Received: 21 April 2023 | Revised: 7 July 2023 | Accepted: 10 July 2023
DOI: 10.1111/fme.12647

Fisheries Management and Ecology
WILEY

ARTICLE

Stock assessment of *Larimus breviceps*, a bycatch species exploited by artisanal beach seining in Northeast Brazil

Lucas Santos[1] | Jonas Vasconcelos-Filho[2] | Leandro N. Eduardo[3] | Alex Lira[4] | Cecília Craveiro[1] | Emanuell F. Silva[5] | Flávia Lucena-Frédou[1]

[1]Departamento de Pesca e Aquicultura, Universidade Federal Rural de Pernambuco, Recife, Brazil
[2]Departamento de Oceanografia, Universidade Federal de Pernambuco, Recife, Brazil
[3]Institut de Recherche pour le Développement, MARBEC, Univ Montpellier, CNRS, Sète, France
[4]Departamento de Pesca e Aquicultura, Universidade Federal de Sergipe, Sao Cristovao, Brazil
[5]Instituto Federal de Educação, Ciência e Tecnologia da Paraíba, Cabedelo, Brazil

Correspondence
Lucas Santos, Universidade Federal Rural de Pernambuco, Departamento de Pesca e Aquicultura, Rua Dom Manoel de Medeiros, s/n, CEP 52171-900, Recife - PE, Brazil.
Email: contatolucassantoss@gmail.com

Funding information
Conselho Nacional de Desenvolvimento Científico e Tecnológico; Ministério da Agricultura, Pecuária e Abastecimento, Grant/Award Number: 445766/2015-8

Abstract
Motorized trawling was banned off part of the Brazilian coast in 1990 due to environmental impacts, thus artisanal fishermen adopted large beach seines as an alternative. No impact assessments have been conducted on any species; therefore, we examined the life history and stock status of shorthead drum, *Larimus breviceps*, a primary bycatch in tropical shrimp fisheries. Between 2016 and 2017, 969 shorthead drum were collected and analyzed using ELEFAN-based models. Females were larger, more abundant, and older than males. Capture rates of juvenile were high, and no mega-spawners were found. Integrated stock assessment indicated slight overexploitation and growth overfishing. Increased yield per recruit was indicated by high length at first capture. Shorthead drum segregate ontogenetically by size. Growth, mortality, and longevity may be temperature-influenced. We found that beach seine fisheries may impact shorthead drum by population depletion and potential disruptions to reproductive capacity and recommend further studies and management to improve sustainability.

KEYWORDS
depth segregation, growth overfishing, life history, management, mega-spawners, overexploitation

1 | INTRODUCTION

Small-scale fisheries employ over 90% of the world's fishers and play a critical socioeconomic role in coastal communities worldwide, especially in developing countries (Schuhbauer & Sumaila, 2016). These operations make significant contributions to global fish production and food security (Berkes et al., 2001; Dyck & Sumaila, 2010). The scope of these fisheries includes a diverse array of fishing practices, typically implemented at local or community levels, and vary in scale, technological utilization, and organizational structure (Berkes et al., 2001; Frawley et al., 2019). Predominantly, these operations are conducted by individual fishers or small groups, often reliant on local knowledge and traditional practices. Capital investment is typically limited, and methods, passed down through generations, foster a profound connection to cultural heritage and local ecosystems (Berkes et al., 2000; Rousseau et al., 2019).

Fishing communities in Brazil comprise more than 1.5-million people and play a significant role in national seafood harvest that accounts for ~70% of total harvest (Dornelas, 2015). These communities heavily rely on fishing income and often depend on bycatch as a source of sustenance (Passarone, 2020; Tischer & Santos, 2001). Within the bycatch, species belonging to the Sciaenidae family constitute ~20% of overall marine fish landings in Brazil (Chao et al., 2015). However, these populations are declining due to intense fishing exploitation and other anthropogenic activities (Nunoo & Nascimento, 2015; Vasconcellos & Haimovici, 2006). Among affected species, small Sciaenids (<20 cm of total length) are particularly impacted by the cumulative effects of overfishing, habitat degradation, pollution, and climate change (Haimovici & Mendonça, 1996; Isaac et al., 1998). In addition, given their low commercial value, small Sciaenids are frequently overlooked in scientific surveys and management policies.

The shorthead drum, *Larimus breviceps* Cuvier, 1830, is a small-sized Sciaenidae with a maximum recorded length of 32.5 cm (Aparecido et al., 2019) that is predominantly found in coastal areas and classified as a high-risk marine migrant species using estuaries to feed and spawn (Elliott et al., 2007; Santos et al., 2021, 2022). Its distribution spans the West Atlantic region from Costa Rica to Santa Catarina in Brazil (Cattani et al., 2011). The shorthead drum holds significant socioeconomic importance, as bycatch and a food source for fishing crews and local communities (Bomfim et al., 2019; Lira et al., 2022; Silva-Júnior et al., 2019). In artisanal beach seining fisheries in Brazil, this species can comprise up to 28% of total biomass (Freitas et al., 2011; Santos et al., 2021). However, despite its ecological and socioeconomic significance, understanding of basic life history of shorthead drum is limited, because research has been focused on specific locations, such as southern Brazil (Aparecido et al., 2019; Bessa et al., 2013) and the Caribbean Sea (García & Duarte, 2006). This knowledge gap hinders a comprehensive assessment of stock status and conservation needs of this species.

In 1990, the use of motorized trawling off Paraíba coast in Northeast Brazil was prohibited due to its adverse environmental effects (ordinance IBAMA n° 833/ 1990). However, a few months later, artisanal fishermen introduced the large beach seine as an alternative method for shrimp harvesting. While implementation of the large beach seine was intended to be a more sustainable solution, with reduced damage to the seafloor than motorized trawling, large beach seining still negatively impacts juvenile fish (Passarone, 2020) that are often disregarded and remain unassessed. For example, despite the critical role of large beach seining in providing income and ensuring food security for local communities, no comprehensive stock assessment has been conducted to evaluate effects on target and bycatch species. Neglecting to assess impacts can lead to severe long-term consequences for ecosystems and local subsistence activities, including overfishing and declining yield (Hsieh et al., 2010; Pelage et al., 2021). Therefore, studies of population dynamics and stock status are needed to identify and monitor the impacts of large beach seining. Such research is essential for understanding the extent of impacts and to implement management strategies to mitigate impacts.

Studies of large beach seine fisheries are challenging due to scarcity of information that hampers application of conventional stock assessment methods reliant on catch and effort data. These methods are robust for informing management strategies (Dowling et al., 2019; Prince & Hordyk, 2019). Nevertheless, length-based stock assessment methods have emerged in recent decades as alternatives to estimate stock status of data-limited fisheries (Costello et al., 2012). These methods have been successfully applied in data-limited fisheries worldwide (Cope et al., 2023; Quinn & Deriso, 1999), by providing reliable estimates (Pons et al., 2019; Santos et al., 2023) and enhancing management practices. Use of length-based approaches can enable management of data-limited fisheries (Costello et al., 2012; Dowling et al., 2016), thereby supporting implementation of precautionary measures based on informed decision-making. This approach offers a viable means to improve management and conservation of large beach seine fisheries, despite limited availability of catch and effort data.

