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Fisheries catch reconstructions for Brazil's mainland and Oceanic Islands

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Fisheries Centre, University of British Columbia, Canada

Edited by

Kátia de Meirelles Felizola Freire and Daniel Pauly

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Preface

Catch data are essential to the management of fisheries. In Brazil, the compilation and analysis of catch data from the marine fisheries, for various reasons, have always been a difficult issue.

One of these reasons is the sheer size of the country, which ranges from the tropics (6°N) to the temperate area (34°S),i.e. from climate zone where multispecies fisheries predominate to a climate zone where single-species fish stocks can become so abundant as to support targeted fisheries. This wide range of ecological conditions, matched by a similarly wide range of cultural and economic conditions, is reflected in the different coastal states of Brazil. This is the reason why the reconstruction of the fisheries catches of Brazil were done by state-by-state, then added up. This is also the reason why the catch reconstruction for the Brazilian mainland has many co-authors, most of them contributing their state-specific knowledge of and perspective on 'their' fisheries.

This Fisheries Centre Research Report also includes a contribution on the oceanic islands of Brazil, i.e. the St. Peter and St. Paul Archipelago in the Northeast, Fernando de Noronha off Recife and Trindade & Martim Vaz Islands in the Southwest of the Brazilian coast.

Data on the fisheries of these islands were quite scarce, and we hope that this report motivates Brazilian colleagues in assembling and publishing more information on these islands, to help correct, update and/or complement what islands, are in fact, very preliminary reconstructions.

We are well aware that this also applies to our reconstruction of the marine fisheries catches of the Brazilian mainland, which need to be reviewed by more colleagues and revised as required. Also, the catch data it presents, covering the years from 1950 to 2010, will soon need to be updated to 2014. In the meantime, we hope that this report will be found useful.

The Editors

Reconstruction of catch statistics for Brazilian marine waters (1950-2010)[1]

Kátia de Meirelles Felizola Freire[a], José Augusto Negreiros Aragão[b]; Ana Rosa da Rocha Araújo[c], Antônio Olinto Ávila-da-Silva[d], Maria Camila dos Santos Bispo[e], Gonzalo Velasco[f], Marcus Henrique Carneiro[g], Fernanda Damaceno Silva Gonçalves[h], Karina Annes Keunecke[i], Jocemar Tomasino Mendonça[j], Pietro S. Moro[k], Fabio S. Motta[l], George Olavo[m], Paulo Ricardo Pezzuto[n], Raynara Filho Santana[o], Roberta Aguiar dos Santos[p], Isaac Trindade-Santos[q], José Airton Vasconcelos[r], Marcelo Vianna[s] and Esther Divovich[t]

