



A review of the scientific production and research output on the demersal marine fishery resources of the Brazilian Meridional Margin, SW Atlantic

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Received: 16 October 2024 / Accepted: 4 September 2025 / Published online: 28 October 2025
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Abstract An analysis was conducted to evaluate the scientific production related to marine demersal fishery resources along the Brazilian Meridional Margin of the Southwest Atlantic (21°S—34°S), recognized as the most productive fishing area in Brazil. With a focus on life history, population dynamics and fisheries, our review encompassed 1,091 references published between 1960 and 2021s, covering 166 species: 82 teleosts, 40 elasmobranchs, 24 crustaceans, 8 cephalopods, and 12 other molluscs. Research was predominantly focused on target species (59%), followed by commercially valuable by-catch (27%) and

discarded species (13%). The volume of publications increased exponentially from 1.2 per year in the 1960s to 41.2 per year during 2020s. While significant advancements have been made in understanding the growth, reproduction, distribution and life cycles of commercially important species, there remains a notable knowledge gap regarding species of no commercial value. Addressing these gaps is crucial for a comprehensive ecosystem-based management approach, ensuring sustainable fisheries and informed stock assessments.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11160-025-09992-1>.

Keywords Bibliometric analysis · Fish · Teleosts · Southern Brazil · Southeastern Brazil

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Introduction

Marine fishing resources are essential for ensuring food security, supporting fisheries-based production chains, and providing employment and income opportunities worldwide (FAO 2022). Fisheries have been important throughout human history (Callum 2007) and have expanded rapidly since the beginning of the industrial era due to technological advances, leading to widespread overexploitation of fish populations in the present day and a consensus on the need to restore most marine stocks to more productive states (Pauly et al. 2002; Christensen 2011). Throughout the twentieth century, most fisheries management efforts focused on individual populations or species

to sustain catches and maximise profits (Dolan et al. 2016). Under certain conditions, stock-based fisheries management has been successful in achieving its objectives (Hilborn et al. 2020). However, this approach has not prevented the global trend of increasing overfishing and the collapse of marine resources (FAO 2022). Consequently, the overall poor results of individual stock management have led to an increased focus on ecosystem-based approaches in recent decades (Dolan et al. 2016). Based on that, Perez et al. (2024) emphasised the need for an ecosystem-based approach to spatial planning for managing the marine demersal fisheries resources along the southernmost region of Brazil, hereafter referred to as the Brazilian Meridional Margin (BMM).

The BMM area spans over 2500 km of coastline between 21°S and 34°S and accounts for more than 40% of Brazil's total marine demersal landings (Freire et al. 2021). It is located within the warm-temperate Southwestern Atlantic Province (Spalding et al. 2007) and it encompasses two subregions the "Southeastern Brazil" (SEB) and "Southern Brazil" (SB) divided by the Cape of Santa Marta Grande (28° 36'S [Fig. 1]). The SEB is influenced by the Brazil Current (BC), a contour current of the South Atlantic subtropical gyre. The BC flows southward along the shelf break and slope, carrying Tropical Waters (TW) and, below it, South Atlantic Central Waters (SACW), which seasonally intrudes nutrient-rich deep waters onto the continental shelf (Silveira et al. 2000). Further south, the SB is influenced by sub-Antarctic waters, the Brazil-Malvinas Confluence and the Rio de la Plata flowing northwards (Matano et al. 2010). The outflow from the Patos-Mirim lagoons complex seasonally enhances productivity along the southernmost continental shelf of Brazil (Ciotti et al. 1995; Moller et al. 2008). This transitional zone between the subtropical and warm temperate zones of the western Atlantic supports a wide diversity of benthic, benthopelagic and demersal fish and invertebrate species (Haimovici et al. 1994; 1996; 2004, 2007; Muelbert et al. 2015), forming distinct spatial and temporal benthic and nektonic assemblages (Capitoli and Benvenuti, 2006; Martins and Haimovici 2017).

Until the first half of the twentieth century, most demersal fisheries in the BMM were coastal and of small-scale (Pinto Paiva 2004). The larger scale fishing operations, including industrial bottom trawlers, started to emerge only in the early 1950s (Yesaki and

Bager 1975; Pinto Paiva 2004). Since the 1970s fisheries have significantly expanded and diversified as Argentina and Uruguay excluded Brazilian trawlers from their richer fishing grounds. However, this shifts intensified fishing efforts in Brazilian waters, leading to the collapse of several species and the severe overfishing of many others (Vooren and Klippel 2005; Haimovici and Cardoso 2017). The collapse of these fisheries led the Brazilian government to implement, from the 1980s onwards, several regulatory actions aimed at the sustainable use of these stocks. These actions included restrictions of the size of the fishes in the catches and control of licenses for new vessels, freezing the size of the trawler fleet at the time (Perez et al. 2001) and, later, a ban on landings of various elasmobranchs, including sharks and rays (Vooren & Klippel 2005).

While informative of the poor performance of the management system in the region, this assessment also highlighted the value of efforts to compile existing population parameters, vital to assess the stock status and the impacts of fishing on ecosystem structure, function, and resilience (FAO 2003; Pikitch et al. 2004). Incorporating these parameters into ecosystem models enables a more comprehensive assessment of the cumulative impacts of human activities and natural processes, ultimately supporting more effective and holistic management strategies (Hilborn 2011). Without accurate data on population parameters of species, both targeted and non-targeted by commercial fisheries, ecosystem-based approaches to fisheries management may face challenges in effectively addressing overexploitation and maintaining the health of marine ecosystems (Marshall et al., Marshall et al. 2019).

Since the 1960's numerous studies have investigated demersal species inhabiting the BMM. However, this body of knowledge remains sparsely documented in the literature and is often found in grey literature, which can be relatively difficult to find and access. This includes discontinued journals unavailable online, non-indexed journals, book chapters, technical reports, and academic products. Analyzing large datasets of publications can reveal historical trends and shifts in research focus over time besides providing, evidence-based insights for strategic planning and decision making. In this context, a systematic review is an optimal approach to consolidate and

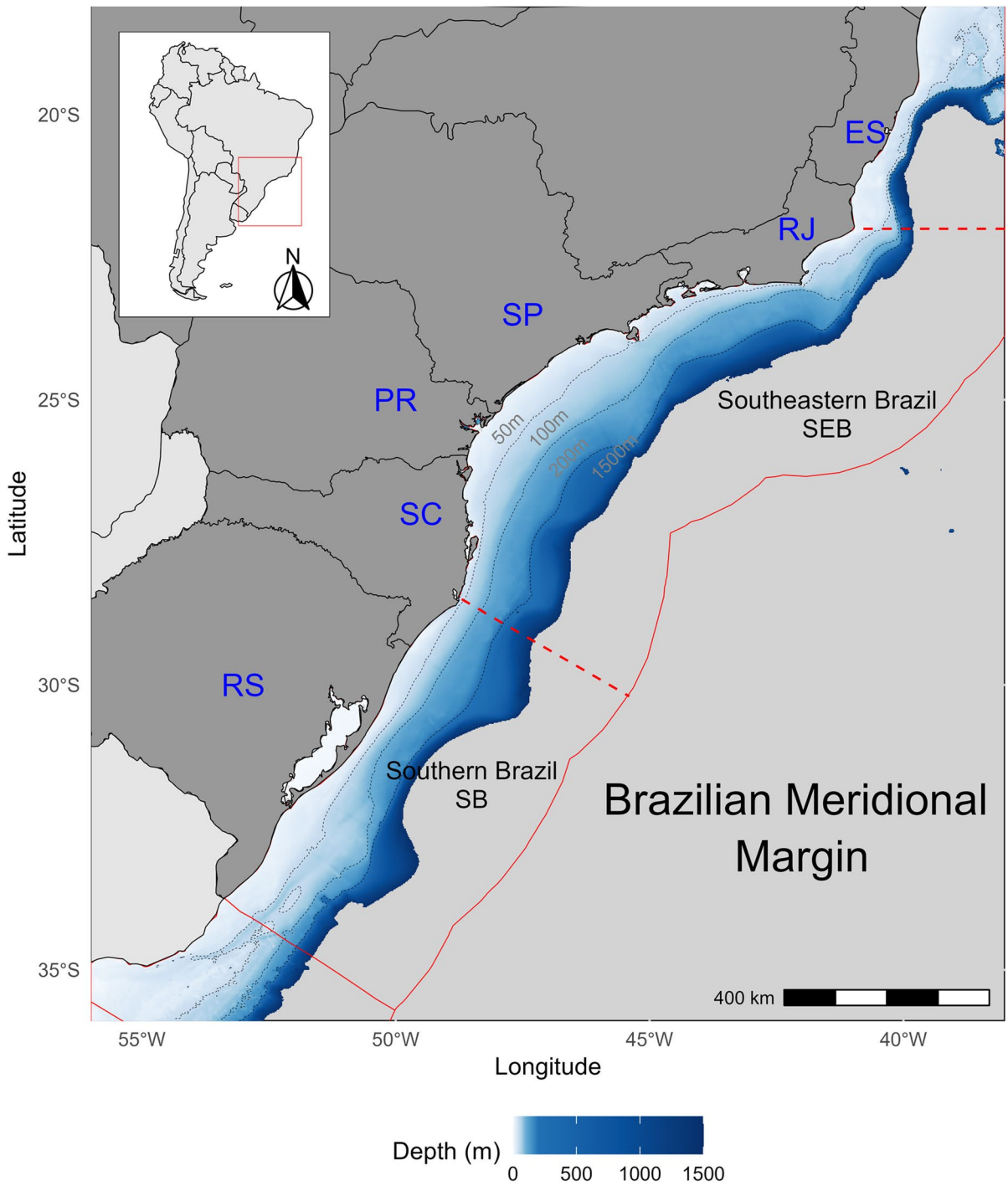


Fig. 1 Brazilian Meridional Margin (BMM) highlighting its two sub regions: SEB and SB. Acronyms of Brazilian states RS: Rio Grande do Sul, SC: Santa Catarina, PR: Paraná, SP: São Paulo, RJ: Rio de Janeiro, ES: Espírito Santo

summarize clearly defined questions while critically evaluating relevant research (Moher et al. 2010).

This study combines a comprehensive review approach with a survey of current knowledge on

various aspects of the population dynamics of marine demersal fishery resources, including fish, crustaceans, cephalopods and other molluscs. It aims to provide a baseline of current knowledge and identify research priorities for strategic planning and decision-making focused on the sustainable management of the environment and fisheries of the BMM. To this end, more than a thousand references produced between 1960 and August 2021 have been analysed. In the first part, we present the evolution of scientific production and the topics covered in ecology, population dynamics and fisheries. In the second part, we analyse the information on various topics related to the population dynamics of fishery resources to identify the gaps in knowledge and help guide the focus of future studies.

Material and methods

Bibliographical references

The starting point was to compile a list of fishes, crustaceans, cephalopods and other molluscs that could potentially interact with bottom fisheries in the region. This list includes all species and genera reported in the landing statistics of Brazil's five southernmost coastal states: Rio de Janeiro to Rio Grande do Sul (IBAMA, 2008). Species not reported in the landing statistics but recorded in exploratory surveys of demersal fisheries using bottom trawls, bottom longlines and traps were also included (Haimovici et al. 1994; 1996; 2004, 2008; Bernardes et al. 2005; Costa et al. 2015).

