problem is even greater in hypersaline lagoons, which present limited water circulation with the adjacent ocean. This vulnerability is clear at Araruama Lagoon, which continuously receives untreated domestic sewage inputs (Ecodebate, 2009).

Some important gear alterations are noted when comparing the results reported herein with previous data for the same area from about 65 years ago (Bernardes and Bernardes, 1950). Many of the old gear are not used any more, such as "redes de cauda" or "dois calões", replaced by others in search of greater fishery productivity. These gears were always used at night at São Pedro da Aldeia and Cabo Frio, in the narrowest regions of the Itajuru channel, mainly to catch shrimp, measuring 7 meters in length, 2 m in height and with a 3.5 m opening, and were considered as hindering small production and thus, sometimes banned (Bernardes and Bernardes, 1950). This net in fact stopped being used at Araruama Lagoon, as well as the staked net with "trimbombó", an out-of-water net system attached by stakes that trapped fish that jump (mainly mullets) in an attempt to escape (Bernardes and Bernardes, 1950). Similar structures are seen today around mullet hooks, also used to prevent fish from jumping out during the harvest. However, in general, few updates in the use of fishing gear were observed, and the same basic equipment continues to be used, with the inclusion of longlines. However, gear material has been significantly altered. According to Bernardes and Bernardes (1950), fishing nets at Araruama Lagoon were made manually with tucum palm fibers (*Bactris setosa*) and thread stiffening by the infusion of peruvian pepper bark tea (*Schinus molle*). From the 1960s, natural fiber nets were replaced by synthetic yarns (nylon), reducing mesh size and net maintenance time (Seixas, 2004).

Other studies following the assessment carried out by Bernardes and Bernardes (1950) report hooks, troia and gillnets as the main gear used at Araruama Lagoon (Barroso and Fabiano, 1995; Saad, 2003), corroborated by the findings reported herein. However, the landing configuration has changed. Saad (2003) report the Lebranche mullet (*Mugil liza*) as the most frequently caught fish, followed by Brazilian mojarra (*Eugerres brasilianus*), white mullet (*Mugil curema*) and black drum (*Pogonias courbina*). In our study, though, the main captured species was black drum (*P. courbina*), contributing to almost half of the total production. However, FIPERJ (2014) presents similar data to that reported by Saad (2003), where mullet, pink shrimp, silver mullet, black drum and Brazilian mojarra were the most prevalent species. Thus, we hypothesize that the mullet harvest during our monitoring period was lower, that landings occurred at unmonitored points during the study period (probably in the Itajurú Canal, in Cabo Frio), or that this data reflects the January fish mortality event (Ecodebate, 2009), although black drum was one of the most affected species in the recorded with 40 tons (Marcelo Vianna, personal observation). Yet, Ajemian et al. (2018) studying a similar hypersaline ecosystem in southern Texas (USA) highlight the significance *P. courbina* in the region's fisheries. This species shows site fidelity and is present in the studied ecosystem throughout almost the entire year, although it is sensitive to hypersalinity periods, altering its distribution and abundance (Ajemian et al., 2018). This may explain the annual fluctuations observed for black drum at Araruama Lagoon. Olsen (2019), in a more in-depth study in a coastal lagoon in the same region as that evaluated by Ajemian et al. (2018), indicate increased recruitment associated with salinities over 40. A clear association is also reported between salinity and certain parameters, such as fish mortality and growth rates, to the detriment of the other environmental factors. The findings reported by Olsen (2019) may indicate an additional reason for the high presence of *P. courbina* at Araruama Lagoon landings, as this species may benefit from greater recruitment due to the combination of favorable factors, including environmental lagoon parameters and easy recruit estuary access through the Itajurú Canal. This opportunistic strategy was also hypothesized by Olsen (2019) for the Texas lagoon.

Concerning shrimp fishing at Araruama Lagoon, Bernardes and Bernardes (1950) called attention to the predatory methods used for this fishery. At that time, the "troia" (or "trolha") fishing method was banned because of its very small mesh size. Saad (2003) also reports the importance of this resource and considers pollution as another aggravating factor for sustainable shrimp fishing. Despite these factors, shrimp landing at Araruama Lagoon during the monitoring period corresponded to about 1/3 of the total production, not higher only due to the exclusion of Camerum, São Pedro da Aldeia, from the study which, according to reports and observations, is an important shrimp landing point. Concerning the highest landings at Araruama Lagoon, internal quadrants were highly visited by fishers, even though fishers from the municipality of Araruama did not fish much towards the channel, due to distance from their homes. Apparently, fishers from other municipalities also restrict their fishing areas from the central part of the lagoon towards the south, classified by Slack-Smith (1974) as Area III and identified by Barroso and Fabiano (1995) and Saad (2003) as the most productive area at Araruama Lagoon, which seems to still be the case when assessing the results reported herein.