[a]*Universidade Federal de Sergipe (UFS), Departamento de Engenharia de Pesca e Aquicultura (DEPAQ), São Cristóvão, Sergipe, Brazil,*
kmffreire2015@gmail.com; coordinator, commercial (all states), recreational (all states)
[b]*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), Fortaleza, Ceará, Brazil,*
j_aragao@hotmail.com; commercial (Ceará)
[c]*UFS/DEPAQ, anarosaaraujop@gmail.com; commercial (Amapá, Pará, Sergipe)*
[d]*Instituto de Pesca, Unidade Laboratorial de Referência em Controle Estatístico da Produção Pesqueira Marinha (IP-ULRCEPPM), Santos, São Paulo, Brazil, aolinto@pesca.sp.gov.br; commercial (São Paulo)*
[e]*UFS/DEPAQ, mila-beijaflor@hotmail.com; commercial (all states)*
[f]*Universidade Federal do Rio Grande (FURG), Instituto de Oceanografia, Rio Grande, Rio Grande do Sul, Brazil,*
gonzalo.velasco.c@gmail.com; commercial (Rio Grande do Sul)
[g]*Instituto de Pesca, Núcleo de Pesquisa e Desenvolvimento do Litoral Norte (IP-NPDLN), Ubatuba, São Paulo, Brazil, mcarneiro@pesca.sp.gov.br; commercial (São Paulo)*
[h]*UFS/DEPAQ; fernanda.ceno@hotmail.com; commercial (Piauí, Paraíba, Bahia)*
[i]*Universidade Federal Rural do Rio de Janeiro (UFRRJ), Rio de Janeiro, Brazil,*
keunecke@ufrrj.br; commercial (Rio de Janeiro)
[j]*Instituto de Pesca, Núcleo de Pesquisa e Desenvolvimento do Litoral Sul (IP-NPDLS), Cananéia, São Paulo, Brazil,*
jmendonca@pesca.sp.gov.br; recreational (São Paulo, Paraná)
[k]*Programa Costa Atlântica, Fundação SOS Mata Atlântica, São Paulo, São Paulo, Brazil, Pietro*
pietro_moro@moroassessoria.com; recreational (São Paulo)
[l]*Universidade Federal de São Paulo, Departamento de Ciências do Mar, Baixada Santista, Santos, São Paulo, Brazil, limbatus@gmail.com; recreational (São Paulo)*
[m]*Universidade Estadual de Feira de Santana, Departamento de Ciências Biológicas, Laboratório de Biologia Pesqueira, Feira de Santana, Bahia, Brazil, georgeolavo@uol.com.br; commercial (Bahia)*
[n]*Universidade do Vale do Itajaí (UNIVALI), Itajaí, Santa Catarina, Brazil,*
pezzuto@univali.br; commercial (Santa Catarina)
[o]*UFS/DEPAQ, raynarafs@hotmail.com; commercial (Maranhão, Espírito Santo, Rio de Janeiro)*
[p]*Instituto Chico Mendes de Conservação da Biodiversidade, Centro de Pesquisa e Gestão de Recursos Pesqueiros do Litoral Sudeste e Sul (ICMBio/CEPSUL), Itajaí, anta Catarina, Brazil,*
roberta.santos@icmbio.gov.br; commercial (Paraná, Santa Catarina)
[q]*UFS/DEPAQ, isaacmordaz@hotmail.com; commercial (Santa Catarina, Rio Grande do Sul), subsistence (all states)*
[r]*IBAMA, Divisão de Controle, Monitoramento e Fiscalização Ambiental (DICAFI-Pesca), Natal, Rio Grande do Norte, Brazil, ja_vasconcelos@ig.com.br; commercial (Rio Grande do Norte)*
[s]*Universidade Federal do Rio de Janeiro, Instituto de Biologia, Rio de Janeiro, Rio de Janeiro, Brazil*
mvianna@biologia.ufrj.br; commercial (Rio de Janeiro)
[t]*Sea Around Us, Fisheries Centre, University of British Columbia, Vancouver, Canada*
e.divovich@fisheries.ubc.ca; discards (all states)

[1] Cite as: Freire, KMF, Aragão, JAN, Araújo, ARR, Ávila-da-Silva, AO, Bispo, MCS, Velasco, G, Carneiro, MH, Gonçalves, FDS, Keunecke, KA, Mendonça, JT, Moro, PS, Motta, FS, Olavo, G, Pezzuto, PR, Santana, RF, Santos, RA, Trindade-Santos, I, Vasconcelos, JA, Vianna, M and Divovich, E. (2015) Reconstruction of catch statistics for Brazilian marine waters (1950-2010). pp. 3-30. *In:* Freire, KMF and Pauly, D (eds). Fisheries catch reconstructions for Brazil's mainland and oceanic islands. Fisheries Centre Research Reports vol.23(4). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Abstract