The next step was to compile the bibliographic references produced between 1960 and August 2021 for each of the species, containing information on life history, population parameters, distribution assessment and management. For this purpose, we consulted (1) the personal libraries of the authors, primarily for older references not available in online format; (2) references of articles or book chapters published in Brazil and abroad; (3) websites of various postgraduate courses in marine biology and biological oceanography in Brazil; (4) web pages of institutions involved with fisheries management in Brazil and abroad, such as IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis), INIDEP (Instituto Nacional de Desarrollo Pesquero- Argentina),

NOAA (National Oceanic and Atmospheric Administration USA) and CTMFM (Comisión Técnica Mixta do Frente Marítimo); (5) Fishbase and Google Scholar websites using the name of each species; (6) finally, a screening of the CVs of 144 marine scientists available in the Brazilian online platform database (Lattes / CNPq database; <http://buscatextual.cnpq.br/buscatextual/index.jsp>).

The temporal evolution of the collected references was organised according to the type of publication and taxonomic group. The references were classified as (1) scientific journals published abroad, (2) Brazilian scientific journals, (3) books and book chapters, (4) technical reports, and (5) academic products as dissertations/theses/monographs. In terms of taxonomy, the references were classified into taxonomic groups: (1) teleosts, (2) elasmobranchs, (3) crustaceans, (4) cephalopods, and (5) other molluscs. The compiled species were also classified into three categories of fisheries importance: (1) targeted by at least one demersal fishing gear during part or all of the period analysed, (2) bycatch of commercially valuable species landed, (3) species of no commercial value discarded on board.

Topics in the bibliographic references

Each bibliographic reference was indexed into one or more thematic areas based on its content, referred to hereafter as "topics." Table 1 lists the 15 different topics along with their definitions.

References covering the most relevant biological topics for stock assessment—such as age determination, growth, and size at first maturity were examined in more detail. In addition to providing an overview of these topics for each taxonomic group, average values were calculated for species with reported data. These averages were derived from the references for the following parameters: maximum observed length (L_{max}) or maximum observed age (A_{max}), von Bertalanffy growth parameters (asymptotic length L_{∞} , growth coefficient k , and theoretical age at size zero t_0), size and age at first maturity (L_{50} and A_{50} , respectively). Moreover, the seasonality of the reproductive cycle was assessed, considering the months during which maturing or spawning specimens were observed. The methods for stock identification were quantified per taxa.

Table 1 Thematic areas (topics) used to index bibliographic references in the review of scientific production on demersal marine fishery resources of the Brazilian Meridional Margin, including their definitions

Topic	Description
Age & Growth	Studies on age and growth patterns, including ageing and validation methods, von Bertalanffy parameters (t_0 , k , and L_∞), length–weight relationship parameters, and maximum age
Age Structure	Analysis of the distribution of different age classes in samples collected by different fishing gears and fishing grounds
Assessment & Management	Research on the state of the stocks, reference points and biomass estimates. Fisheries management strategies and enforcement
Distribution & Environmental Factors	Studies on the spatial distribution of spawning, nursery and fishing grounds and associated environmental factors
Early Life History & Life Cycle	Research on the early developmental stages and overall life cycle of marine species
Feeding & Trophic Relationships	Studies on diet, feeding habits, and the trophic interactions among species
Fisheries	Research on the fishing industry, including fishing methods and impacts
Landings & CPUE	Analysis of catch data and Catch Per Unit Effort (CPUE) as indicators of fishery productivity
Mortality	Studies on natural and fishing-induced mortality rates, instantaneous coefficients, exploitation rates
Onboard Discard	Research on bycatch and discards Species composition, their sizes and proportion of the catches
Reproduction	Studies on the reproductive biology and spawning behavior of marine species, including reproductive cycles, sizes and ages at first and full maturity, fecundity and spawning potential
Selectivity	Research on the selectivity of fishing with different gears. Sizes at 50% and full selection, and selection factors
Size Structure	Analysis of the size compositions for different gears and fishing grounds
Stock Identification	Studies that attempt to discriminate populations, stocks, groups, etc. Stock identification methods
Synopsis	Summaries and reviews of existing knowledge on specific topics related to biological and fisheries dynamics

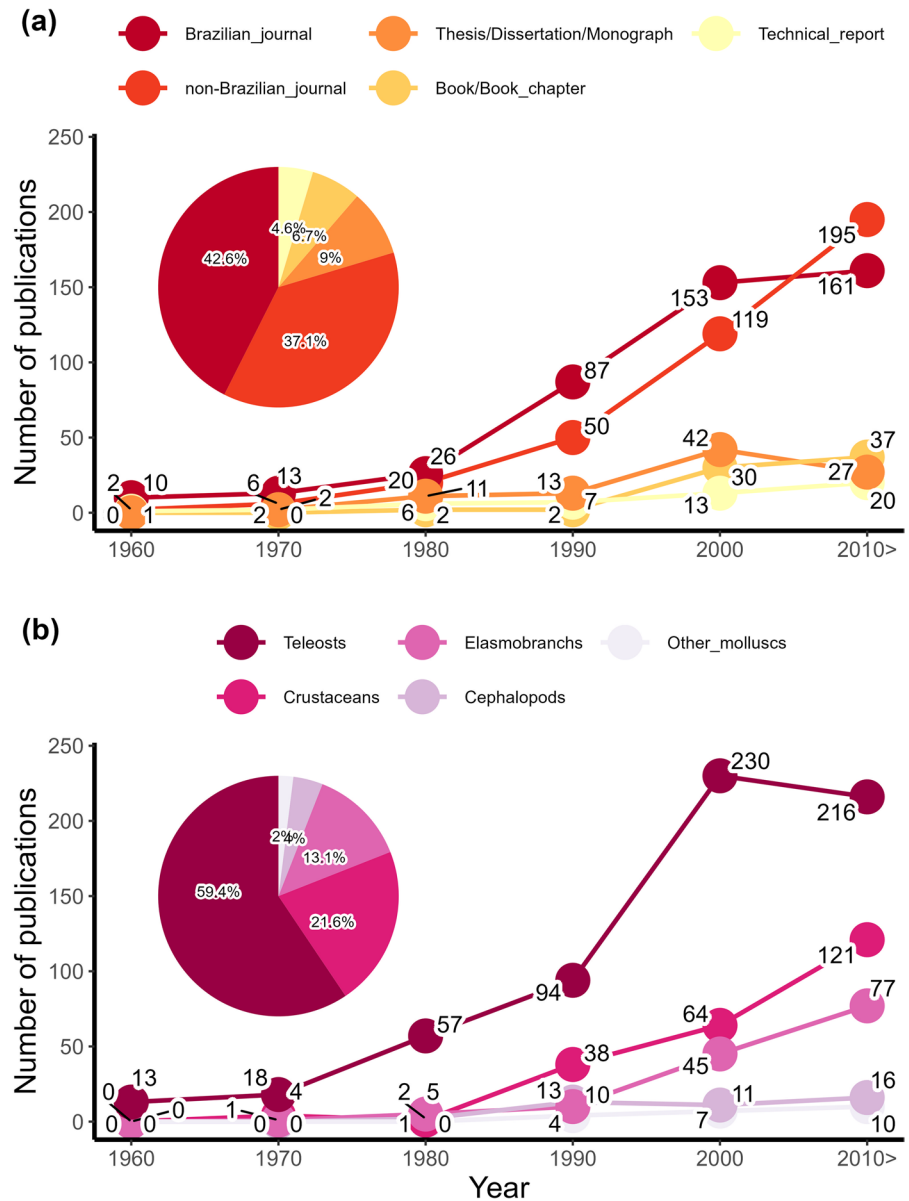
The authors did not evaluate the quality of the data, the methods of analysis, or the conclusions drawn in the references. For comprehensive details on specific species or topics, readers are encouraged to refer to (Table S1, Supplementary Material), which contains full references and repository addresses. The oldest references, which are available only in paper form, can be requested from the Fishery Population Dynamics Laboratory (LADIPP, IO-FURG: www.demersais.furg.br).

Results

In total, the 1091 references with relevant information included studies on the life cycle, population dynamics and fisheries of 166 species or genera of 82 teleosts, 40 elasmobranchs, 24 crustaceans, 8 cephalopods and 12 other invertebrates (Table 1). The

number of references per year increased exponentially from 1.3 per year in the 1960s to 41.2 per year between January 2010 and August 2021 (Fig. 2). The teleost species with the highest number of recorded studies were the whitemouth croaker *Micropogonias furnieri* ($n=65$), the red porgy *Pagrus pagrus* ($n=42$), the king weakfish *Macrodon atricauda* ($n=41$), the black drum *Pogonias courbina* (formerly known as *P. cromis*) (26) and the marine catfish *Genidens barbatus* ($n=24$). Elasmobranchs included the rays *Atlantoraja cyclophora* ($n=10$), *Atlantoraja castelnaui* ($n=9$), *Pseudobatos horkelii* ($n=8$) and *Rioraja agassizi* ($n=8$). Among the crustaceans, the shrimps *Xiphopenaeus kroyeri* ($n=65$), *Artemesia longinaris* (22), *Penaeus paulensis* ($n=22$), and several species of crab of the genus *Callinectes* ($n=47$). Cephalopods, included the squids *Doryteuthis plei* ($n=15$), *Illex argentinus* ($n=10$), and *Doryteuthis sanpaulensis* ($n=10$), and other molluscs the scallop

Fig. 2 Percentages of references recorded from 1960 to 2021 (n = 1091) and in number per decade for **a** publication type and **b** taxonomic group



Euvola ziczac (n=8) and the cockle *Anomalocardia brasiliiana* (n=4) (Table 2).

References were also distributed among three categories of commercial fishing importance (FI) of species or genera (Table 2). The first group (A) included references of species that have been or are targeted by demersal fishing gear continuously since the 1960s, such as *M. furnieri*, or those that were major targets until the 1980s, including *E. ziczac*, *P. courbina*, *Genidens spp* and *P. pargus*. This group also included species that became targets more recently, such as the

monkfish *Lophius gastrophysus* and the deep-sea hake *Urophycis mystacea*, (Perez et al. 2003), which only became targets in the 2000s. The second group (B) comprised species caught incidentally, which may have resulted in large landings on occasion but have not been primary targets of any fishery, such as the cusk eel *Genypterus brasiliensis*. The third group (C) includes species with no current commercial value, typically discarded on-board, such as *Dules auriga*. It was observed that 42 species were or are targeted by demersal fishing gears (group A), accounting for 59.0% of the studies;

Table 2 Number of references compiled by species, genera or higher taxons (N). Category of fishing importance (FI) was classified as A: target of at least one demersal fishing gear in part of the entire period 1960–2021; B: species with commercial value incidentally landed as by-catch or C: discarded on board