Despite the fact that the present study assessed only one season, different types of fish were registered, suggesting a seasonal pattern. Barroso and Fabiano (1995) and Saad (2003) recorded the largest fishery production at Araruama Lagoon from January to May, corroborating the landing data presented herein, where the highest production was observed from March to June, with only differences in caught fish species. Barroso and Fabiano (1995) and Saad (2003) recorded the highest landings for mullet/silver mullet/white mullet, followed by the Brazilian mojarra and, finally, black drum. During our fishing monitoring, the most landed categories were, in order of importance, black drum, mullet/silver mullet/white mullet and Brazilian mojarra, the same categories but differential importance between mugilids and black drum. However, the importance of shrimp landings cannot be minimized, due to higher financial gains, even when landing lower biomasses.

Data from the Pescarte Census clearly indicate that fishing remains the main activity and source of income for many residents living around this coastal lagoon. Currently, fishing at Araruama Lagoon is regulated by INI MPA/MMA, nº 2/2013 (Brasil, 2013), which establishes fishing criteria. For fisheries management purposes, this regulation categorizes the lagoon into three areas (Figure 1), defining the closed fishing season, periods, gear characteristics, minimum capture size and other measures. When comparing the adequacy of this regulation to our results, we identified that the closed fishing season period proposed in Article nº 2, of 01 August to 31 October (Brasil, 2013), does not include the fishing season at Araruama Lagoon and causes less financial income impacts to local fishers. However, the Pescarte Census clearly indicates that most fisher profits are higher than the amount of the closed fishing season insurance, which is a benefit that can be requested by artisanal fishers during the period in which they are prevented from fishing, in the amount of one minimum wage a month (Brasil, 2020). Nevertheless, some points are subject to conflict, as follows. Apparently, the Normative Instruction neglects the main fishery at Araruama Lagoon, which is gillnet fishing, as Articles 5 and 6 ban gillnets in Areas I and II. However, Area I is used by fishers from São Pedro da Aldeia and Iguaba Grande, while Area II is used by fishers from São Pedro da Aldeia and Arraial do Cabo, all of whom use gillnets. The banning of a particular gear in a traditionally exploited area by a given fishery is questionable, mainly because selective gear is used, such as gillnets. This is another questionable point of INI nº 2/2013 (Brasil, 2013). The regulation also establishes the mesh sizes that must be used for fishing at Araruama Lagoon in its Article 7, which defines that gillnets must have different meshes depending on the caught species. For example, a 25 mm mesh must be used for mojarra fishing and a 60 mm mesh for black drum. However, one of the main characteristics of these nets is the possibility of working with different net configurations, in the present study, ranging from 45 to 70 mm in the same net. In other words, specific meshes for fishing a given species makes the use of traditional networks with varied meshes and the seasonal gear changes described by the respondents, unfeasible. In addition, this determination does not match reality. How to prevent a mullet (*M. liza*), which should be captured by a 45 mm mesh net, from getting caught in the white mullet (*M. curema*) 35 mm mesh net, since both species are syntopic and sympatric? The same reasoning applies to Gerreidae members such as the Brazilian mojarra, whose correct mesh is a 45 mm mesh, and which cannot be fished using a 25 mm mesh mojarra net. This brings us to another flawed regulation point, concerning minimum catch sizes. The regulation presents in its Annex II (Brasil, 2013), a list of species with their respective permitted lengths. However, only some species are listed, no information for several others. Despite our results confirming that Brazilian mojarra (*E. brasilianus*) is the most captured gerreid in the lagoon, and the only one present in Annex II, other very morphologically similar species, such as mojarra (*Eucinostomus* spp.) and the caitipa mojarra (*D. rhombeus*), are also landed, which can leave room for questioning. The same is noted for snook, where only the common snook (*C. undecimalis*), which is the most abundant, has an established minimum capture size, but the fat snook (*C. parallelus*) is also landed without any protective regulations. This is important because most fishers claim to have different fish as their main landing products. Regarding shrimp, fishing with a troia net is authorized, as long as it presents 12 mm between adjacent nodes, does not exceed 3 m in height, 60 m in length and the clogs used during fishing do not exceed 10 cm. Gomes et al. (2013) demonstrated that the marine closed fishing shrimp season is consistent with the fishing recruitment period for the pink shrimp (*Penaeus* spp), at Araruama Lagoon and, consequently, adequate. However, the same authors report that shrimp from troia net fisheries is caught in their immature stage, which may result in overfishing (Gomes et al., 2013). Furthermore, the current regulation directs shrimp "troia" fishing to shallow areas ("coroas"), where the smallest individuals are usually found, also leading to overfishing.