In the present study, we estimated life-history characteristics of shorthead drum captured by beach seining. Our primary objective was to evaluate the current stock status of the shorthead drum population using length-based assessment models, despite limited availability of data. By employing data-limited models, we provided valuable insights into the abundance, distribution (including growth comparisons with previous studies), and potential vulnerabilities of the shorthead drum population. This research offered a unique perspective on the species and contributed to understanding of population dynamics. Our findings have important implications for management and decision-making. Our results provided guidance for future studies and actions aimed at ensuring sustainability of beach seining and the shorthead drum stock. Our recommendations encompassed sustainable management strategies, conservation measures, and potential harvest regulations that can help to ensure long-term viability of beach seining and preservation of the shorthead drum population. Ultimately, insights aimed to support effective decision-making in support of fisheries management.

2 | METHODS

2.1 | Study area and sampling

Larimus breviceps were collected by beach seining in the local artisanal fishery at the Lucena beach (6°89′96.69″ S, 34°86′17.04″ W), in Paraíba state, from December 2016 to November 2017, except in May, due to meteorological events that hampered fishing (Figure 1). The beach seine had a side length of 2-cm body mesh, 1.5-cm cod-end mesh, entrance dimensions of 120-m horizontal × 6-m vertical, deployed from a small, non-motorized craft, the predominant fishing mode in the region for catching shrimp. Sampling for 50 min from the moment of deployment to the end of fishing was performed monthly at a depth of 6 m to the surf zone. Once collected, specimens were immediately put on ice, transported to the laboratory, and stored in a freezer (−18°C) until analysis.

2.2 | Biological measurements

For each specimen, total length (TL, cm) was measured, and sex was identified from gonad observation. Sex ratio was tested for significant deviations from 1:1 with a χ^2 test ($p < 0.05$) (Dagnelie, 1975) for juveniles shorter than L_{50} and adults longer than L_{50}; Santos et al., 2021).

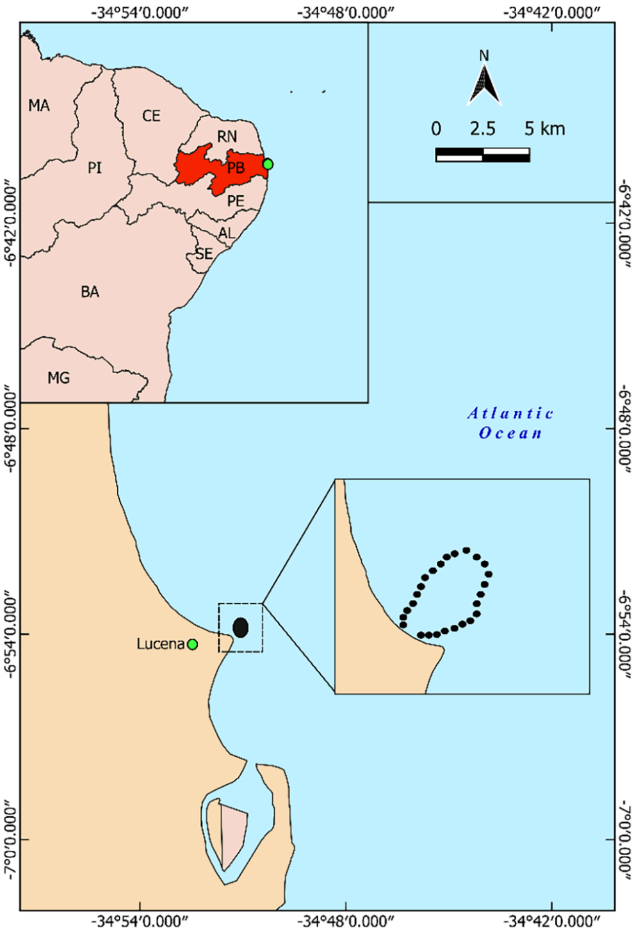

FIGURE 1 Study area in the coast of state of Paraíba, northeastern Brazil, where shorthead drum, *Larimus breviceps*, were harvested by beach seine from December 2016 to November 2017. Black dots represent the fishing method (adapted from Passarone et al., 2019).

2.3 | Growth and longevity

Length-frequency data were analyzed using electronic length-frequency analysis with genetic algorithm using bootstrapping with 1000 runs (ELEFAN_GA_Boot) (Schwamborn et al., 2019) and moving average (MA) of 5 for reconstructed length-frequency data grouped in 1-cm classes. This ELEFAN-based method considers (i) sample size and structure; (ii) variability in the population; and (iii) sampling uncertainty of individuals, considering sample size and precision of the method. Additionally, ELEFAN implemented in TropFishR and fishboot does not estimate the parameter t_0 (theoretical age at length zero), but returns a parameter called t_{anchor}, the fraction of the year where yearly repeating growth curves cross length equal to zero (Mildenberger et al., 2017). However, this parameter may not impact the growth model (Zhou et al., 2022); therefore, the von Bertalanffy growth function (VBGF) was fitted to size-at-age data of males, females, and both sexes of *L. breviceps* $L_t = L_\infty\left[1 - e^{-K(t - t_{anchor})}\right]$, where L_t = the total length (cm) at age t (in years), L_∞ = the theoretical asymptotic length (cm), and K = the growth constant (year^{-1}). Growth parameters were compared between sexes using the two-tailed Mann–Whitney test. This model was applied to adjust the somatic growth for the complete dataset to determine asymptotic length (L_∞), growth constant (K), and growth performance index (ϕ') parameters, and confidence intervals (95%) for males, females, and both sexes combined, using the same search space regardless of sex (L_∞ = 20 to 30, K = 0 to 1 and t_0 = −1 to 0). Longevity ($A_{0.95}$) was estimated using the formula of Taylor (1975): $A_{0.95} = \frac{(t_0 + 2.996)}{K}$.

2.4 | Mortality and exploitation rate

Growth parameters for both sexes combined were used to estimate total instantaneous mortality (Z) using a linearized catch curve (Pauly & Munro, 1984). ANCOVA was used to compare Z between sexes. Instantaneous natural mortality (M) was estimated using growth parameters and the online tool (http://barefootecologist.com.au/shiny_m.html). Natural mortality was defined as the median value calculated through the combination of natural mortality values created by each method (Data S1). Instantaneous fishing mortality (F) and exploitation (E) were estimated from Z and M by:

$$F = Z - M$$

$$E = \frac{F}{Z}$$

where $E > E_{msy}$ was considered overfishing, $E < E_{msy}$ was considered underfishing and $E = E_{msy}$ was maximum sustainable yield (MSY) (Pauly, 1987).