Teleosts	N	FI	Teleosts (cont)	N	FI	Elasmobranchs (cont)	N
<i>Micropogonias furnieri</i>	65	A	<i>Lutjanus synagris</i>	1	B	<i>Pseudobatos percellens</i>	1
<i>Pagrus pagrus</i>	42	A	<i>Mycteroperca acutirostris</i>	1	B	<i>Rhinobatos lentiginosus</i>	1
<i>Macrodon atricauda</i>	41	A	<i>Peprilus paru</i>	1	B	<i>Rhinobatos percellens</i>	1
<i>Pogonias courbina</i>	26	A	<i>Pseudopercis numida</i>	1	B	<i>Rhinoptera bonasus</i>	1
<i>Genidens barbuis</i>	24	A	<i>Trachinotus carolinus</i>	1	B	<i>Etmopterus bigelowi</i>	1
<i>Cynoscion guatucupa</i>	21	A	<i>Trachinotus marginatus</i>	1	B	<i>Fontitrygon colarensis</i>	1
<i>Genidens genidens</i>	21	C	<i>Symphurus</i> spp.	1	C	<i>Tetronarce puelcha</i>	1
<i>Trichiurus lepturus</i>	21	B	<i>Conodon nobilis</i>	1	B	<i>Etmopterus</i> sp.	1
<i>Menticirrhus americanus</i>	20	B	<i>Ctenoscoiaena gracilicirrhus</i>	1	C	Crustaceans	
<i>Paralonchurus brasiliensis</i>	20	C	<i>Diapterus rhombeus</i>	1	C	<i>Xiphopenaeus kroyeri</i>	65
<i>Merluccius hubbsi</i>	18	A	<i>Diplectrum formosum</i>	1	C	<i>Artemesia longinaris</i>	22
<i>Epinephelus marginatus</i>	17	B	<i>Diplectrum radiale</i>	1	C	<i>Penaeus paulensis</i>	22
<i>Cynoscion jamaicensis</i>	17	A	<i>Diplodus argenteus</i>	1	C	<i>Callinectes danae</i>	21
<i>Polyprion americanus</i>	16	A	<i>Oligoplites saliens</i>	1	C	<i>Callinectes ornatus</i>	17
<i>Lophius gastrophysus</i>	14	A	<i>Porichthys porosissimus</i>	1	C	<i>Pleoticus muelleri</i>	14
<i>Umbrina canosai</i>	14	A	<i>Sciadeichthys luniscutis</i>	1	C	<i>Penaeus brasiliensis</i>	12
<i>Prionotus punctatus</i>	13	A	<i>Umbrina coroides</i>	1	C	<i>Achelous spinimanus</i>	12
<i>Urophycis brasiliensis</i>	13	A	<i>Bellator brachychir</i>	1	C	<i>Arenaeus cribrarius</i>	12
<i>Balistes caprisiscus</i>	12	A	<i>Citharichthys bleeker</i>	1	C	<i>Chaceon notialis</i>	9
<i>Mugil liza</i>	12	A	<i>Citharichthys spilopterus</i>	1	C	<i>Chaceon ramosae</i>	6
<i>Paralichthys patagonicus</i>	11	A	<i>Dules auriga</i>	1	C	<i>Callinectes sapidus</i>	5
<i>Pomatomus saltatrix</i>	11	A	<i>Engraulis anchoita</i>	1	C	<i>Rimapenaeus constrictus</i>	5
<i>Urophycis mystacea</i>	7	A	Tetraodontiformes	1	C	<i>Litopenaeus schmitti</i>	4
<i>Lopholatilus villarii</i>	7	A	<i>Polymixia lowei</i>	1	C	<i>Aristaeopsis edwardsiana</i>	3
<i>Menticirrhus littoralis</i>	7	B	Elasmobranchs			<i>Callinectes</i> spp.	3
<i>Stellifer rastrifer</i>	7	C	<i>Atlantoraja cyclophora</i>	10	B	<i>Metanephrops rubellus</i>	3
<i>Percophis brasiliensis</i>	6	C	<i>Atlantoraja castelnaui</i>	9	B	<i>Achelous spinicarpus</i>	3
<i>Paralichthys isosceles</i>	6	B	<i>Pseudobatos horkelii</i>	8	B	<i>Penaeus</i> spp.	2
<i>Paralichthys orbignyanus</i>	6	B	<i>Rioraja agassizi</i>	8	B	<i>Aristeus antillensis</i>	2
<i>Epinephelus itajara</i>	5	B	<i>Prionace glauca</i>	6	B	<i>Scyllarides</i> sp.	1
<i>Genypterus brasiliensis</i>	5	B	<i>Rhizoprionodon lalandii</i>	6	B	<i>Aristaeopsis</i> spp.	1
<i>Hyporthodus niveatus</i>	5	B	<i>Mustelus schmitti</i>	6	B	Nephropidae	1
<i>Chaetodipterus faber</i>	4	B	<i>Zapteryx brevirostris</i>	6	B	<i>Panulirus</i> sp.	1
Pleuronectiformes	4	B	<i>Myliobatis goodei</i>	5	B	<i>Callinectes bocourt</i>	1
<i>Ocyurus chrisurus</i>	4	B	<i>Mustelus fasciatus</i>	5	B	<i>Sergio mirim</i>	1
<i>Isopisthus parvipinnis</i>	3	B	<i>Narcine brasiliensis</i>	5	C	<i>Callinectes major</i>	1
<i>Orthopristis ruber</i>	3	B	<i>Galeorhinus galeus</i>	4	B	Cephalopods	
<i>Pomadasys corvinaeformis</i>	3	B	<i>Carcharhinus galapagensis</i>	4	B	<i>Doryteuthis plei</i>	15
<i>Genidens genidens</i>	3	C	<i>Sphyrna lewini</i>	4	B	<i>Illex argentinus</i>	11
<i>Prionotus nudigula</i>	3	C	<i>Sympterygia bonapartii</i>	4	C	<i>Doryteuthis sanpaulensis</i>	10
<i>Balistes vetula</i>	2	C	<i>Carcharias taurus</i>	4	B	<i>Eledone massyae</i>	2
<i>Genidens planifrons</i>	2	B	<i>Squatina occulta</i>	4	B	<i>Octopus americanus</i>	2
<i>Xystreuris rasile</i>	2	B	<i>Psammobatis extenta</i>	4	C	<i>Doryteuthis</i> spp.	1
<i>Centropomus parallelus</i>	2	B	<i>Squatina guggenheim</i>	3	B	<i>Eledone gaucha</i>	1

Table 2 (continued)

Teleosts	N	FI	Teleosts (cont)	N	FI	Elasmobranchs (cont)	N
<i>Cynoscion leiachus</i>	2	B	<i>Gymnura altavela</i>	3	C	<i>Octopus tehuelchus</i>	1
<i>Zenopsis conchifer</i>	2	C	<i>Mustelus canis</i>	3	B	<i>Lolliguncula brevis</i>	1
<i>Lagocephalus laevignatus</i>	2	C	<i>Rhinoptera brasiliensis</i>	3	B	Other molluscs	
<i>Trachurus lathami</i>	2	C	<i>Squatina argentina</i>	3	B	<i>Euvola ziczac</i>	8
<i>Larimus breviceps</i>	2	C	<i>Sphyrna zygaena</i>	2	B	<i>Anomalocardia brasiliiana</i>	4
<i>Ariomma bondi</i>	2	C	<i>Squalus acanthias</i>	2	C	<i>Tagelus plebeius</i>	2
<i>Aspistor luniscutis</i>	2	C	<i>Sympterygia acuta</i>	2	C	<i>Tivela mactroides</i>	2
<i>Bairdiella ronchus</i>	2	C	<i>Atlantoraja platana</i>	1	B	<i>Chione pubera</i>	1
<i>Cathorops spixii</i>	2	C	<i>Atlantoraja</i> spp.	1	B	<i>Crassostrea brasiliiana</i>	1
<i>Dactylopterus volitans</i>	2	C	<i>Squatina</i> spp.	1	B	<i>Crassostrea rhizophorae</i>	1
<i>Stellifer brasiliensis</i>	2	C	Rhinopteridae	1	B	<i>Perna perna</i>	1
<i>Mugil platanus</i>	1	B	<i>Myliobatis freminvillei</i>	1	B	<i>Crassostrea</i> sp.	1
<i>Conger orbygnianus</i>	1	B	<i>Myliobatis ridens</i>	1	B	<i>Diplodonta punctata</i>	1
<i>Cynoscion acoupa</i>	1	B	<i>Notorynchus cepedianus</i>	1	B	<i>Isognomon bicolor</i>	1
<i>Cynoscion virascens</i>	1	B	<i>Pristis pectinata</i>	1	B	<i>Mytella falcata</i>	1
<i>Epinephelus niveatus</i>	1	B	<i>Pristis pristis</i>	1	B		

The bold names indicate the major taxonomic groups in which the species are grouped/listed

Table 3 Number of references on the demersal and benthic resources of the Brazilian Southern Margin classified in categories of fishing importance (FI) as: A—target of at least one demersal fishing gear in part of the entire period 1960–2021; B—species with commercial value incidentally landed as bycatch; or C—discarded on board

FI	Number of species or higher taxa	Number of References	Accumulated taxa (%)	Accumulated references (%)
A	42	633	23.8	59.0
B	72	292	65.8	86.2
C	62	148	100	100

the 72 incidentally caught species of commercial value (group B) accounted for 27.2% of the studies; and the remaining 62 species of no commercial interest discarded on-board (group C) were represented in 13.8% of the studies (Table 3).

References compiled by types of publication and taxonomic groups

Of the total publications, 454 (42.6%) were published in scientific journals based in Brazil, while 406 (37.1%) appeared in scientific journals from other countries. Additionally, 72 (6.7%) were in the form

of books and book chapters, 64 (4.6%) were technical reports, and 95 (9%) were academic products such as thesis, dissertations and monographs. Over the decades, there has been a significant increase in both the number and proportion of references published in scientific journals since the 1990s. Meanwhile, the production of academic products, technical documents and book chapters has also risen, albeit at a slower pace, beginning in 2000s (Fig. 2a).

As regarding taxonomic groups, a total of 650 (59.6%) references focused on demersal teleosts, 147 (13.5%) on demersal elasmobranchs, 230 (21.1%) on crustaceans, 43 (3.9%) on cephalopods, and 21 references (1.9%) on other molluscs. In terms of temporal evolution, until the 1980s, more than 88% of references were on teleosts. From the 1990s onwards, the number of references on other taxa began to rise. Since the 2010s, references on teleosts have stagnated or even declined, while references on other taxa have continued to increase (Fig. 2b).

References compiled by topics

The following quantifications refer to the 2547 different ‘topics’ classified in the 1091 references. There were 2.33 topics per reference as each reference often included studies on more than one topic. The most

frequent topics were Reproduction (15%), followed by Species Distribution (14%), Size structures (11%), Age and Growth (9%), Assessment and Management (9%) and Feeding and Trophic Relationships (8%) (Fig. 3a). Of the topics identified, 62% were found in scientific articles, 19% in book chapters, 12% in academic products and 6% in technical documents (Fig. 3b).

When quantified by topic, the “Synopsis” category was most numerous for teleosts and elasmobranchs, with the majority published as book chapter, particularly for endangered species, followed by technical documents, such as those from the IUCN on species conservation status. “Fisheries Descriptions” and “Landings and CPUE” studies were most commonly conducted on crustaceans and teleosts, and were primarily published as articles and book

chapters. Studies on “Size structure” were most frequent for teleosts and crustaceans and were predominantly published as articles. “Age Structure” studies, mostly focused on teleosts, were mainly published as articles and book chapters. “Selectivity” studies were also predominantly on teleosts and appeared in all types of references. “Discard” studies were primarily related to crustacean fisheries and were published as articles. With few exceptions, “Stock Identification” studies focused on teleosts and were mainly published as articles. The remaining topics were more evenly distributed among taxa, but teleosts were consistently the focus, with most references published as scientific articles.