Ajemian et al. (2018) highlight the complexity of fisheries management in hypersaline lagoons and reverse estuaries. Hypersalinity periods alter the spatial distribution patterns of local species and compromise zoning-based ordering. Fishing at Araruama Lagoon presents different characteristics between landing ports, and a signifcant sectorization. However, a preference for gillnets and the combination of different netting fabrics was noted in all monitored locations, and differences between ports are with regard to the mesh size used in the combinations. Thus, despite the importance of mullet and shrimp for this coastal lagoon's fishing economy, the significant relevance of other fish categories, especially other fish landed throughout the year, which support fishing other than the well-marked harvests of mullet and shrimp (Saad, 2003), cannot be neglected.

CONCLUSION

Although the data presented in this study are from 2009 and only one fishing season, we believe that the enormous lack of more recent and complete information justifies this assessment and the dissemination of its results, as the current fishing regulation basically uses information from Saad (2003). We advocate an urgent review of the fishing management measures currently in force at Araruama Lagoon, with greater local fishing community participation, in order to overcome the current failures in addressing gillnet fishing and the capture of various fish species. Thus, based on inconsistencies present in the currently enforced Normative Instruction, we recommend that the regulation be reviewed and established in a participatory manner, to implement shared management and reduce possible conflicts.

ACKNOWLEDGEMENTS

We are grateful to the entire fishing community surrounding Araruama Lagoon who voluntarily and cordially contributed to the progress of this study. Thank you very much.

REFERENCES

Ajemian, M.J.; Mendenhall, K.S.; Pollack, J.B.; Wetz, M.S.; Stunz, G.W. 2018. Moving forward in a reverse estuary: habitat use and movement patterns of Black Drum (*Pogonias cromis*) under distinct hydrological regimes. Estuaries and Coasts, 41: 1410-1421. https://doi.org/**10.1007/s12237-017-0363-6**.

Almeida-Silva, P.H.; Tubino, R.A.; Zambrano, L.C.; Hunder, D.A.; Garritano, S.R.; Monteiro-Neto, C. 2015. Trophic ecology and food consumption of fishes in a hypersaline tropical lagoon. Journal of Fish Biology, 86(6): 1781-1795. https://doi.org/**10.1111/jfb.12689**.

Barroso, L.V.; Fabiano, F.F.C. 1995. Estudo da pesca com artes fixas na Lagoa de Araruama (RJ). Oecologia Brasiliensis, 1(1): 569-585.

Bernardes, L.M.C.; Bernardes, N. 1950. Pesca no litoral do Rio de Janeiro. Revista Brasileira de Geografia, 12(1): 17-53.

Bidegain, P.; Bezerril, C. 2002. Lagoa de Araruama: perfil ambiental do maior ecossistema lagunar hipersalino do mundo. Rio de Janeiro: SEMADS. 160p.

Brasil. 2013. Instrução Normativa Interministerial MPA/MMA nº 2, de 16 de maio de 2013. Estabelece critérios para pesca na Lagoa Aruarama no Rio de Janeiro. Diário Oficial da União, Brasília, 17 de maio de 2013, nº. 94, Seção 01: p. 125-127.

Brasil. 2020. Portaria Conjunta nº 14, de 07 de julho de 2020. Estabelece novos procedimentos para a análise dos requerimentos de Seguro-Desemprego do Pescador Profissional Artesanal - SDPA. Diário Oficial da União, Brasília, 09 de julho de 2020, nº. 130, Seção 01: p. 62.