Catch data are the most basic information to be collected for managing fisheries everywhere. However, in many regions around the globe, including Brazil, this information is not available in a quality that is satisfactory. The objective of the initiative presented in this paper was to compile a country-wide database of marine commercial catch data in its original form (landings only) and a reconstructed version (which includes artisanal, industrial, recreational, and subsistence landings, as well as major discards), as well as to analyze historical trends. The basis for the country-wide database of marine catch statistics compiled here were the national official bulletins published in Brazil for the period 1950 to 2010. They represent an update of previous databases compiled for 1980-2000 and later for 1950-2004. These databases were revised and extended to include the whole period from 1950 to 2010 and all 17 coastal states in Brazil, from Amapá to Rio Grande do Sul. Estimates for recreational and subsistence catches and discards were added. Our analysis indicates that total catches for Brazil may be almost 2 times the baseline reported for Brazil. Besides the previously known low taxonomic resolution of catch statistics in Brazil, taxonomic losses were observed when local data were incorporated into the national bulletins and later in the FAO database (FishStatJ). Regional analyses indicate that the highest catches are associated with the southern region, except when there is a peak in sardine catches. However, this result may be biased as those values may include catches off the southeastern region that end up being landed in the south. The same is true for other regions in Brazil. Sardine and demersal fishes comprise the largest portion of the catches. This reconstruction is preliminary and should be revised by local experts to improve the local database and hence the national and global databases.

Introduction

Catch data are the most basic information to be collected in order to manage fisheries. However, in many regions around the globe this information is not available in a quality that is satisfactory. The same is true even for economies in transition such as Brazil. In 1953, the Food and Agriculture Organization of the United Nations (FAO) released a report where the reasons for the deficiency of the collection system of catch statistics in Brazil were pointed out: time lag of over six months between the period when catch data was sent by state or region and arrival in Rio de Janeiro where data were processed, catch data not species-specific, and different weight measurements presented together, among others (FAO 1953). In fact, during that period, the national bulletins available for Brazil reported only total catch, with no detail about species or groups caught.

Figure 1. Map of Brazil mainland and Exclusive Economic Zone (EEZ).

Pauly (2013) discusses the danger of some discourses stressing that lower catches do not mean fewer fish (Hilborn and Branch 2013). Pauly (2013) suggests that this discourse can lead to the erroneous message that there is no need to collect catch information. In Brazil, for example, the collection system of catch statistics has collapsed. Currently, there is no national standardized collection system in place, with the situation being as such for a long time. Several institutions were in charge of collecting catch statistics throughout the period studied here. Freire and Oliveira (2007) compiled historical catch series for the period 1950-2004, based on a previous effort by Freire (2003). However, the authors were not able to establish a reasonable connection between common and scientific names for the species caught. From 1990 to 2007, the Brazilian Institute for the Environment and Renewable Resources (IBAMA) was in charge of collecting catch statistics. After 2007, this responsibility was transferred to SEAP/PR (Special Secretariat for Aquaculture and Fisheries from the Presidency of the Republic, created in 2003), which evolved into the Fisheries and Aquaculture Ministry (MPA) in 2009, when methodological changes were discussed in order to improve the older system. That led to a break in the data collection process, and catch statistics have not yet become standardized nor implemented nation-wide. Thus, the most recent information available on landing statistics for Brazil are based only on estimation models and refers to years 2008-2011, with no detail provided about catches by species for each state.

In 1995, a National System of Information on Fisheries and Aquaculture (Sistema Nacional de Informações da Pesca e Aquicultura – SINPESQ) was created and should be maintained by the Brazilian Institute for Geography and Statistics (IBGE). The objectives of the system were to collect, compile, analyze, exchange, and disseminate information about the national fishing sector. This system currently comprises many modules, some of which are active (e.g., boat satellite tracking system, PREPS, since 2006 and general fisheries registry, RPG, developed between 2008 and 2011) and others inactive (notably the landings and production data tool; sinpesq.mpa.gov.br). It was conceived as an on-line, web-service oriented system to be fed with data. Instead, the Ministry of Fisheries and Aquaculture have been making available written reports for the period 2005-2011 (www.mpa.gov.br/index.php/informacoes-e-estatisticas/estatistica-da-pesca-e-aquicultura).