2.5 | Length-based approaches

Selectivity was assumed to be logistic, and recruitment was assumed to be constant because mesh size of beach seining was less likely to retain smaller fish than larger fish within schools. Length-based models were used to assess shorthead drum exploitation status

2.5.1 | Indicators of overfishing

The length at which fish become vulnerable to the gear (L_r) was defined as the length at which 1% of individuals were retained by the gear (Froese et al., 2018). Length at first capture (Lc) was estimated as the length corresponding to 50% and 95% capture probability from the accumulated capture curve (Pauly & Munro, 1984). Three indicators of overfishing were estimated from the length composition of captured fish (Froese, 2004): (i) the percentage of mature individuals captured (goal = let 100% of adult fish spawn at least once before being harvested); (ii) the percentage of fish within the optimum size range (goal = catch 100% of fish within ±10% of the optimum length), estimated by the equation,

$$L_{opt} = L_\infty \times \left(\frac{3}{\left(3 + \left(\frac{M}{K}\right)\right)} \right)$$

where L_{opt} = optimum length; and (iii) the percentage of mega-spawners (goal = harvest 0% of mega-spawners), calculated by,

$$\text{Mega} = L_{opt} + 0.1 \times L_\infty$$

2.5.2 | Yield per recruitment (Y/R) model

The Beverton and Holt (1966) yield/recruit model (Y/R) was used to estimate the fishing mortality rate of the stock at 50% of virgin biomass (optimum yield = $F_{0.5}$), the fishing mortality at 10% of the slope at the origin of the Y/R curve (maximum economic yield = $F_{0.1}$), and fishing mortality at maximum sustainable yield (F_{msy}). Corresponding exploitation rates ($E_{0.5}$, $E_{0.1}$, and E_{msy}) were also estimated. This is considered the most conservative and reliable estimate to guarantee sustainability of a fishery (King, 2007). In addition, the Thompson and Bell (1934) model was used to estimate the impact of adjusting *Lc* values and changing fishing mortality and exploitation rates in the Y/R.

All statistical analyses used R version 4.2.3 (Team, 2023). Length-frequency data were analyzed using *Fishboot* ("Bootstrap-based methods for the study of fish stocks and aquatic population;" Schwamborn et al., 2019 https://github.com/rschwamborn/fishboot); and Beverton-Holt and Thompson-Bell models were analyzed using *TropFishR* ("Tropical Fisheries Analysis;" Taylor & Mildenberger, 2017 https://github.com/tokami/TropFishR).

3 | RESULTS

3.1 | Life-history parameters

Of 969 *L. breviceps* collected, 549 were female (56%) and 420 were male (44%). Females predominated as adults (1:0.53; $\chi^2 = 16.891$, $df = 1$, $p = 3.959e^{-5}$). Total length ranged from 4.2 to 23 cm, with females ranging from 4.3 to 23 cm, and males ranging from 4.2 to 22.8 cm. Females (11.31 ± 2.94 cm; mean ± SD) were larger than males (10.46 ± 2.62 cm; Kruskal-Wallis, $\chi^2 = 25.412$, $df = 1$, $p < 0.05$; Figure 2).

Asymptotic length L_∞ ranged from 22.23 to 27.2 and differed between males and females ($W = 410169$, $df = 1$, $p = 3.488e^{-12}$) and instantaneous growth *K* ranged from 0.64 to 0.76 and differed between males and females ($W = 553098$, $df = 1$, $p = 3.924e^{-5}$; Data S2), whereas t_{anchor} ranged from −0.30 and −0.51 but did not differ between males and females ($W = 500072$, $p = 0.9956$; Data S2) (Table 1). Furthermore, there were no significant differences in instantaneous natural mortality *M* and instantaneous mortality Z between males and females ($W = 14$, $df = 1$, $p = 0.1143$; and $F = 0.008$, $df = 1$, $p = 0.9289$, respectively). As a result, there were also no significant differences in instantaneous fishing mortality *F* and exploitation rate *E* (Table 1). Estimated mortality and exploitation rates for both sexes combined were $Z = 2.71$ years^{-1} (SE ± 0.29), $M = 1.17$ years^{-1}, $F = 1.54$ years^{-1}, and $E = 0.56$ year^{-1} (Data S4).

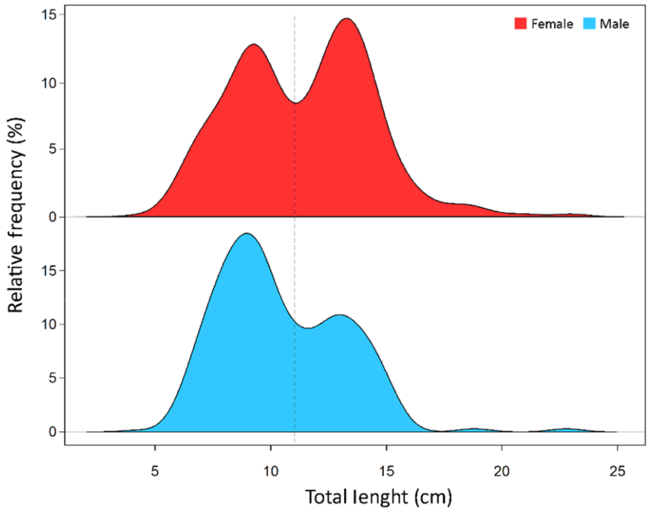

FIGURE 2 Length-frequency of male and female shorthead drum, *Larimus breviceps*, harvested by beach seine off the coast of Paraíba state, Northeast Brazil, from December 2016 to November 2017 (dashed black line, L50 = 11.1; Santos et al., 2021).

3.2 | Length-based assessment

3.2.1 | Indicators of overfishing

Mean lengths at 50% (Lc_{50}) and 95% (Lc_{95}) of first capture were 10.48 and 14.53 cm for males, and 11.34 and 16.03 cm for females, and differed between sexes ($t = 9.59$; $df = 212$; $p < 0.05$). For both sexes combined, Lc50 = 11.05 cm and Lc95 = 15.2 cm (Data S4 and Figure 3). For both sexes combined, fish first recruited to the gear at 6 cm, the maximum observed length (L_{mobs}) was 22.8 cm, the estimated optimum length (L_{opt}) was 21 cm, mega-spawners (Mega) were 23.4 cm, and the maximum length published (L_{mref}) was 32 cm (Figure 3). Adults comprised 50% of the catch (L_{50}, Santos et al., 2021).

3.2.2 | Yield per recruit

Estimated rates of fishing mortality and exploitation were higher than estimated sustainable thresholds (Table 2; Figure 4). In addition, larger length at first capture led to higher yield per recruit and lower fishing mortality and exploitation rates at existing fishing mortality (Figure 5).

4 | DISCUSSION

The large beach seine fishery in Lucena encompasses an area that extends up to 600 m from the coast to a depth of 6 m beyond the

TABLE 1 Asymptotic length (L_∞), instantaneous growth coefficient (K), theoretical age at length = 0 (t_{anchor}), growth performance index (ϕ'), longevity ($A_{0.95}$), instantaneous natural mortality (M), instantaneous fishing mortality (F), instantaneous total mortality (Z), and exploitation rate (E) for female, male, and both sexes pooled shorthead drum, *Larimus breviceps*, harvested by beach seine off the coast of Paraíba state, Northeast Brazil, from December 2016 to November 2017.