Costa, R.C.; Fransoz, A.; Melo, G.A.S.; Freire, F.A.M. 2003. An illustrated key for dendrobranchiata shrimps from the northern coast of São Paulo, Brazil. Biota Neotropica, 3(1): BN01503012003. https://doi.org/**10.1590/S1676-06032003000100011**.

Cruz, L.R.; Santos, L.N.; Santos, A.F.G.N. 2018. Changes of fish trophic guilds in Araruama Lagoon, Brazil: What can be inferred about functioning and structure of hypersaline lagoons?. Estuarine, Coastal and Shelf Science, 211: 90-99. https://doi.org/**10.1016/j.ecss.2017.11.024**.

D'incao, F.; Valentini, H.; Rodrigues, L.F. 2002. Avaliação da pesca de camarões nas regiões Sudeste e Sul do Brasil 1965-1999. Atlântica, 24(2): 103-116.

Ecodebate. 2009. Site de informações, artigos e notícias socioambientais. [online] URL: <https://www.ecodebate.com.br/2009/02/02/mortandade-de-peixes-na-lagoa-de-araruama-rio-de-janeiro-pode-se-repetir-nos-proximos-dois-anos>.

FIPERJ – Fundação Instituto de Pesca do Estado do Rio de Janeiro. 2014. Relatório Final. 2014. Secretaria de Desenvolvimento Regional Abastecimento e Pesca, Rio de Janeiro. 141p. Available at: <https://www.icmbio.gov.br/cepsul/images/stories/biblioteca/download/estatistica/rj/est_2014_relatorio.pdf>. Accessed: Dec. 09, 2018.

Gomes, A.P.P.; Keunecke, K.A.; Silva, D.R.; Vianna, M. 2013. Modulating reproduction of Penaeide shrimps: ecological responses of two simpatric species (Decapoda: Dendrobranchiata) on south-eastern Brazilian coast. Journal of the Marine Biological Association of the United Kingdom, 93(3): 733-740. https://doi.org/**10.1017/S0025315412000835**.

Kjerfve, B.; Schettini, C.A.F.; Knoppers, B.; Lessad, G.; Ferreira, H.O. 1996. Hydrology and salt balance in a large, hypersaline coastal lagoon: Lagoa de Araruama, Brazil. Estuarine, Coastal and Shelf Science, 42(6): 701-725. https://doi.org/**10.1006/ecss.1996.0045**.

Lima, N.R.W.; Bizzeril, C.R.S.F.; Caniçali, M.R.; Suzuki, M.S.; Assumpção, J. 2001. Atividade de pesca durante a abertura da barra da Lagoa de Iquipari, São João da Barra, RJ. Boletim do Instituto de Pesca, 27(2): 191-200.

Olsen, Z. 2019. Quantifying nursery habitat function: Variation in habitat suitability linked to mortality and growth for juvenile black drum in a hypersaline estuary. Marine and Coastal Fisheries, 11(1): 86-96. https://doi.org/**10.1002/mcf2.10064**.

Saad, A.M. 2003. Composição, distribuição espacial, dinâmica de populações de peixes e estatística pesqueira na Lagoa Hipersalina de Araruama, RJ. São Carlos. 105f. (Doctoral Thesis, Universidade Federal de São Carlos, UFSCar). Available at: <https://repositorio.ufscar.br/handle/ufscar/1895>. Accessed: Nov. 15, 2021.

Sales, N.D.; Baeta, A.S.B.V.; Lima, L.G.; Pessanha, A.L.M. 2018. Do the shallow-water habitats of a hypersaline tropical estuary act as nursery grounds for fishes? Marine Ecology, 39(1): e12473. https://doi.org/**10.1111/maec.12473**.

Sales, N.S.; Dias, T.L.P.; Baeta, A.; Pessanha, A.L.M. 2016. Dependence of juvenile reef fishes on semi-arid hypersaline estuary microhabitats as nurseries. Journal of Fish Biology, 89(1): 661-679. https://doi.org/**10.1111/jfb.13006**.

Seixas, C.S. 2004. Instituições e manejo pesqueiro: o caso da lagoa de Ibiraquera, SC. In: Begossi, A. (org.). Ecologia de Pescadores da Mata Atlântica e da Amazônia. São Paulo: HUCITEC. pp. 285-312.

Slack-Smith, R.J. 1974. Administração da pesca artesanal na Lagoa de Araruama. Rio de Janeiro: SUDEPE/PDP/FAO. 28p.