The number of topics covered by references increased exponentially, rising from 17 in the 1960s to 1,292 from 2010 to 2021 (2010>). A rapid

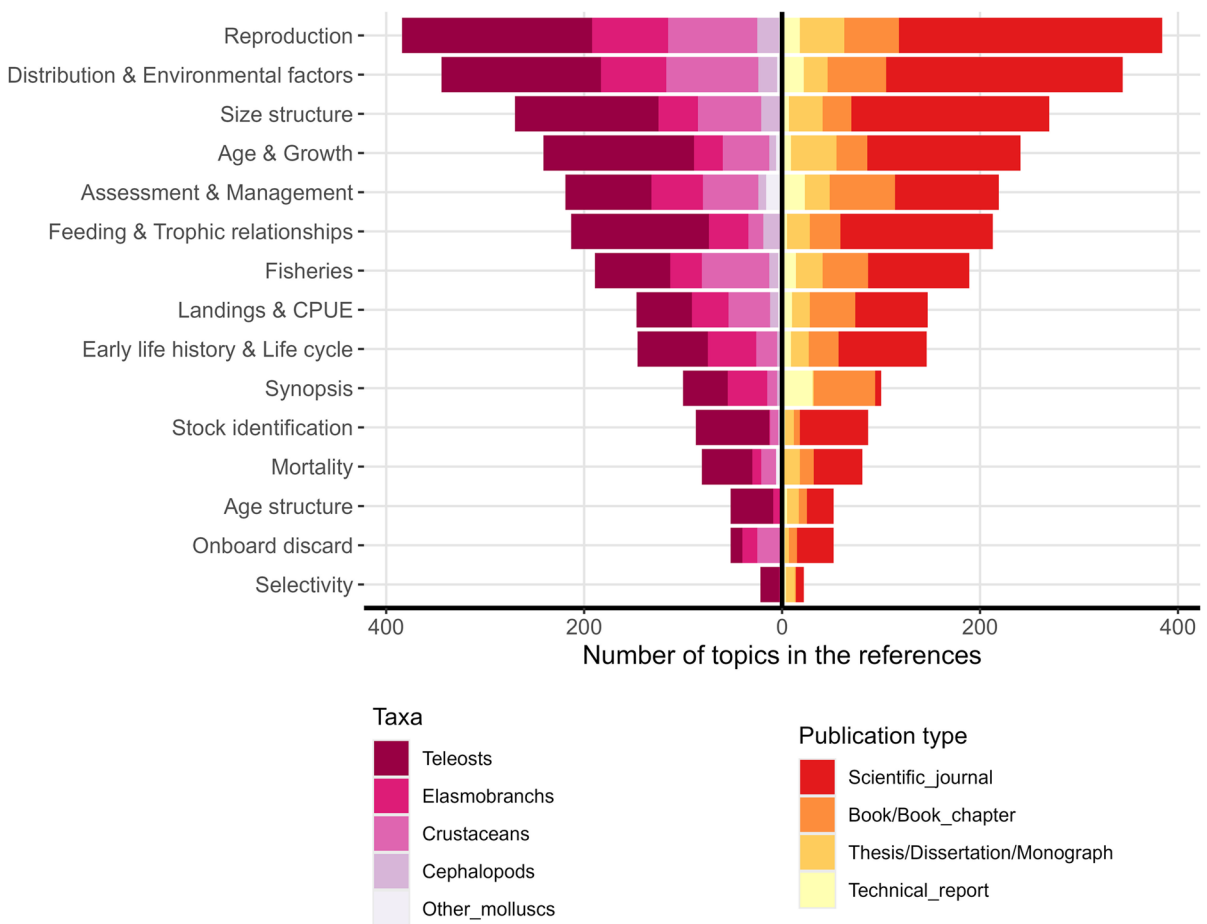


Fig. 3 Number of times a given topic was covered in the 1091 references by taxon (left) and by publication type (right)

increase in studies on reproduction, feeding, growth and size structure was observed from the 1980s onwards, while other topics began to gain traction in publications from the 1990s (Fig. 4).

Overview of the available information on the selected topics

Teleosts

Growth information was available for 45 teleosts species (Table 4). Of these, 30 species had the age determined (or estimated) from appositional structures: 24 from otoliths, 8 from scales, and two from dorsal spines, with the latter method applied to two species of triggerfish of the genus *Balistes*. For 13 species, growth was determined (or estimated) using length compositions with polymodal decomposition routines in stock assessment tools (Gayanillo and Pauly, 1997), while for other three species, growth estimates were derived from both appositional structures and length compositions.

Most age determinations were made on thin transverse sections of sagitta otoliths, with some conducted on uncut sagitta otoliths. For two catfishes of

the genus *Genidens*, age was determined using sections of lapilli otoliths. Validation analysis was presented for all studied species, focusing on seasonal variations in edges types or marginal increments. Maximum ages were reported for 33 species, most of which had short (<10 years) or medium (10 to 20 years) lifespans. A few species, which generally attain large sizes, were shown to live 35 to 40 years, including: *Polyprion americanus*, *Pogonias courbina*, *Hyporthodus niveatus*, *Epinephelus marginatus*, *Lopholatilus villari* and *Micropogonias furnieri*. Significant age discrepancies between different studies were noted in three species (*Balistes capriscus*, *Mugiliza* and *Prionotus punctatus*). Misinterpretation of growth bands were the general source of such discrepancies in the spine structure of *B. capriscus* and the otoliths of *M. liza* and *P. punctatus*.

The asymptotic or maximum lengths varied between 178 and 1807 mm, with an average of 555 mm (n=48). The length was less than 400 mm in 17 species; ranged between 400 and 600 mm in 15 species; and exceeded 600 mm in 12 species. Most studies focused on small and medium-sized teleosts, and almost all species with a maximum length of over 600 had their growth studied. The growth

Fig. 4 Cumulative number of topics (n=2547) in the 1091 analysed references

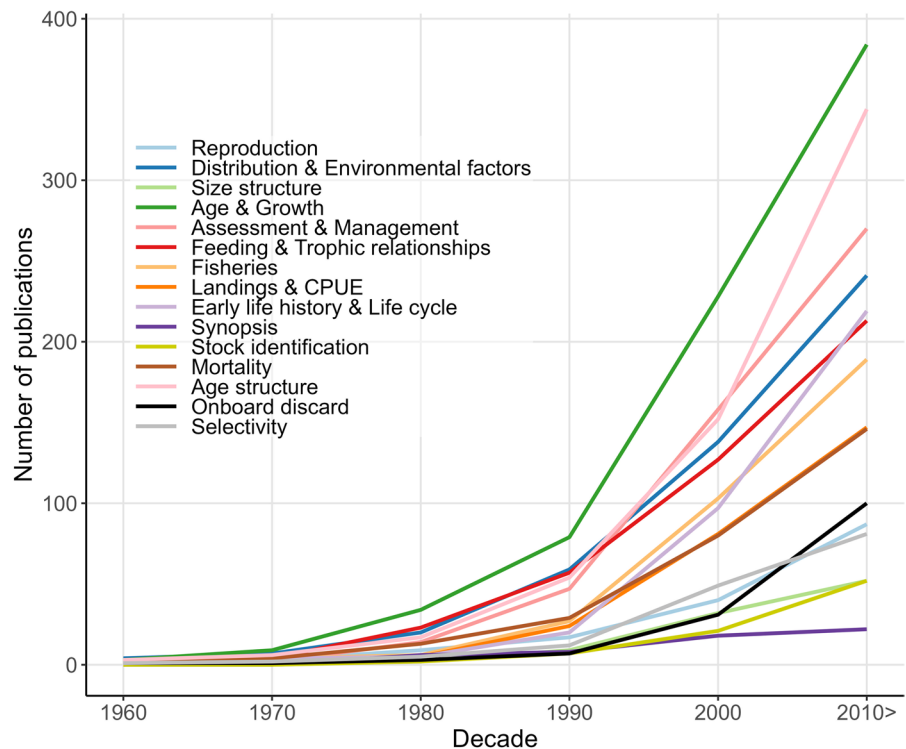


Table 4 Average growth and maturation parameters compiled for demersal teleosts from southeastern and southern Brazil. The measured lengths were categorized as furcal (FL), total (TL) or standard (SL); the asymptotic length (TL_∞) and the first maturation length (L₅₀) are in mm; the growth coefficient (k) in years⁻¹; theoretical age at size zero (t₀) and oldest specimen reported in years.

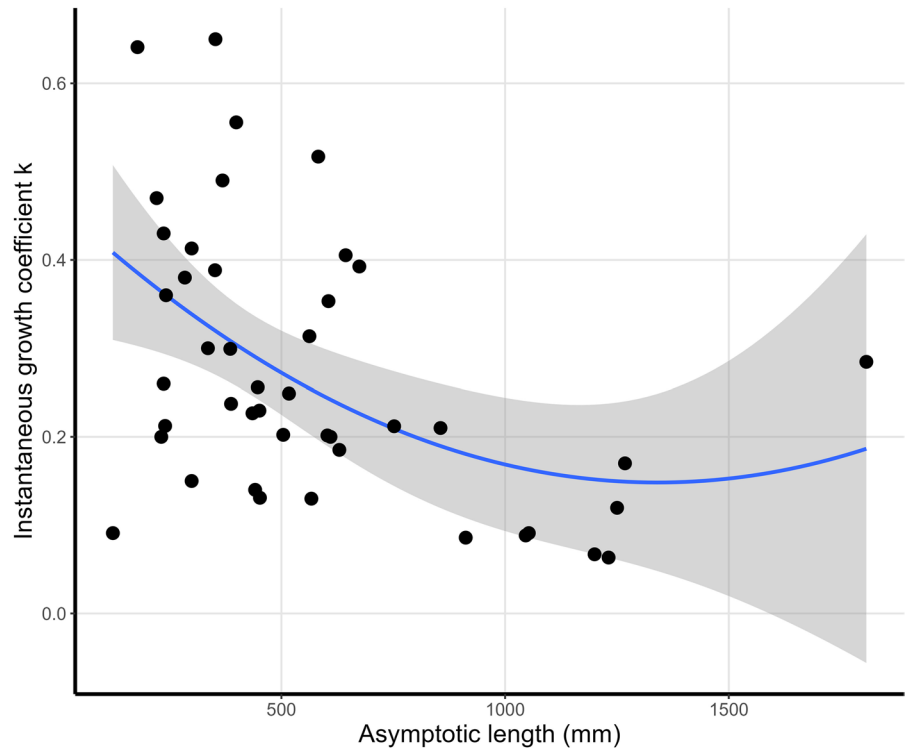
Species	L _∞	k	t ₀	L ₅₀	L ₉₀ /L _∞	Oldest specimen
<i>Ariomma bondi</i>	TL 220*			100	46%	
<i>Baliste Yetula</i>	FL 441	0.14	-1.80			14
<i>Balistes capriscus</i>	FL 504	0.20	-0.57	185	36%	7.5
<i>Caranx crysos</i>	TL 353	0.65	-0.21	204	58%	
<i>Cynoscion guatucupa</i>	TL 517	0.25	-0.72	316	62%	15.3
<i>Cynoscion jamaicensis</i>	TL 352	0.39	-0.52	173	58%	8
<i>Dactylopterus volitans</i>	TL 336	0.30	-0.57	195	58%	
<i>Dules auriga</i>	TL 178	0.64	-0.34	141	79%	9
<i>Epinephelus marginatus</i>	TL 1053	0.09	-1.71	469	44%	22
<i>Eucinostomus argenteus</i>	TL 221	0.47	-0.38	135	61%	
<i>Ganidens barbatus</i>	TL 912	0.09	0.85	431	52%	32.5
<i>Genidens genidens</i>	TL 435	0.23	0.05	172	40%	11.3
<i>Genypterus brasiliensis</i>	TL 1250	0.12	-0.40	527	36%	12.8
<i>Harengula clupeiola</i>	TL 237	0.43	-0.41	143	60%	
<i>Hyporthodus niveatus</i>	TL 1231	0.06	-0.87	469	32%	54
<i>Lagocephalus laevigatus</i>	TL			200>		
<i>Lophius gastrophysus</i>	TL 752	0.21	1.81	467	65%	15.5
<i>Lopholatilus villari</i>	TL 1046	0.09	0.12	381	29%	37.6
<i>Macrondon atricauda</i>	TL 399	0.56	-0.31	241	64%	6
<i>Menticirrhus americanus</i>	TL 452	0.13	0.90	166	37%	7.3
<i>Menticirrhus littoralis</i>	TL 387	0.24		230	59%	
<i>Merluccius hubbsi</i>	TL 610	0.29	-0.60	296	45%	5.6
<i>Microponogonias furnieri</i>	TL 603	0.20	-1.61	343	55%	29
<i>Mugil liza</i>	TL 623	0.59	-1.40	498	61%	7.8
<i>Ocyurus chrysurus</i>	FL 567	0.13	-0.77			19
<i>Orthopristis ruber</i>	TL 284	0.38	-0.44	169	59%	
<i>Pagrus pagrus</i>	TL 451	0.23	-1.15	266	57%	20
<i>Paralichthys isosceles</i>	TL 380*			269	71%	
<i>Paralichthys orbignyanus</i>	TL 856	0.21	-0.64	450	46%	10
<i>Paralichthys patagonicus</i>	TL 563	0.31	0.53	340	58%	12.3
<i>Paralanchurus brasiliensis</i>	TL 232	0.40		168	64%	