Sex	L_∞	K	t_{anchor}	ϕ'	$A_{0.95}$	M	F	Z	E
Females	27.20	0.76	−0.30	2.75	3.63	1.18	1.42	2.60	0.54
Males	22.23	0.69	−0.49	2.55	3.54	1.11	1.32	2.43	0.54
Pooled	23.22	0.64	−0.51	2.54	3.88	1.17	1.54	2.71	0.56

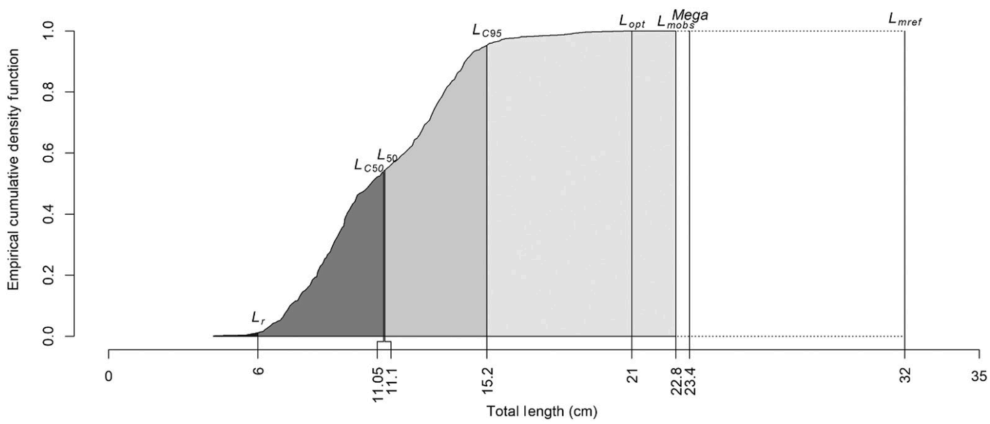

FIGURE 3 Cumulative frequency of shorthead drum, *Larimus breviceps*, harvested by beach seine off the coast of Paraíba state, Northeast Brazil, from December 2016 to November 2017 (L_r = length of first recruitment to the gear; Lc_{50} = mean length at 50% first capture; L_{50} = mean length at 50% first maturity (Santos et al., 2021); Lc_{95} = mean length at 95% first capture; L_{mobs} = maximum observed length; L_{opt} = optimum length; Mega = mega-spawners; L_{mref} = maximum length in the literature (Aparecido et al., 2019).

surf zone that covers the first isobath into the 10-m depth range (Coutinho & Morais, 1970). The shorthead drum inhabits diverse habitats during its life, including estuaries, surf zones, and depths of up to 60 m (Cervigón, 1993; Santos et al., 2021, 2022). In Lucena, the large beach seine fishery operates in areas that encompass multiple habitats used by the shorthead drum, which results in a bimodal length distribution divided at the length at first maturity. This indicates that the shorthead drum population segregates by size based on depth, with smaller individuals being more prevalent in shallower waters. Moreover, beach seine catches did not include mega-spawners, which suggests that larger individuals resided in waters deeper than the reach of the fishing gear (Figure 6). This pattern of size distribution is similar to other coastal species, such as Lutjanid and Sciaenid fishes, where larger individuals are commonly found in deeper waters (Szedlmayer & Lee, 2004). This information is important for fisheries management, particularly for designing and implementing fishery exclusion zones as part of ecosystem-based approaches. Understanding the depth distribution and size composition of target species is crucial for effective management strategies aimed at conserving and sustaining coastal fish populations.

Sexual dimorphism is a common in fish species, wherein females grow larger and live longer than males (Gerking, 1957). We found significant differences between sexes in overall and adult sex ratios, length composition, and growth parameters, which indicate that females are more abundant, reach larger size at a faster rate, and live longer than males. Further, males were captured at an earlier age than females. Larger and more abundant females likely contributed to enhanced reproductive success and survival of offspring (Winemiller & Layman, 2005). Furthermore, despite faster growth and older age of females, males exhibited similar allometry and ecomorphology as females (Santos et al., 2021, 2022). This consistency in geometric growth facilitates implementation of management actions, such as Bycatch Reduction Devices (BRD), to mitigate impact of fishing mortality on the shorthead drum population.

Growth of shorthead drum we observed in northeastern Brazil was similar to previous studies in southeastern Brazil (Aparecido et al., 2019; Bessa et al., 2013), but differed from populations in the Caribbean Sea and Northwest Atlantic (García & Duarte, 2006). Interestingly, growth in the Northwest Atlantic was similar to a congeneric species, *L. fasciatus* (Ross, 1988; Standard & Chittenden, 1984) (Figure 7). Most studies used length-frequency methods (except Ross, 1988), so differences in growth curves among these different regions can be attributed to: (a) differences in temperature, despite all regions being within the tropics, because colder waters would influence growth (Tarkan & Vilizzi, 2015); (b) differences in size of fish sampled in each area, wherein larger samples may lead to higher L_∞ and lower K (Barr et al., 2008); (c) presence of multiple stocks; (d) differences in collection periods; and (e) selectivity of different fishing gears (Lucena & O'Brien, 2001) (Table 3).

TABLE 2 Fishing mortality and exploitation rates to reference points of shorthead drum, *Larimus breviceps*, harvested by beach seine off the coast of Paraíba state, Northeast Brazil from December 2016 to November 2017.

Reference points	Current	0.5	0.1	MSY
Fishing mortality	1.54	0.45	1	1.2
Exploitation	0.56	0.27	0.46	0.5

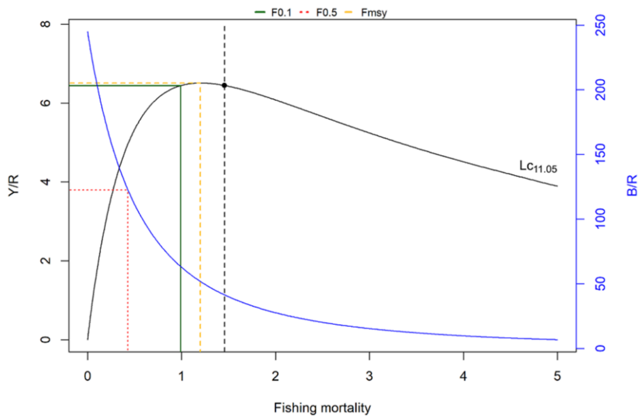

FIGURE 4 Yield–(black line) and biomass-per-recruit (blue line) of shorthead drum, *Larimus breviceps*, harvested by beach seine off the coast of Paraíba state, Northeast Brazil from December 2016 to November 2017 (black dashed line and dot, current fishing pressure: $F=1.54$).

The relative fishing mortality of shorthead drum we estimated differed from a similar study (García & Duarte, 2006), likely because fishing strategies differed. The use of motorized trawling as a fishing method may have a detrimental impact on shorthead drum stocks (Bomfim et al., 2019). Moreover, differences in Z estimated by Bessa et al. (2013) might have been influenced by the sampling method, which primarily targeted juveniles in a limited range of the shorthead drum distribution. Furthermore, differences in longevity values could be attributed to differences in environmental, ecological, and fishing characteristics (Table 4).

Indicators of overfishing play a crucial role in fisheries management by providing reference points for rebuilding stocks, particularly for species with limited available data (Froese, 2004). These species include bycatch and non-commercial species that are vulnerable to fishing, habitat degradation, and other threats to aquatic biodiversity. Based on length at first capture exceeding the length at first maturity, individuals were harvested before they could reproduce and contribute to the replenishment of the stock. Further, mean length was outside ±10% of the optimum length, which indicated a substantial proportion of small individuals were targeted by the fishery and raises concerns about growth overfishing and potential depletion of the population. In contrast, mega-spawners were absent in the harvest, which is a positive indication that these individuals contributed significantly to reproductive success of the population (Solemdal, 1997; Trippel, 1998). Therefore, two of three indicators highlighted the necessity for effective fishery management measures.