Out of the 17 coastal states, only the states of Santa Catarina and São Paulo have online systems of catch statistics. However, the first deals only with industrial fisheries and the second reports data for both artisanal and industrial fleets combined (Ávila-da-Silva *et al.* 1999; Mendonça and Miranda 2008; UNIVALI/CTTMar 2013). Thus, the objective of the initiative described in this paper was to compile a national database of marine commercial catch data in its original form (only landings) and a reconstructed version (which also includes estimates of unreported artisanal, industrial, recreational, and subsistence catches, and major discards) to make them available online and to analyze historical trends. We hope this study will trigger the interest of other scientists to review and update the database for the states where they have been working on.

Material and methods

The basis for the country-wide database of marine catch statistics compiled here were the national official bulletins published in Brazil for the period 1950 to 2010. They represent an update of previous databases compiled by Freire (2003) for 1980-2000 and Freire and Oliveira (2007) for 1950-2004. These databases were revised and extended to include the whole period between 1950 and 2010 and all 17 coastal states in Brazil, from Amapá to Rio Grande do Sul (Figure 1). Estimates for unreported recreational and subsistence catches, and discards were added.

The original database was based only on the sources listed in Table 1. The nature of data available was very heterogeneous throughout the period: total landings (with no taxonomic details) for 1950-1955, landings by group (fishes, crustaceans, mollusks, reptiles, and mammals) for 1956-1961, landings by main species for 1962-1977, landings by species and by fleet – artisanal and industrial – (1978-1989), repeated mean values for 1990-1994, landings by species and by fleet (1995-2007), and back to total landings in 2008-2010 (Table 2). We used a 'bottom-up' strategy to rebuild commercial catches. This strategy consisted of starting the reconstruction of catches based on data from national bulletins and estimated missing values for each species in the beginning, middle and/or end of the time series, excluding categories such as "mistura", "caíco", "outros peixes", and "outras espécies" (all representing miscellaneous fishes). Whenever the sum of reconstructed catches for all species by state did not reach or surpass original catches, we topped up with catches associated to miscellaneous fishes.

For the purposes of the *Sea Around Us* database, adjustments of the reported landings data for the years 1950-1961, 1965, and 2008-2010 were made. We assumed for these adjustments that the catches from the recreational and subsistence sectors, as well as all discards, are entirely unreported. Thus, adjustments were only made to the industrial and artisanal sectors, i.e. the commercial catches, in terms of input, i.e., whether the catches are deemed reported or unreported.

Table 1. Sources used to compile marine landings for Brazilian commercial fisheries (artisanal and industrial) from 1950 to 2010.