Table 4 (continued)

Species	L_{∞}	k	t_0	L_{50}	$\frac{L_{50}}{L_{\infty}}$	Oldest specimen
<i>Peprilus paru</i>	299	0.41	0.66			6
<i>Percophis brasiliensis</i>	605	0.35	-0.74	408	65%	12
<i>Pogonias courbina</i>	1260	0.17	-0.17	590	52%	55
<i>Polymixia lowei</i>	299	0.15	-1.97			
<i>Polyprion americanus</i>	1200	0.07	-5.93	76	65%	73.3
<i>Pomatomus saltatrix</i>	644	0.41	-0.28	279	53%	8.3
<i>Prionotus nudigula</i>	300*	0.41	-0.28	160	53%	
<i>Prionotus punctatus</i>	447	0.26	-2.14	265	61%	11.7
<i>Pseudoperca numida</i>	1230	0.09	-2.60			13
<i>Sardinella brasiliensis</i>	237	0.26	-0.80	158	67%	
<i>Selene setapinnis</i>	368	0.49	-0.30	212	58%	
<i>Trachurus lathami</i>	240	0.21	1.44	123	48%	8
<i>Trichurus lepturus</i>	1807	0.28	-1.26	673	42%	10
<i>Umbrina canosai</i>	386	0.30	-0.97	202	58%	21.3
<i>Upeneus parvus</i>	242	0.36	-0.51	146	60%	
<i>Urophycis brasiliensis</i>	582	0.52	-0.91	349	74%	14.3
<i>Urophycis mystacea</i>	630	0.19	-0.80	439	68%	10.4
<i>Zenopsis conchifera</i>	540*			266	49%	

* Approximate maximum length recorded in the region

Fig. 5 Relationship between the average asymptotic lengths (mm) and instantaneous growth coefficients (k , year⁻¹) of 44 teleost species from the Brazilian Meridional Margin



coefficient (k) varied between 0.06 yr⁻¹ to 0.65 yr⁻¹, with an average of 0.29 yr⁻¹ ($n=44$). There was a negative correlation (ρ =Spearman correlation coefficient) between asymptotic length and k , described by the equation: $k=0.46-4.7e-04L_{\infty}+1.8e-07 L_{\infty}^2$; $\rho=-0.47$, p -value=0.004 (Fig. 5).

For each species, the number of von Bertalanffy parameters varied from 1 to 31 and the number of first maturity estimates from 1 to 16 (Table 5). The number of studies depended on the commercial importance of the species, its distribution and sampling periods, as well as sex differentiation. The references for each set of parameters for each species are given in the Table S2 Supplementary Material. It is strongly recommended to consult the original studies when choosing the appropriate set for modelling purposes.

Mean length at first maturity (L_{50}) was reported for 43 teleost species (Table 4). The average L_{50}/L_{∞} or L_{50}/L_{max} ratio was 54%. The variability between species is large, despite which we observed a positive correlation with the instantaneous growth coefficient k was $L_{50}/k=0.67-2.4e-04 k+4.9e^{-08k^2}$; $\rho=-0.42$ p -value=0.005 (Fig. 6a), and a negative correlation with the asymptotic or maximum length:

$L_{50}/L_{\infty}=0.38+8e-01 L_{\infty}-5.4e^{-01 L_{\infty}^2}$; $\rho=0.49$, p -value=0.0003 (Fig. 6b).

The reproductive period was recorded 58 species of teleosts in total. This includes 39 species in the Southeastern Brazil (SEB) and 33 Southern Brazil (SB), with 14 of these species being fished in both regions of the BMM. The species were classified according to the environment in which they reproduce: estuarine or coastal, open continental shelf, or upper continental slope. In both regions, the highest proportion of reproducing species occurred during the warm season, from October to February. However, in the SEB, reproductive periods were longer and less pronounced than in SB. This same pattern of seasonality was observed when focusing on the 14 teleosts species with data available in both regions (Fig. 7).

Elasmobranchs

Total lengths varied between 285 and 4000 mm, with a mean of 1439 mm, and skates disc widths varied between 318 and 1313 mm, with a mean of 759 mm (Table 5). Information on growth was available for 14 elasmobranch species, 12 of them

Table 5 Average growth and maturation parameters compiled for demersal elasmobranch species from the Brazilian Meridional Margin. TL_{max} and DW_{max} correspond to the larger total length and disc width observed in mm, k , is the growth coefficient in years⁻¹; t_0 is the theoretical age at size zero in years

and TL_{∞} and DW_{∞} are the asymptotic total lengths or disc width parameters of the von Bertalanffy growth model; TL_m and DW_m are sizes at first maturation; A_m and A_{max} are the age of first maturation and the maximum reported age in years

	TL_{max}	DW_{max}	TL_{∞}/DW_{∞}	k	t_0	TL_m	DW_m	A_m	T or DWL_m/TL or DW_{max}	A_{max}
<i>Batoidea</i>										
<i>Atlantoraja castelnaui</i>	1191	786	899	0,06	-2,11	1000	705	16	90%	30
<i>Atlantoraja cyclophora</i>	609	483	498	0,08	-4,50	522	385		80%	23
<i>Atlantoraja platana</i>	730	594	778	0,05	-1,25	649	525		88%	23
<i>Dasyatis violacea</i>	1650									
<i>Dipturus chilensis</i>						945				
<i>Gymnura altavela</i>		1313					1096		83%	
<i>Myliobatis freminvillei</i>	1251	990					700		71%	
<i>Myliobatis goodei</i>	1300	864					580		67%	
<i>Myliobatis ridens</i>		725					662		91%	
<i>Narcine brasiliensis</i>	426					299			70%	
<i>Psammobatis extenta</i>	285					234			82%	
<i>Rioraja agassizi</i>	560	318	450	0,18		300		7	54%	15
<i>Selachimorpha and Rhinomorpha</i>										
<i>Pseudobatos percelles</i>	889		1025	0,18	-1,62					9
<i>Rhinobatos lentiginosus</i>	755									
<i>Rhinoptera brasiliensis</i>	965							7		18
<i>Sympterygia acuta</i>	583					490			84%	
<i>Sympterygia bonapartii</i>	782					635			81%	
<i>Tetronarce puelcha</i>	1040					625	483		60%	
<i>Squatina occulta</i>			1389	0,13	-1,94	1100				28
<i>Squatina argentina</i>	1380					1200			87%	28
<i>Squatina guggenheim</i>	950		947	0,27	-1,15	735		4	77%	13
<i>Zapteryx brevirostris</i>	584		590	0,21	-1,89					9
<i>Pseudobatos horkelii</i>	1073		1268	0,20	-1,33			5		11
<i>Carcharhinus galapagensis</i>	3000									
<i>Carcharhinus longimanus</i>	2428		2849	0,10	-3,39					16
<i>Carcharhinus signatus</i>	2450									
<i>Carcharias taurus</i>	3200					2080		6	65%	35
<i>Galeorhinus galeus</i>	1641		1575	0,08	-2,85	1275			78%	25
<i>Heptranchias perlo</i>	1100									
<i>Isurus oxyrinchus</i>	3300									23
<i>Mustelus canis</i>	1225					930		3	76%	
<i>Mustelus fasciatus</i>	1505					1200			80%	
<i>Mustelus schmitti</i>	901					610		6	68%	22
<i>Notorynchus cepedianus</i>	2000									
<i>Prionace glauca</i>	2808		2496	0,17		1871		7	67%	13
<i>Scyliorhinus haeckelli/besnardi</i>	520									
<i>Sphyrna lewini</i>	3871		3291	0,06	-2,37			21		31
<i>Sphyrna zygaena</i>	4000					2650			66%	
<i>Squalus acanthias</i>	880					644		11	73%	
<i>Squalus megalops</i>	600					480			80%	

Table 5 (continued)

	TL_{max}	DW_{max}	TL_{∞}/DW_{∞}	k	t_0	TL_m	DW_m	A_m	T or DWL_m/TL or DW_{max}	A_{max}
<i>Squalus mitsukurii</i>	840					580			69%	

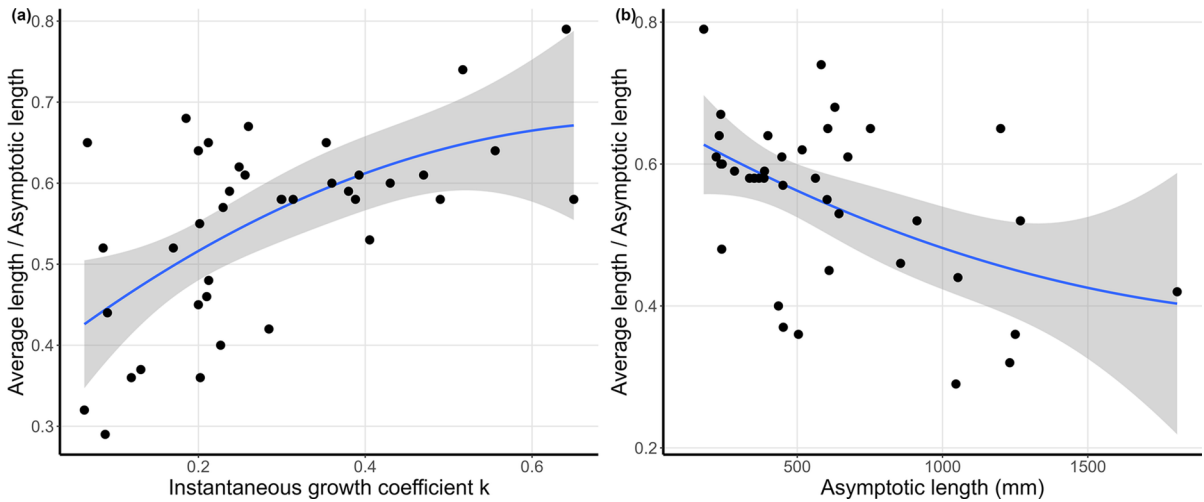


Fig. 6 Relationship between the ratio of lengths at 50% of first sexual maturity and asymptotic or maximum lengths (L_{max}/L_{∞}) as a function of instantaneous growth coefficients k (A: left)

and asymptotic or maximum length (B: right) of 43 teleost species from the Brazilian Meridional Margin for which parameters are available

from ages determined on thin sections of vertebrae and two from length frequency distributions. All studies using vertebrae to determine age included some attempt to validate growth bands by analysing edge types or marginal increments. Maximum ages recorded in vertebrae thin sections ranged from 9 to 35 years, with a mean of 21.0 years. In species where maximum ages were estimated to be 95% of the asymptotic total length or disc width, values ranged from 9.8 to 53.7 years with a mean of 27.0 years. Asymptotic or maximum total lengths varied between 285 and 4000 mm, with a mean of 1439 mm, and disc widths varied between 318 and 1313 mm, with a mean of 759 mm. The instantaneous growth coefficient k varied between 0.05 and 0.27, on average 0.14 year⁻¹. Total lengths and or widths of discs at first sexual maturity were recorded for 27 species (Table 3). The relationship between maturation and maximum length was on average 75%, varying between 54 and 90%.