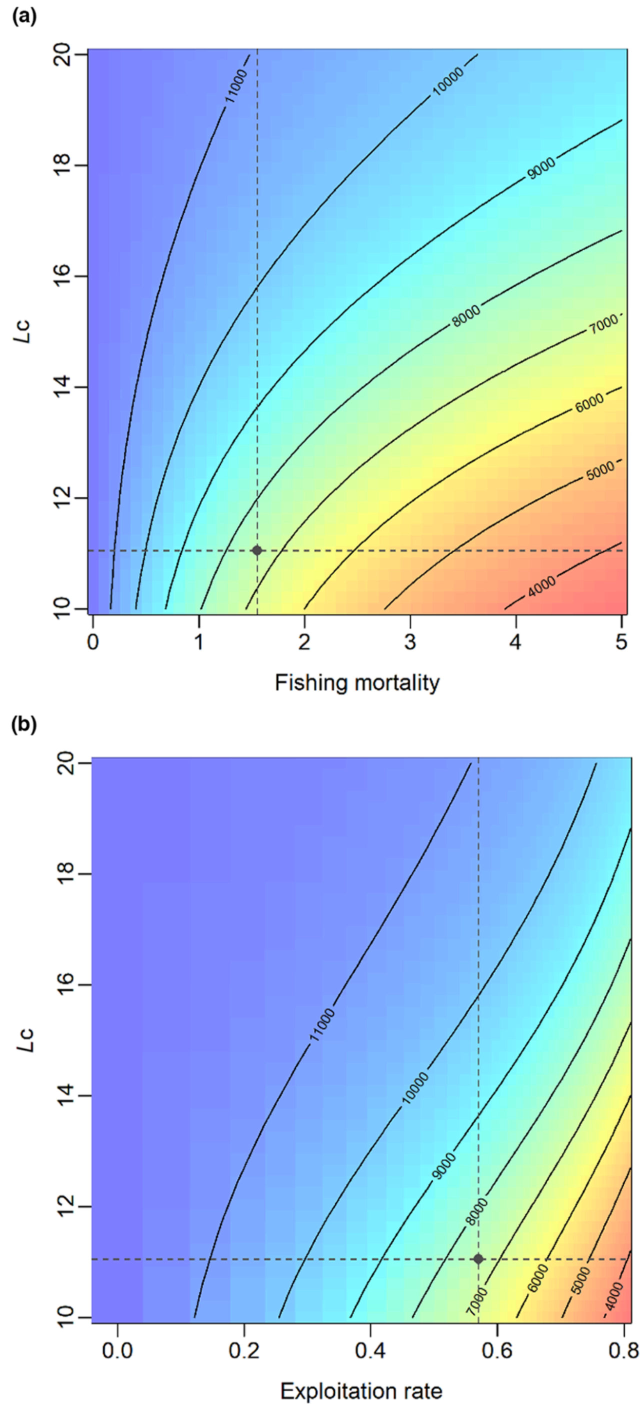

FIGURE 5 Yield per recruit (g) of different fishing mortality (a) and exploitation (b) rates in relation to mean length at first capture of shorthead drum, *Larimus breviceps*, harvested by beach seine off the coast of Paraíba state, Northeast Brazil (black dashed line and dot, current fishing mortality and exploration rate: $F=1.54$ and $E=0.56$).

We found that current exploitation and fishing mortality rates exceeded maximum sustainable yield, which suggested that the shorthead drum population in Lucena was slightly overexploited. Therefore, any increase in fishing effort would likely negatively impact the stock and reduce yield per recruit, although the exploitation

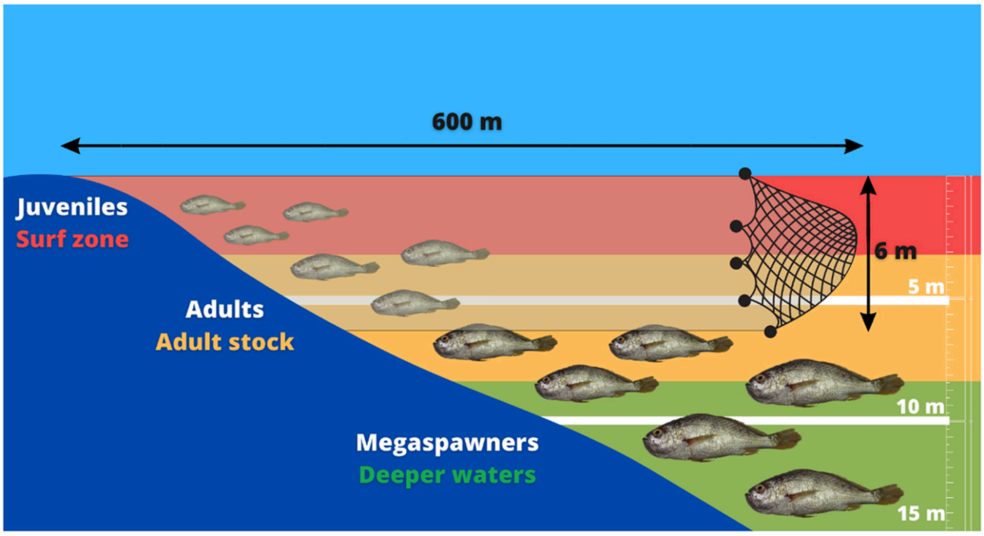

FIGURE 6 Spatial distribution by size of *Larimus breviceps* and operating area of beach seining in Lucena, Paraíba.

rate and fishing mortality rate were very close to maximum sustainable yield levels. By reducing exploitation to 0.5 and fishing mortality to 1.0, yield could be optimized to minimize the impact on the shorthead drum population, thereby preventing depletion and potential disruptions to reproductive capacity. Additionally, optimal and economic reference points ($E_{0.5}$ and $F_{0.5}$, and $E_{0.1}$ and $F_{0.1}$) are alternatives for management. Nevertheless, optimization should be assessed annually to enable better management, by considering the tradeoff between extra mortality over spawning biomass of other non-target and target species (King, 2007).

We found compelling evidence of growth overfishing of the shorthead drum population, thereby indicating a significant ecological impact of the large beach seine fishery, like recent regional studies that emphasized the substantial influence of this fishing method (Passarone et al., 2019). To ensure sustainable exploitation of the species, we recommend implementing enhanced monitoring programs and reassessing current catch levels, fishing efforts, and population trends, while considering the lack of available information for the region. These insights can facilitate the development of management initiatives to regulate fishing effort, modify capture equipment, or establish a targeted fishing season. However, the large beach seine fishery, while requiring specific management measures for the shorthead drum population, also targets multiple species, captures other bycatch species, and is of significant socioeconomic importance, which underscores the necessity for comprehensive and integrated management strategies.

To advance the goals of sustainable resource management, adoption of a comprehensive methodology rooted in ecosystem-based principles is important. This approach would account for intricate interdependencies among diverse species and their habitats, along with socioeconomic factors associated with the fishery. The initial step in implementing such management strategies involves improving the availability of data, with a focus on species abundance, distribution, stock status, and metrics related to size, catch, and fishing

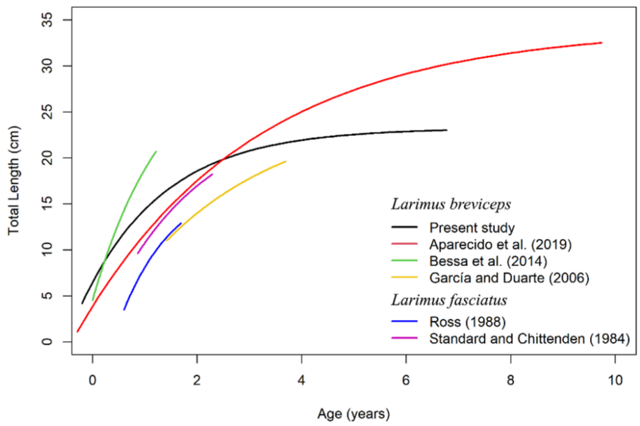

FIGURE 7 Von Bertalanffy length-age curves of *Larimus breviceps* and *L. fasciatus* from the present study and other published studies.

effort. These data would serve as a foundation for shaping future management approaches. Examples of effective methodologies include habitat-based management (Wedding & Yoklavich, 2015), measures to reduce bycatch (Glass, 2000), and implementation of marine spatial planning (Collie et al., 2013). Such approaches have demonstrated how to balance ecological, social, and economic objectives to contribute to long-term sustainability of fisheries. In summary, our study served as a valuable reference for decision-makers, by providing essential information for the development of effective management strategies, stakeholder engagement, and promotion of responsible fishing practices. Additionally, our case study underscored the potential consequences of a targeted ban on a specific fishing gear, by highlighting the need to carefully consider alternative gears and their potential ecological implications. Insights from our study can be adapted and applied across similar fisheries elsewhere in the world to yield valuable lessons for sustainable fisheries management.

TABLE 3 Growth parameters, periods of collection, size range, and fishing strategy of *Larimus breviceps* and *L. fasciatus* from the present study and by different authors (BS, beach seining; MT, motorized trawling).

Species	Author	Period of collection	Size range (cm)	Fishing strategy	L_∞	K	t_0
L. breviceps	Present study	2016–2017	4.2–22.8	BS	23.22	0.64	−0.51
	Aparecido et al., 2019	2007–2017	11–32.5	MT	34.13	0.3	−0.4
	Bessa et al., 2013	2003–2004	3.5–20.7	MT	32.25	0.72	−0.21
	García & Duarte, 2006	1995–1998	11–19.6	MT	25.4	0.4	–
L. fasciatus	Ross, 1988	1975–1976	9.6–18.2	MT	17.8	0.98	0.38
	Standard & Chittenden, 1984	1977–1981	3.5–12.9	MT	25.41	0.55	–

TABLE 4 Mortality rates of *Larimus breviceps* by beach seine and motorized trawling.

Study	Fishing strategy	Z	M	F	F/M	A
Present study	Fishery-dependent beach seine	2.71	1.17	1.56	1.33	3.88
Bessa et al., 2013	Fishery-independent motorized trawling	12.1	–	–	–	4.38
García & Duarte, 2006	Fishery-independent motorized trawling	4.35	1.24	3.11	2.5	–

ACKNOWLEDGMENTS

We would like to acknowledge the fishermen for their contribution to the success of the operations, and the Editor-in-chief for the thorough contributions to the final version of the manuscript.

FUNDING INFORMATION

This study is a contribution to the projects “Shrimp NE_N” (Grant Number: 445766/2015-8), which has receive funding from the Secretaria da Pesca e Aquicultura (MAPA/SAP), Brazil and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil and to “Subsídios para o manejo sustentável da pesca de camarões no litoral norte da Paraíba,” also financed by CNPQ, Brazil. It is also a contribution to the LMI TAPIOCA.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Not applicable.

ORCID

Lucas Santos https://orcid.org/0000-0003-0291-9793
Jonas Vasconcelos-Filho https://orcid.org/0000-0002-2134-2355
Leandro N. Eduardo https://orcid.org/0000-0003-2369-4175
Alex Lira https://orcid.org/0000-0003-1734-1875
Cecília Craveiro https://orcid.org/0000-0003-2514-7423
Emanuell F. Silva https://orcid.org/0000-0002-1376-0653
Flávia Lucena-Frédou https://orcid.org/0000-0001-5492-7205

REFERENCES

Aparecido, K.C., Negro, T.D., Tutui, S.L.S., Souza, M.R. & Tomás, A.R.G. (2019) *Larimus breviceps* Cuvier 1830 at the inner continental shelf of São Paulo and Paraná states. In: Vaz-Dos-Santos, A.M. & Rossi-Wongtschowski, C.L.D.B. (Eds.) *Growth in fisheries resources from the southwestern Atlantic*. São Paulo: Instituto Oceanográfico—USP, pp. 162–164.

Barr, E.E., Cabello, M.G., Solís, E.G.C., Boa, A.G. & Gómez, M.P. (2008) Growth of the Pacific jack *Caranx caninus* (Pisces: Carangidae) from the coast of Colima, México. *Revista de Biología Tropical*, 56(1), 171–179.

Berkes, F., Colding, J. & Folke, C. (2000) Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, 10, 1251–1262.

Berkes, F., Mahon, R., McConney, P., Pollnac, R. & Pomeroy, R. (2001) *Managing small-scale fisheries: alternative directions and methods*. Ottawa, Ontario, Canada: International Development Research Centre.

Bessa, E., Santos, F.B., Pombo, M., Denadai, M., Fonseca, M. & Turra, A. (2013) Population ecology, life history and diet of the shorthead drum *Larimus breviceps* in a tropical bight in southeastern Brazil. *Journal of the Marine Biological Association of the United Kingdom*, 94(3), 615–622. Available from: https://doi.org/10.1017/S0025315413001690

Beverton, R.J.H. & Holt, S.J. (1966) *Manual of methods for fish stock assessment, part 2. Tables of yield functions, fisheries technical paper*. Québec: Food And Agriculture Organization of the United Nations.

Bomfim, A.C., Farias, D.S.D., Morais, I.C.C., Rossi, S., Gavilan, S.A. & Silva, F.J.L. (2019) The impact of shrimp trawl bycatch on fish reproduction in northeastern Brazil. *Biota Amazônia*, 9(1), 37–42. Available from: https://doi.org/10.18561/2179-5746

Cattani, A.P., Santos, L.O., Spach, H.L., Budel, B.R. & Gondim-Guanais, J.H.D. (2011) Avaliação da ictiofauna da fauna acompanhante da pesca do camarão sete-barbas do município de Pontal do Paraná, litoral do Paraná, Brasil. *Boletim do Instituto de Pesca*, 37(2), 247–260.

Cervigón, F. (1993) *Los peces marinos de Venezuela*, vol. 1. Caracas, Venezuela: Fundación Científica Los Roques, p. 497.

Chao, N.L., Frédou, F.L., Haimovici, M., Peres, M.B., Polidoro, B., Raseira, M. et al. (2015) A popular and potentially sustainable fishery resource under pressure–extinction risk and conservation of Brazilian Sciaenidae (Teleostei: Perciformes). *Global Ecology and Conservation*, 4, 117–126. Available from: https://doi.org/10.1016/j.gecco.2015.06.002

Collie, J.S., Adamowicz, W.L., Beck, M.W., Craig, B., Essington, T.E., Fluharty, D. et al. (2013) Marine spatial planning in practice. *Estuarine, Coastal and Shelf Science*, 117, 1–11. Available from: https://doi.org/10.1016/j.ecss.2012.11.010

Cope, J.M., Dowling, N.A., Hesp, S.A., Omori, K.L., Bessell-Browne, P., Castello, L. et al. (2023) The stock assessment theory of relativity: deconstructing the term "data-limited" fisheries into components and guiding principles to support the science of fisheries management. *Reviews in Fish Biology and Fisheries*, 33, 241–263. Available from: https://doi.org/10.1007/s11160-022-09748-1

Costello, C., Ovando, D., Hilborn, R., Gaines, S.D., Deschenes, O. & Lester, S.E. (2012) Status and solutions for the world's unassessed fisheries. *Science*, 338, 517–520. Available from: https://doi.org/10.1126/science.1223389

Coutinho, P.N. & Morais, J.O. (1970) Distribución de los sedimentos en la plataforma continental norte y nordeste del Brasil. *Arquivos de Ciências do Mar*, 10, 79–90.