Data on reproductive seasonality were recorded for 22 elasmobranchs (Table 6). Of the 10 Batoidea, six reproduce throughout the year and four during the warm season. Of the six Rhinopristiformes, one reproduces throughout the year and five during the warm season. Among the Batoidea, one reproduces in the cold season and five in the warm season.

Crustacean

Population parameters were recorded for 21 of decapod crustaceans from four suborders and seven families: Brachyura Geryonidae and Portunidae, Pleocymata Nehropida and Palinuridae, Achelata Scyllaridae and Dendrobranchiata Aristidae and Penaeidae (Table 4): Twelve species had their growth studied, all of which through length distribution analysis (LDA). The lengths at first maturity and the relationships are shown for 19 species where the relationship with the maximum length and between this and the maximum length varied between 35 and 72%

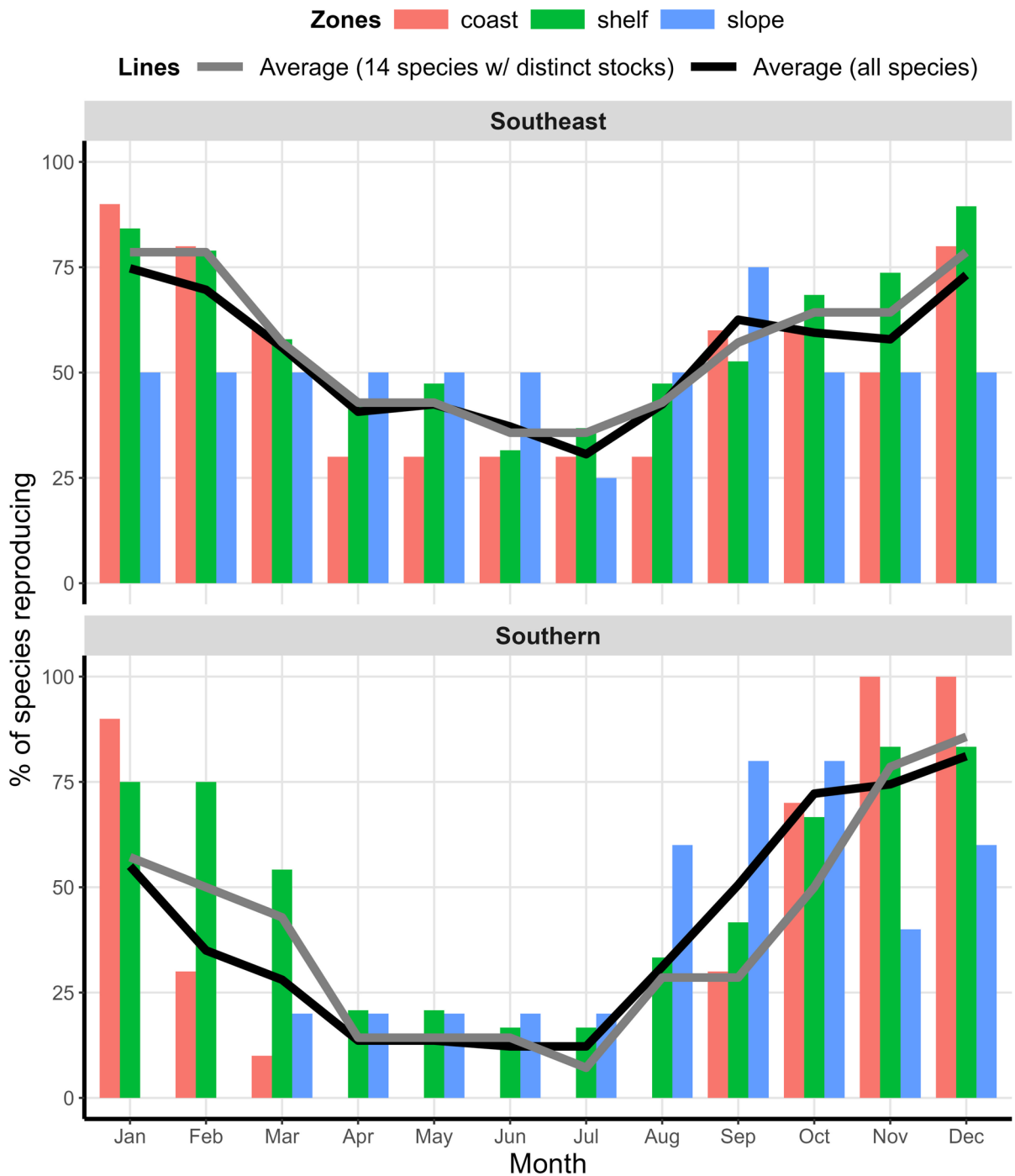


Fig. 7 Percentage of teleosts in reproductive activity per month in the southeast region (N=39) and in the southern region (N=33) of the Brazilian Meridional Margin for in the coastal zone (red) continental shelf (green) and continental

slope (blue). The black lines represent the means of all 58 species. The grey line represent the mean for the 14 species for which distinct stocks were identified in both regions

Table 6 Seasonality in the reproduction of elasmobranchs from the Brazilian Meridional Margin

Suborders	Year-round	Cold season	Warm Season	Total
Batoidea	6		4	10
Rhinoprisiformes	1		5	6
Selachii		1	5	6
Total	7		14	22

Table 7 Average growth and maturation parameters compiled for demersal crustacean species from the Brazilian Meridional Margin. Length was categorized as total (TL) or carapace length or width (CW) in mm; TL_{max} and CW_{max} correspond to the maximum observed size; TL and CW_∞ are the asymptotic total or carapace length or width; k is growth coefficient in years⁻¹; TL_m and CW_m correspond to the length at first maturation

Species	TL _{max}	CC _{max}	TL _∞	CC _∞	k	TL _{50%}	CC _{50%}	CC _{50%} /CC _{max} or TL _{50%} /TL _{max}
<i>Achelata Scyllaridae</i>								
<i>Scyllarides deceptor</i>		360	388		0.42	253	253	70%
<i>Brachyura Geryonidae</i>								
<i>Chaceon notialis</i>		159					91	57%
<i>Chaceon ramosae</i>		181					129	71%
<i>Brachyura Portunidae</i>								
<i>Achelous spinicarpus</i>		67					24	36%
<i>Achelous spinimanus</i>	125	79	134		0.59		51	65%
<i>Arenaeus cribrarius</i>		97		111	1.70		62	64%
<i>Callinectes danae</i>		114		127	1.25		73	64%
<i>Callinectes ornatus</i>	119	97	108	94	1.00		59	61%
<i>Callinectes sapidus</i>		158					102	65%
<i>Dendrobranchiata Aristeidae</i>								
<i>Aristeus antillensis</i>		64					33	52%
<i>Dendrobranchiata Penaeidae</i>								
<i>Artemesia longinaris</i>	102	26		24	4.80	63	14	54%
<i>Penaeus brasiliensis</i>	240		211		1.35	150	38	63%
<i>Penaeus paulensis</i>	208		226		1.34	150	42	72%
<i>Litopenaeus schmitti</i>		43		48	2.01		16	37%
<i>Pleoticus muelleri</i>		36		35	4.95		13	36%
<i>Rimapenaeus constrictus</i>		17		15	10.77		8	47%
<i>Xiphopenaeus kroyeri</i>	143	32	143	31	2.90	81	17	53%
<i>Pleocyemata Nephropidae</i>								
<i>Metanephrops rubellus</i>	185	62				84	28	45%
<i>Pleocyemata Palinuridae</i>								
<i>Panulirus argus</i>	470		44			201		43%
<i>Panulirus laevicauda</i>	380		38			94	110	25%

(Table 7). The differences between the life history, the small number of species in each family and the lack of a robust validation of the age groups in LDA make it difficult to establish patterns both between and within suborders.

Cephalopods

The cephalopods whose growth has been studied in the region are semelparous species that spawn when they reach maximum length. These are short-lived and their growth trajectory tends to be poorly described by the Bertalanffy model (Boyle and Rodhouse, 2005) (Table 8). The loliginid squid *Doryteuthis plei*

Table 8 Maximum ages of cephalopods fished along southern and southeastern Brazil

	Ageing method	Maximum age	References
<i>Doryteuthis plei</i>	Microincrements counts in statoliths	Nine months	Aguiar et al. (2012); Perez et al. (2006)
<i>Illex argentinus</i>	Microincrements counts in statoliths and gladius	Seven to twelve months	Schwarz & Perez (2010); Bainy and Haimovici, (2012), Shroederer and Perez, (2013)
<i>Octopus americanus</i>	Bands counted in lateral walls of the beaks	One year	Castanhari & Tomas, (2012)

was aged by counting increments deposited daily (Aguiar et al. 2012) and reached up to nine months of age (Perez et al. 2006). The ommastrephid squid *Illex argentinus* from southern Brazil was also aged by counting microincrements in their statoliths and gladius (Schwarz & Perez 2010; Bainy and Haimovici, 2012, and Shroederer and Perez, 2013) for which the maximum longevity was estimated to range from seven months to one year. Large interannual variability in both age and maximum ML was reported by Haimovici et al., (2013). The growth of the octopus *Octopus americanus* was studied by counting marks on the lateral walls of the beaks, assuming their daily formation, analogous to other species and the maximum age recorded was for a female with 356 marks, suggesting a life cycle shorter than two years (Castanhari & Tomas, 2012).

Other topics

A total of 64 **stock identification studies** between neighbouring regions were recorded for 28 species: 19 teleosts, one elasmobranch, three crustaceans, three cephalopods and one bivalve). The studies used a variety of methods: 30 involved molecular methods, seven compared otolith shape, 10 compared other morphometric characters, six compared otolith microchemistry, seven compared parasite communities and four compared aspects of life cycle and population dynamics.

The **distribution** of most fishing resources of the continental shelf is reasonably well known due to exploratory fishing projects targeting different species with different gears from the 1960s to the 1980s (Neiva and Moura 1977; Haimovici org, 2007) and those of the continental slope from the late 1990s to early 2000s (REVIZEE 2005).

The number of studies on the **incidental catch and discards** is relatively low, most were on the number and sizes of fishes in small scale trawl shrimp fisheries in the southeastern region in which no relationship with total catches were calculated. Only a handful were focused in industrial trawl fishing for sciaenid fish and shrimps and gillnet fisheries in the sampling design permitted estimates of the proportions of discards of demersal scienids, bluefish, monkfish and elasmobranchs on the total catches.

Only a small number of studies on the **selectivity** of fishing gears were performed, all of them before 2010 and almost all on teleosts. Most were for the selectivity of gillnets for estuarine and coastal species and only one for the most important teleosts in the trawl fishery along southern Brazil (Vooren 1983). This is somewhat surprisingly, as a large proportion of the management measures for estuarine and marine fishes in the region are based on fish size restrictions (Vasconcellos et al. 2005).

Discussion

This literature survey synthesized the extensive body of scientific research on the fishery biology of benthic and demersal species along southern and southeastern Brazil. Research in this area began shortly after the onset of industrial fishing in the 1950s, initially focusing on the distribution and abundance of species targeted by trawl fisheries (Yesaki et al. 1976) and key species such as the king weakfish (*M. atricauda*) (Yamaguti and Santos 1966) and the whitemouth croaker (*M. furnieri*) (Vazzoler, 1971). As industrial fishing practices evolved, so did the scope of research, expanding to cover both the continental shelf and slope in

response to increased fishing activities (Haimovici et al. 2006; Perez et al. 2003).

Despite these advancements, the research landscape remains uneven across species and topics. Syntheses by Haimovici (2006), Cergole et al. (2006, 2006), and others have provided valuable insights into population dynamics and fisheries management, including studies on endangered species (Pinheiro and Boos 2016; ICMBio 2018). Our study expands on these efforts by offering a comprehensive temporal overview, highlighting how scientific knowledge has evolved over the past six decades.