Dagnelie, P. (1975) Théorie et méthodes statistiques: applications agronomiques. In: *Les méthodes de l'inférence stastique*, Vol. 2. Gembloux: Les presses agronomiques de Gembloux.

Dornelas, M.A.S. (2015) *Comunidades tradicionais pesqueiras. Arte e Sustento Em águas e Terras Brasileiras*. Available at: http://cppnacional.org.br/sites/default/files/Jornal-Mundo-Jovem-Edi%C3%A7%C3%A3o-Mar%C3%A7o-2015-Comunidades-Tradicionais-Pesqueiras.pdf [Accessed on 10th January 2023].

Dowling, N.A., Smith, A.D.M., Smith, D.C., Parma, A.M., Dichmont, C.M., Sainsbury, K. et al. (2019) Generic solutions for data-limited fishery assessments are not so simple. *Fish and Fisheries*, 20, 174–188. Available from: https://doi.org/10.1111/faf.12329

Dowling, N.A., Wilson, J.R., Rudd, M.B., Babcock, E.A., Caillaux, M., Cope, J. et al. (2016) *FishPath: a decision support system for assessing and managing data-and capacity-limited fisheries. Assessing and managing data-limited fish stocks*. Fairbanks: Alaska Sea Grant, University of Alaska Fairbansk, p. 37. Available from: https://doi.org/10.4027/amdlfs.2016.03

Dyck, A.J. & Sumaila, U.R. (2010) Economic impact of ocean fish populations in the global fishery. *Journal of Bioeconomics*, 12, 227–243. Available from: https://doi.org/10.1007/s10818-010-9088-3

Elliott, M., Whitfield, A.K., Potter, I.C., Blaber, S.J.M., Cyrus, D.P., Nordlie, F.G. et al. (2007) The guild approach to categorizing estuarine fish assemblages: a global review. *Fish and Fisheries*, 8, 241–268.

Frawley, T.H., Finkbeiner, E.M. & Crowder, L.B. (2019) Environmental and institutional degradation in the globalized economy: lessons from small-scale fisheries in the Gulf of California. *Ecology and Society*, 24(1), 1–7. Available from: https://doi.org/10.5751/ES-10693-240107

Freitas, M.O., Vasconcelos, S.M., Hostim-Silva, M. & Spach, H.L. (2011) Length weight relationships for fishes caught by shrimp trawl in Santa Catarina coast, South Atlantic, Brazil. *Journal of Applied Ichthyology*, 27(6), 1427–1428. Available from: https://doi.org/10.1111/j.1439-0426.2011.01749.x

Froese, R. (2004) Keep it simple: three indicators to deal with overfishing. *Fish and Fisheries*, 5(1), 86–91. Available from: https://doi.org/10.1111/j.1467-2979.2004.00144.x

Froese, R., Winker, H., Coro, G., Demirel, N., Tsikliras, A.C., Dimarchopoulou, D. et al. (2018) A new approach for estimating stock status from length frequency data. *ICES Journal of Marine Science*, 76, 350–351. Available from: https://doi.org/10.1093/icesjms/fsy078

García, C.B. & Duarte, L.O. (2006) Length-based estimates of growth parameters and mortality rates of fish populations of the Caribbean Sea. *Journal of Applied Ichthyology*, 22(3), 193–200. Available from: https://doi.org/10.1111/j.1439-0426.2006.00720.x

Gerking, S.D. (1957) Evidence of ageing in natural populations of fishes. *Gerontologia*, 1, 287–305. Available from: https://doi.org/10.1159/000210706

Glass, C.W. (2000) Conservation of fish stocks through bycatch reduction: a review. *Northeastern Naturalist*, 7(4), 395–410. Available from: https://doi.org/10.2307/3858520

Haimovici, M. & Mendonça, J.T. (1996) Descartes da fauna acompanhante na pesca de arrasto de tangones dirigida a linguados e camarões na plataforma continental do sul do Brasil. *ATLÂNTIDA, Rio Grande*, 18, 161–177.

Hsieh, C.H., Yamauchi, A., Nakazawa, T. & Wang, W.F. (2010) Fishing effects on age and spatial structures undermine population stability of fishes. *Aquatic Sciences*, 72(2), 165–178. Available from: https://doi.org/10.1007/s00027-009-0122-2

IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis). (1990) Ordinance 833/1990, June 7, 1990. To prohibit trawling by motorized vessels in the state of Paraíba, up to a distance of three miles from the coast.

Isaac, V.J., Ruffino, M.L. & Mcgrath, D. (1998) In search of a new approach to fisheries management in the middle Amazon region. In: F. Funk, J. Heifetz, J. Ianelli, J. Power, T. Quinn, J. Schweigert, P. Sullivan & C.I. Ahang, (Eds.) *Proceedings of the Symposium on Fishery Stock Assessment Models for the 21st Century*. Fairbanks: Alaska Sea Grant College Program, pp. 889–902.

King, M. (2007) *Fisheries Biology, Assessment and Management*. Oxford: Blackwell Publishing, p. 341.

Lira, A.S., Loc'h, F.L., Andrade, H.A. & Lucena-Frédou, F. (2022) Vulnerability of marine resources affected by a small-scale tropical shrimp fishery in Northeast Brazil. *ICES Journal of Marine Science*, 79(3), 633–647. Available from: https://doi.org/10.1093/icesjms/fsac004

Lucena, F.M. & O'Brien, C.M. (2001) Effects of gear selectivity and different calculation methods on estimating growth parameters of bluefish, *Pomatomus saltatrix* (Pisces: Pomatomidae), from southern Brazil. *Fishery Bulletin*, 99(3), 432.

Mildenberger, T.K., Taylor, M.H. & Wolff, M. (2017) TropFishR: an R package for fisheries analysis with length-frequency data. *Methods in Ecology and Evolution*, 8, 1520–1527. Available from: https://doi.org/10.1111/2041-210X.12791

Nunoo, F. & Nascimento, J. (2015) *Pseudotolithus senegalensis*. United Kingdom: The IUCN red list of threatened species.

Passarone, R. (2020) *Avaliação da fauna acompanhante da pesca camareira e comparação entre as modalidades de arrasto de praia e arrasto motorizado na Paraíba, Nordeste Brasileiro, Master thesis*. Recife: Universidade Federal Rural de Pernambuco.

Passarone, R., Aparecido, K.C., Eduardo, L.N., Lira, A.S., Silva, L.V.S., Justino, A.K.S. et al. (2019) Ecological and conservation aspects of bycatch fishes: Na evaluation of shrimp fisheries impacts in northeastern Brazil. *Brazilian Journal of Oceanography*, 67, 1–10. Available from: https://doi.org/10.1590/s1679-87592019029106713

Pauly, D. (1987) A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates. *ICLARM Conference Proceedings*, 13, 7–34.

Pauly, D. & Munro, J.L. (1984) Once more on the comparison of growth in fish and invertebrates. *Fishbyte*, 2(1), 1–21.