The review identifies both significant progress and ongoing challenges. For example, studies on age and growth have been conducted for 75 species, including teleosts, elasmobranchs, crustaceans, and cephalopods. Notably, the majority of age determinations for teleosts come from the southern region, where seasonal variations in temperature and photoperiod facilitate more accurate assessments (Green, 2009). Trends such as decreasing growth coefficients with increasing asymptotic length align with established literature (Beverton and Holt 1959). However, refining age determination methods for species in the northern part of the study area remains a priority (Cavole and Haimovici 2015; Giombelli-da-Silva et al. 2021). Elasmobranch age determination remains problematic due to high rates of underestimation (Harry 2018). For crustaceans, growth studies predominantly rely on length-frequency data, which is prone to sampling errors (Kilada and Driscoll 2017). Innovations such as using lipofuscin pigment concentration could enhance age determinations in future studies (Zapata et al. 2016). Cephalopods present unique challenges due to their rapid growth and short lifespans, exhibiting notable interannual variability in species such as *Illex argentinus* (Aguilar et al. 2012; Perez et al. 2009; Schwarz and Perez 2010; Bainy and Haimovici, 2012). This variability complicates the assessment of growth patterns and necessitates ongoing research to improve our understanding of their life history dynamics.

The information collected reveals that demersal and benthic elasmobranchs reach sexual maturity at larger sizes and older ages compared to their teleost counterparts in the BMM, which has important implications for their susceptibility to overfishing (Haimovici et al. 2006; ICMBio 2018). Furthermore, latitudinal variations in reproductive cycles, driven

by temperature and photoperiod, are evident. Species in the warmer southeastern region demonstrate more continuous spawning patterns, whereas those in the cooler southern region exhibit more seasonal spawning behaviors (Fig. 7; Jobling 1995). This distinction is crucial for formulating effective seasonal closures aimed at safeguarding spawning populations (Jakobsen et al. 2009; Bucaram et al. 2018). However, a significant gap remains in the knowledge of spawning seasons for molluscs, which constrains our understanding of their reproductive dynamics (Pinheiro and Boos 2016). Addressing this gap is essential for developing comprehensive management strategies that account for the reproductive biology of all key species.

Effective fisheries management in southern and southeastern Brazil necessitates a comprehensive understanding of the complex dynamics governing demersal and benthic species (Perez and Sant'Ana, 2022a). The extensive scientific production documented over the past six decades highlights significant progress in understanding species distribution, population dynamics, and ecological interactions. Nonetheless, challenges persist, particularly in managing the impacts of overfishing and climate change on marine ecosystems.

Climate change is increasingly impacting the southwestern Atlantic, with rising temperatures contributing to the tropicalization of Brazil's Meridional Margin (Franco et al. 2020; Gianneli et al. 2023). This shift alters species distributions, stocks productivity patterns and their phenology (Poloczanska et al. 2013; Perez and Santana, 2022b). Monitoring these changes is essential for predicting future impacts on fish populations' distribution and adjusting management strategies accordingly (Rodrigues et al. 2023a, 2023b). While current surveys provide a good understanding of the bathymetric and latitudinal limits of demersal nektonic fauna, gaps remain in data on spawning areas and early life stages, particularly for pelagic spawners. Addressing these gaps will be critical for anticipating and managing the effects of climate change on marine ecosystems.

Shifting from stock-based to ecosystem-based fisheries management is crucial for addressing the broader ecological impacts of fishing activities (Link & Browman 2014). Strong declines in the demersal fish stocks and the high level of overfishing have been observed in the region (Haimovici and Cardoso 2017;

Cardoso et al. 2021) highlighting the need for a more integrated approach that considers not only the sustainability of individual species but also the health of the entire marine ecosystem (Patrick and Link, 2015). Implementing effective management strategies will require a combination of improved data on population parameters, better understanding of ecological interactions, and adaptive measures that account for ongoing environmental changes (Levin et al. 2009).

The review of the references showed the limited knowledge on some topics, particularly on those related to those selectivity and discards, currently used for the regulatory measures in place based in fishing sizes restrictions. Other regulatory measures such as catch limits, seasonal closures, and protected areas are fundamentally reliant on robust scientific data to accurately reflect the dynamic nature of fish populations and environmental conditions (Hilborn 2004). Our study provides a detailed bibliographic compilation and systematization of population parameters and fishing dynamics for demersal and benthic species of the Brazilian Meridional Margin serving as a critical foundation for future studies and management measures.

Author contribution Conceptualization: MH. Methodology: MH, LR, EK. Software: MH, LR, EK. Validation: MH, LR, EK. Formal Analysis: MH, LR, EK. Investigation: MH, LR, EK. Resources: MH, EK, LR, RSM, RS, AOAS, JAAP, LGC. Data Curation: MH, LR, EK, RS. Writing – Original Draft: MH. Writing – Review and Editing: MH, EK, LR, RSM, RS, AOAS, JAAP, LGC. Visualization: MH, LR, EK. Supervision: MH. Project Administration: JAAP. Funding Acquisition: JAAP.

Funding National Council for Scientific and Technological Development—CNPq and the Ministry of Fisheries and Aquaculture—MPA within the scope of the Call MCTI/MPA/CNPq No. 22/ 2015—Ordenamento da Pesca Marinha Brasileira, 22/ 2015, 22/ 2015, 22/ 2015, 22/ 2015, 22/ 2015, 22/ 2015, 22/ 2015, 22/ 2015

Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

References

- Aguair DC, Wongtchowski CL, Perez JAA (2012) Validation of daily growth increments of Brazilian squids *Doryteuthis plei* and *D. sanpaulensis* (Cephalopoda: Loliginidae) statoliths. *Bioikos* 26:13–21
- Bainy MCRS, Haimovici M (2012) Seasonality in growth and hatching of the Argentine short-finned squid *Illex argentinus* (Cephalopoda: Ommastrephidae) inferred from aging on statoliths in southern Brazil. *J Shellfish Res* 31(1):135–143
- Bernardes RA, Figueiredo JL, Rodrigues AR, Fischer LG, Vooren CM, Haimovici M, Wongtchowski CR (2005) Peixes da zona econômica exclusiva da região sudeste-sul do Brasil: levantamento com armadilhas, pargueiras e redes de arrasto de fundo. São Paulo: Edusp 295
- Beverton RJH, Holt SJ (1959) A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. In: Wolstenholme GEW, O'Connor M (eds) Ciba foundation colloquium on ageing: the lifespan of animals, Churchill, London, 5 pp 142–177
- Bucaram SJ, Hearn A, Trujillo AM, Rentería W, Bustamante RH, Reck G (2018) Assessing the effectiveness of the Galapagos Marine Reserve as a large-scale marine protected area. *Mar Policy* 93:1–10. <https://doi.org/10.1016/j.marpol.2018.03.002>
- Callum R (2007) The unnatural history of the sea. Island Press, Washington
- Capitoli RR, Bemvenuti CE (2006) Associações de macroinvertebrados bentônicos de fundos inconsolidados da plataforma continental e talude superior no extremo sul do Brasil. *Atlântica (Rio Grande)* 28(1):47–60
- Cardoso LG, Haimovici M, Abdallah PR, Secchi ER, Kinas PG (2021) Prevent bottom trawling in southern Brazil. *Science* 372(6538):138–138
- Cardoso LG, Sant'Ana R, Mourato BL, Kikuchi E, Haimovici M, Perez JAA (2023) Os impactos da pesca demersal sobre o ambiente marinho. In: Perez JAA, Cardoso LG, (eds). A pesca demersal nas regiões sudeste e sul do Brasil: síntese espacial e modelo de gestão baseada no ecossistema. relatório final do projeto meee pdses – subsídios científicos para o manejo espacial e com enfoque ecossistêmico da pesca demersal nas regiões sul e sudeste do Brasil – chamada MCTI/MPA/CNPq No. 22/2015, Ordenamento da Pesca Marinha Brasileira, Processo 445782/2015–3
- Castanhari G, Tomás ARG (2012) Beak increment counts as a tool for growth studies of the common octopus *Octopus vulgaris* in southern Brazil. *Bol Inst Pesca* 38(4):323–331
- Cavole LM, Haimovici M (2015) The use of otolith microstructure in resolving issues of ageing and growth of young *Micropogonias furnieri* from southern Brazil. *Mar Biol Res* 11(9):933–943
- Cergole MC, Ávila-da-Silva AO, Rossi-Wongtschowski CLDB (eds) (2006) Análise das principais pescarias comerciais da região sudeste-sul do Brasil: dinâmica populacional das espécies em exploração – I. Série documentos REVIZEE – score sul, Instituto Oceanográfico – USP, São Paulo

- Christensen V (2011) Introduction: Toward ecosystem-based management of fisheries. In: Christensen V, Maclean J (eds) *Ecosystem Approaches to Fisheries - A Global Perspective*. Cambridge University Press, pp 1–8
- Ciotti AM, Odebrecht C, Fillmann G, Moller OO Jr (1995) Freshwater outflow and subtropical convergence influence on phytoplankton biomass on the southern Brazilian continental shelf. *Cont Shelf Res* 15(14):1737–1756
- Costa PAS, Mincarone MMA, Braga AC, Martins AS, Lavrado HP, Haimovici M, Falcão APC (2015) Megafaunal communities along a depth gradient on the tropical Brazilian continental margin. *Mar Biol Res* 11(1):1–12
- Dolan TE, Patrick WS, Link J (2016) Delineating the continuum of marine ecosystem-based management: a US fisheries reference point perspective. *ICES J Mar Sci* 73(4):1042–1050. <https://doi.org/10.1093/icesjms/fsv242>
- FAO (2022) The state of World fisheries and aquaculture 2022: towards blue transformation. FAO, Rome
- FAO (2003) Fisheries management. 2. The ecosystem approach to fisheries. FAO technical guidelines for responsible fisheries. Rome, FAO, No 4, Suppl 2, pp 112
- Franco BC, Defeo O, Piola AR, Barreiro M, Yang H, Ortega L et al (2020) Climate change impacts on the atmospheric circulation, Ocean, and fisheries in the southwest South Atlantic Ocean: a review. *Clim Change*. <https://doi.org/10.1007/s10584-020-02783-6>
- Freire KMF et al (2021) Reconstruction of marine commercial landings for the Brazilian industrial and artisanal fisheries from 1950 to 2015. *Front Mar Sci* 8:659110
- Gayanilo FC Jr, Pauly D (eds) (1997) FAO-ICLARM stock assessment tools (FiSAT). Reference manual. FAO computerized information series (Fisheries), Rome, FAO, No 8, 262 p.
- Gianelli I, Orlando L, Cardoso LG et al (2023) Sensitivity of fishery resources to climate change in the warm-temperate Southwest Atlantic Ocean. *Reg Environ Change* 23:49. <https://doi.org/10.1007/s10113-023-02049-8>
- Giombelli-da-Silva A, Monteiro-Neto C, Vaz-dos-Santos AM (2021) A new perspective of *Mugil liza*: the fast growth in an impacted subtropical bay. *Reg Stud Mar Sci* 48:102008
- Green BS, Mapstone BD, Carlos G, Begg GA (2009) Tropical fish otoliths: Information for assessment, management and ecology. Springer, Netherlands, Dordrecht
- Haimovici M, Cardoso LG (2017) Long-term changes in the fisheries in the Patos Lagoon estuary and adjacent coastal waters in southern Brazil. *Mar Biol Res*. <https://doi.org/10.1080/17451000.2016.1228978>
- Haimovici M, Martins AS, Figueiredo JL, Vieira PC (1994) Demersal bony fish of the outer shelf and upper slope off southern Brazil subtropical convergence ecosystem. *Mar Ecol Prog Ser* 108(1–2):59–77
- Haimovici M, Martins AS, Vieira PC (1996) Distribuição e abundância de teleósteos demersais sobre a plataforma continental do sul do Brasil. *Rev Bras Biol* 56(1):27–50
- Haimovici M, Ávila da Silva AO, Tutui SLS, Bastos GC, Santos RA, Fischer LG (2004) Prospecção pesqueira de espécies demersais com espinhel-de-fundo na região Sudeste-Sul do Brasil. In: Haimovici M, Ávila-da-Silva AO, Rossi-Wongtschowski CLDB (eds) *Prospecção pesqueira de espécies demersais com espinhel-de-fundo na zona econômica exclusiva da região sudeste-sul do Brasil*. Série relatórios revizee score sul instituto oceanográfico - USP, pp 11–78
- Haimovici M (org) (2007) A prospecção pesqueira e abundância de estoques marinhos no Brasil nas décadas de 1960 a 1990: levantamento de dados e avaliação crítica. Brasília: Ministério do Meio Ambiente/Secretaria de Mudanças Climáticas e Qualidade Ambiental. ISBN 978-85-7738-083-1
- Haimovici M, Santos RA, Bairy MCRS, Fischer LG, Cardoso LG (2013) Abundance, distribution and population dynamics of the short fin squid *Illex argentinus* in Southeastern and Southern Brazil. *Fish Res* 125:1–12
- Haimovici M, Cergole MC, Lessa RP, Madureira LS, Jablonski S, Rossi-Wongtschowski CLDB (2006) Capítulo 2: panorama nacional. In: Programa REVIZEE: avaliação do potencial sustentável de recursos vivos da zona econômica exclusiva: relatório executivo. Brasília: ministério do meio ambiente, (ISBN: 85–7738–027–0), pp 77–120
- Haimovici M, Rossi-Wongtschowski CLDB, Bernardes RA, Fischer LG, Vooren CM, Santos RA, Rodrigues AR (2008) Prospecção pesqueira de espécies demersais com rede de arrasto-de-fundo na região sudeste-sul do Brasil. IOUSP
- Harry AV (2018) Evidence for systemic age underestimation in shark and ray ageing studies. *Fish Fish* 19(2):185–200
- Hilborn R (2004) Ecosystem-based management of fisheries: some practical suggestions. *Mar Ecol Prog Ser* 274:275–278. <https://doi.org/10.3354/meps274275>
- Hilborn R (2011) Future directions in ecosystem-based fisheries management: a personal perspective. *Fish Res* 108(2–3):235–239
- Hilborn R, Amoroso RO, Anderson CM, Baum JK, Branch TA, Costello C, Ye Y (2020) Effective fisheries management instrumental in improving fish stock status. *Proc Nat Acad Sci* 117(4):2218–2224
- IBAMA (2008) Estatística da Pesca 2006 Grandes regiões e unidades da federação. Instituto Brasileiro do meio ambiente e dos recursos naturais renováveis, Brasília, p 180
- ICMBio (2018) Livro vermelho da Fauna Brasileira ameaçada de extinção volume VI: peixes. Instituto Chico Mendes de conservação da biodiversidade, Brasília, p 1217
- Jakobsen T, Fogarty MJ, Megrey BA, Moksness E (2009) Fish reproductive biology: implications for assessment and management. Wiley-Blackwell. <https://doi.org/10.1002/9781444315774>
- Jobling M (1995) Environmental biology of fishes. Chapman & Hall, London
- Kilada R, Driscoll JG (2017) Age determination in crustaceans: a review. *Hydrobiologia* 799(1):21–36
- Levin PS, Fogarty MJ, Murawski SA, Fluharty D (2009) Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. *PLoS Biol* 7(1):e1000014. <https://doi.org/10.1371/journal.pbio.1000014>
- Link JS, Browman HI (2014) Integrating ecosystem considerations into fisheries management: advances, challenges and emerging tools. *ICES J Mar Sci* 71(5):1187–1197. <https://doi.org/10.1093/icesjms/fst125>
- Marshall KN, Koehn LE, Levin PS, Essington TE, Jensen OP (2019) Inclusion of ecosystem information in US fish stock assessments suggests progress toward

- ecosystem-based fisheries management. *ICES J Mar Sci* 76(1):1–9
- Martins AS, Haimovici M (2017) Seasonal mesoscale shifts of demersal nekton assemblages in the subtropical Southwestern Atlantic. *Mar Biol Res* 13(1):88–97
- Matano RP, Palma ED, Piola AR (2010) The influence of the Brazil and Malvinas currents on the Southwestern Atlantic Shelf circulation. *Ocean Sci* 6:983–995
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Prisma Group (2010) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg* 8(5):336–341
- Möller OO, Piola AR, Freitas AC, Campos EJ (2008) The effects of river discharge and seasonal winds on the shelf off southeastern South America. *Cont Shelf Res* 28:1607–1624
- Muelbert JH, Acha EM, Chiaradia A, Muto E (2015) Comparative reproductive biology of two closely related species of the family Sciaenidae: *Cynoscion guatucupa* and *Cynoscion virescens*. *J Fish Biol* 86(1):229–241
- Neiva GS, Moura SJC (1977) Sumário sobre a exploração de recursos marinhos do litoral brasileiro: situação atual e perspectivas. *PDP Documentos Opcionais* 27:44
- Pauly D, Christensen V, Guénette S et al (2002) Towards sustainability in world fisheries. *Nature* 418:689–695
- Perez JAA, Sant'Ana R (2022) Tropicalization of demersal megafauna in the western South Atlantic since 2013. *Commun Earth Environ* 3:227. <https://doi.org/10.1038/s43247-022-00450-7>
- Perez JAA, Pezzuto PR, Rodríguez LF, Valentini H, Vooren CM (2001) Relatório da reunião técnica de ordenamento da pesca demersal nas regiões Sudeste e Sul do Brasil. *Notas Técnicas Da FACIMAR* 5:1–34
- Perez JAA, Wahrlich R, Pezzuto PR, Schwingel PR, Lopes FRA, Rodrigues-Ribeiro M (2003) Deep-sea fishery off Southern Brazil: recent trends of the Brazilian fishing industry. *J Northwest Atl Fish Sci* 31:1
- Perez JAA, Aguiar DCD, Santos JATD (2006) Gladius and statolith as tools for age and growth studies of the squid *Loligo plei* (Teuthida: Loliginidae) off southern Brazil. *Braz Arch Biol Technol* 49:747–755
- Perez JAA, Silva TN, Schroeder R, Schwarz R, Martins RS (2009) Biological patterns of the Argentine shortfin squid *Illex argentinus* in the slope trawl fishery off Brazil. *Lat Am J Aquat Res* 37(3):409–428
- Perez JAA, Silva AOÁ, Cardoso LG, Haimovici M, Dias MC, Pezzuto PR, Sant'ana R (2024) Remodeling the demersal fishery management system of southeastern and southern Brazil. *Desenvolvimento e Meio Ambiente* 63:48–65
- Perez JAA, Sant'Ana R (Org) (2022a) A pesca demersal nas regiões sudeste e sul do Brasil: síntese espacial e modelo de gestão baseada no ecossistema. relatório final do projeto MEEE PDSSES - subsídios científicos para o manejo espacial e com enfoque ecossistêmico da pesca demersal nas regiões sul e sudeste do Brasil – chamada MCTI/MPA/CNPq no. 22/2015, ordenamento da pesca marinha Brasileira. Processo 445782/2015–3, pp 452
- Pikitch EK, Santora C, Babcock EA, Bakun A, Bonfil R, Conover DO, Sainsbury KJ (2004) Ecosystem-based fishery management. *Science* 305(5682):346–347
- Pinheiro M, Boos H (eds) (2016) Livro vermelho dos crustáceos do Brasil: avaliação 2010–2014. Sociedade Brasileira de Carcinologia, Porto Alegre
- Pinto Paiva M (2004) Administração pesqueira no Brasil. Editora Interciência, Rio de Janeiro, p 177
- Poloczanska ES, Brown CJ, Sydeman WJ, Kiessling W, Schoeman DS et al (2013) Global imprint of climate change on marine life. *Nat Clim Chang* 3:919–925. <https://doi.org/10.1038/nclimate1958>
- REVIZEE (2005) Avaliação do potencial sustentável de recursos vivos da zona econômica exclusiva: relatório executivo. Brasília: ministério do meio ambiente, Brasília, (ISBN: 85–7738–027–0), pp 280
- Rodrigues LdS, Pennino MG, Conesa D, Kikuchi E, Kinas PG, Barbosa FG, Cardoso LG (2023a) Modelling the distribution of marine fishery resources: where are we? *Fish Fish* 24(1):159–175
- Rodrigues LdS, Daut NW, Cardoso LG, Kinas PG, Conesa D, Pennino MG (2023b) Species distribution modelling in the Southwestern Atlantic Ocean: a systematic review and trends. *Ecol Modell* 486:110514
- Schroeder R, Perez JAA (2010) The study of intra-specific growth variability of *Illex argentinus* (Cephalopoda: Teuthida) in Brazilian waters as reconstructed from the gladius microstructure. *Fish Res* 106:163–170
- Schwarz R, Perez JAA (2010) Growth model identification of short-finned squid *Illex argentinus* (Cephalopoda: Ommastrephidae) off southern Brazil using statoliths. *Fish Res* 106:177–184
- Silveira ICA, Schmidt AKC, Campos EJD, Godoi SS, Ikeda Y (2000) A Corrente do Brasil ao largo da costa leste brasileira. *Rev Bras Oceanogr* 48:171–183
- Spalding MD, Fox HE, Allen GR, Davidson N, Ferdaña ZA, Finlayson M, Halpern BS, Jorge MA, Lombana A, Lourie SA, Martin KD, McManus E, Molnar J, Recchia CA, Robertson J (2007) Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *Bioscience* 57:573–583. <https://doi.org/10.1641/b570707>
- Vasconcellos MC, Kalikoski D, Haimovici M, Abdallah PR (2005) Capacidad excesiva del esfuerzo pesquero en el sistema estuario-costero del sur de Brasil. p. 275–308. In: Aguero M (ed) Capacidad de pesca y manejo pesquero en América latina y el caribe. FAO documento técnico de Pesca, Roma: FAO, No 461, pp 405
- Vazzoler AEA de M (1971) Diversificação fisiológica e morfológica de micropogonias furnieri (Desmarest, 1823) ao sul de cabo frio, Brasil. *Boletim do instituto Oceanográfico*, 20(2): 1-71
- Vooren CM (1983) Seleção pela malha na pesca de arrasto da castanha, Umbrina canosai, pescada, *Cynoscion striatus*, e pescadinha, *Macrodon ancylodon*, no Rio Grande do Sul. Documento Técnico De Oceanografia - FURG 4:32
- Vooren CM, Klippel S (eds) (2005) Ações para a conservação de tubarões e raias no sul do Brasil. Igaré, Porto Alegre
- Yamaguti N, Santos EP (1966) Crescimento da pescadafoguete (*Macrodon ancylodon*): aspecto quantitativo. *Boletim Do Instituto Oceanográfico* 15(1):75–78
- Yesaki M, Bager KJ (1975) Histórico da evolução da pesca industrial em rio grande. Série documentos técnicos SUDEPE/PDP, No. 11. Rio de janeiro: Programa de pesquisa e desenvolvimento pesqueiro do Brasil. 15

- Yesaki M, Rahn E, Silva AG (1976) Sumário das explorações de peixes de arrasto de fundo ao largo da costa sul do Brasil. documentos técnicos n° 19. Programa de pesquisa e desenvolvimento pesqueiro do Brasil, PNUD/FAO – MA SUDEPE. 44
- Zapata J et al (2016) Lipofuscin and its role as an indicator of aging in crustaceans. *Mar Biol* 163(4):1–13

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