Pelage, L., Bertrand, A., Ferreira, B.P., Lucena-Frédou, F., Justino, A.K.S. & Frédou, T. (2021) Balanced harvest as a potential management strategy for tropical small-scale fisheries. *ICES Journal of Marine Science*, 78(7), 2547–2561. Available from: https://doi.org/10.1093/icesjms/fsab136

Pons, M., Lucena-Frédou, F., Frédou, T. & Mourato, B. (2019) Exploration of length-based and catch-based data-limited assessments for small tunas. *Collective Volume of Scientific Papers, ICCAT*, 76, 78–95.

Prince, J. & Hordyk, A. (2019) What to do when you have almost nothing: a simple quantitative prescription for managing extremely data-poor fisheries. *Fish and Fisheries*, 20, 224–238. Available from: https://doi.org/10.1111/faf.12335

Quinn, T.J. & Deriso, R.B. (1999) *Quantitative fish dynamics*. New York: Oxford University Press.

Ross, S.W. (1988) Age, growth, and mortality of the banded drum, *Larimus fasciatus* (Sciaenidae) in North Carolina. *Northeast Gulf Science*, 10(1), 2. Available from: https://doi.org/10.18785/negs.1001.02

Rousseau, Y., Watson, R.A., Blanchard, J.L. & Fulton, E.A. (2019) Defining global artisanal fisheries. *Marine Policy*, 108, 103634. Available from: https://doi.org/10.1016/j.marpol.2019.103634

Santos, L., Kikuchi, E., Lucena-Frédou, F., Bezerra, N., Travassos, P., Hazin, F. et al. (2023) Assessment of the stock status of blackfin tuna Thunnus atlanticus in the Southwest Atlantic Ocean: a length-based approach. *Regional Studies in Marine Science*, 65, 103061. Available from: https://doi.org/10.1016/j.rsma.2023.103061

Santos, L.V., Craveiro, C.F.F., Soares, A., Eduardo, L.N., Passarone, R., Silva, E.F.B. et al. (2021) Reproductive biology of the shorthead drum *Larimus breviceps* (Acanthuriformes: Sciaenidae) in northeastern Brazil. *Regional Studies in Marine Science*, 48, 102052. Available from: https://doi.org/10.1016/j.rsma.2021.102052

Santos, L.V., Vasconcelos-Júnior, J.V., Lira, A.S., Eduardo, L.N., Passarone, R., Le Loc'h, F. et al. (2022) Trophic ecology and ecomorphology of the shorthead drum *Larimus breviceps* (Acanthuriformes: Sciaenidae), from the northeastern Brazil. *Thalassas*, 38, 1–11. Available from: https://doi.org/10.1007/s41208-021-00365-6

Schuhbauer, A. & Sumaila, U.R. (2016) Economic viability and small-scale fisheries—a review. *Ecological Economics*, 124, 69–75. Available from: https://doi.org/10.1016/j.ecolecon.2016.01.018

Schwamborn, R., Mildenberger, T.K. & Taylor, M.H. (2019) Assessing sources of uncertainty in length-based estimates of body growth in populations of fishes and macroinvertebrates with bootstrapped ELEFAN. *Ecological Modelling*, 393, 37–51. Available from: https://doi.org/10.1016/j.ecolmodel.2018.12.001

Silva-Júnior, C.A.B., Lira, A.S., Eduardo, L.N., Viana, A.P., Frédou, F.L. & Frédou, T. (2019) Ichthyofauna bycatch of the artisanal fishery of penaeid shrimps in Pernambuco, Northeastern Brazil. *Boletim do Instituto de Pesca*, 45(1), 1–10. Available from: https://doi.org/10.20950/1678-2305.2019.45.1.435

Solemdal, P. (1997) Maternal effects – a link between the past and the future. *Journal of Sea Research*, 37, 213–227.

Standard, G.W. & Chittenden, M.E. (1984) Reproduction, movements, and population dynamics of the banded drum, *Larimus fasciatus*, in the Gulf of Mexico. *Fishery Bulletin*, 82(2), 337–363.

Szedlmayer, S.T. & Lee, J.D. (2004) Diet shifts of juvenile red snapper (*Lutjanus campechanus*) with changes in habitat and fish size. *Fishery Bulletin*, 102(2), 366–375.

Tarkan, A.S. & Vilizzi, L. (2015) Patterns, latitudinal clines and counter gradient variation in the growth of roach *Rutilus rutilus* (Cyprinidae) in its Eurasian area of distribution. *Reviews in Fish Biology and Fisheries*, 25(4), 587–602. Available from: https://doi.org/10.1007/s11160-015-9398-6

Taylor, L.R. (1975) Longevity, fecundity and size; control of reproductive potential in a polymorphic migrant, Aphis fabae Scop. *The Journal of Animal Ecology*, 59, 135–163.

Taylor, M. & Mildenberger, T. (2017) Extending electronic length frequency analysis in R. *Fisheries Management and Ecology*, 24, 330–338. Available from: https://doi.org/10.1111/fme.12232

Team, R.C. (2023) *R version 4.2.3: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Thompson, W.F. & Bell, H. (1934) Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield, and yield per unit gear. *Reports of International Fisheries Communication*, 8, 1–49.

Tischer, M. & Santos, M.C.F. (2001) Algumas considerações sobre a ictiofauna acompanhante da pesca de camarões na foz do rio São Francisco (Alagoas/Sergipe-Brasil). *Boletim Técnico-Científico Do CEPENE*, 9(1), 155–165.

Trippel, E.A. (1998) Egg size and viability and seasonal offspring production of young Atlantic cod. *Transactions of the American Fisheries Society*, 127, 339–359.

Vasconcellos, M. & Haimovici, M. (2006) Status of white croaker Micropogonias furnieri exploited in southern Brazil according to alternative hypotheses of stock discreetness. *Fisheries Research*, 80(2–3), 196–202. Available from: https://doi.org/10.1016/j.fishres.2006.04.016

Wedding, L. & Yoklavich, M.M. (2015) Habitat-based predictive mapping of rockfish density and biomass off the Central California coast. *Marine Ecology Progress Series*, 540, 235–250. Available from: https://doi.org/10.3354/meps11442

Winemiller, K.O. & Layman, C.A. (2005) Food web science: moving on the path from abstraction to prediction. In: Ruiter, P.C., Wolters, V. & Moore, J.C. (Eds.) *Dynamic food webs: multispecies assemblages, ecosystem development and environmental change*. Amsterdam: Elsevier, pp. 10–23. Available from: https://doi.org/10.1016/B978-012088458-2/50003-5

Zhou, S., Hutton, T., Lei, Y., Miller, M., Velde, T.D. & Deng, R.A. (2022) Estimating growth from length frequency distribution: comparison of ELEFAN and Bayesian approaches for red Endeavour prawns (*Metapenaeus ensis*). *ICES Journal of Marine Science*, 79(6), 1942–1953. Available from: https://doi.org/10.1093/icesjms/fsac131

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Santos, L., Vasconcelos-Filho, J., Eduardo, L.N., Lira, A., Craveiro, C., Silva, E.F. et al. (2024) Stock assessment of *Larimus breviceps*, a bycatch species exploited by artisanal beach seining in Northeast Brazil. *Fisheries Management and Ecology*, 31, e12647. Available from: https://doi.org/10.1111/fme.12647