Year	Source	Type
1950-52	IBGE (1955)	PDF1
1953-55	IBGE (1956)	PDF1
1956-57	IBGE (1959)	PDF1
1958-60	IBGE (1961)	PDF1
1961	IBGE (1962)	PDF1
1962	MA/SEP (1965b)	Paper
1963	MA/SEP (1965a)	Paper
1964	MA/SEP (1965b)	Paper
1965	No bulletin found	—
1966	MA/SEP (1967)	Paper
1967	MA/ETEA (1968)	Paper
1968	MA/ETEA (1969)	Paper
1969	MA/ETEA (1971)	Paper
1970	MA/EE (1971)	Paper
1971	SUDEPE/IBGE (1973)	Paper
1972	SUDEPE/IBGE (1975)	Paper
1973	SUDEPE/IBGE (1976a)	Paper
1974	SUDEPE/IBGE (1976b)	Paper
1975	SUDEPE/IBGE (1977)	Paper
1976	SUDEPE/IBGE (1979a)	Paper
1977	SUDEPE/IBGE (1979b)	Paper
1978	SUDEPE (1980a)	Paper
1979	SUDEPE (1980b)	Paper
1980	IBGE (1983a)	Paper
1981	IBGE (1983b, 1983c)	Paper
1982	IBGE (1983d, 1984a)	Paper
1983	IBGE (1984b, 1985a)	Paper
1984	IBGE (1985b, 1985c)	Paper
1985	IBGE (1986, 1987a)	Paper
1986	IBGE (1987b, 1988a)	Paper
1987	IBGE (1988b, 1988c)	Paper
1988	IBGE (1989a, 1989b)	Paper
1989	IBGE (1990, 1991)	Paper
1990	CEPENE (1995a)	Paper
1991	CEPENE (1995b)	Paper
1992	CEPENE (1995c)	Paper
1993	CEPENE (1995d)	Paper
1994	CEPENE (1995e)	Paper
1995	CEPENE (1997a)	Paper
1996	CEPENE (1997b)	Paper
1997	CEPENE (1998)	Paper
1998	CEPENE (1999)	Paper
1999	CEPENE (2000)	Paper
2000	CEPENE (2001)	PDF (reduced version) and Excel
2001	IBAMA (2003)	PDF2
2002	IBAMA (2004a)	PDF2
2003	IBAMA (2004b)	PDF2
2004	IBAMA (2005)	PDF2
2005	IBAMA (2007a)	PDF2
2006	IBAMA (2008)	PDF2
2007	IBAMA (2007b)	PDF2
2008	MPA (undated)	PDF3
2009	MPA (undated)	PDF3
2010	MPA (2012)	PDF3

[1] http://biblioteca.ibge.gov.br/d_detalhes.php?id=720
[2] www.ibama.gov.br/documentos-recursos-pesqueiros/estatistica-pesqueira
[3] www.mpa.gov.br/index.php/informacoes-e-estatisticas/estatistica-da-pesca-e-aquicultura

For the years 1950-1958, zero to very small catches were reported in the national data sources. However, as there are FAO data for this period, and since national statistics and FAO data were almost identical in the first few years of mutual availability (i.e., 1959-1961), we decided to accept the FAO data as the reported tonnage for the beginning of the time period.

However, the reconstructed commercial landings for those years were less than the FAO data. Thus, we accepted all of the commercial catches reconstructed for this period (1950-1958) as reported. Hence, during this period, there are no unreported landings for the artisanal and industrial sector. In the year 1965, there was a sudden and unexplained drop in reported landings which rebounded immediately in the next year. We deemed this abrupt one-year drop to be a data reporting error, and therefore interpolated reported landings between 1964 and 1966 to derive a new reported catch amount for 1965.

For the years 2008-2010, the ratio between the reported FAO landings and the reconstructed catches in 2007 was maintained and the new reported landings were calculated. The total reconstructed catch amount was not changed.

Thus, when referring to the baseline reported landings, it is the combination of the data from the national/local bulletins and the amount assigned from the FAO data which are accepted as the reported landings data in this study.

Table 2. Type of data used in the catch reconstruction for Brazilian marine waters for the period 1950-2010 (national and local bulletins, and other sources as also indicated in the database).

Years	AP	PA	MA	PI	CE	RN	PB	PE	AL	SE	BA	ES	RJ	SP	PR	SC	RS
1950-55	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB	TotalB
1956-61	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB	GroupB
1962-75	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB	SpRB
1976-77	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB	SpHB
1978-79	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB	SpB
1980-89	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM
1990-94	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp	SpMRp
1995-2007	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM	SpM
2008	None	None	None	None	SpM	SpM	None	None	None	None	None	None	SpM	SpM	None	SpMI	SpM
2009	None	None	None	None	None	SpM	None	None	None	None	None	None	SpM	SpM	None	SpMI	SpM
2010	None	None	None	None	None	SpMI	None	None	None	SpM	None	None	SpM	SpM	None	SpMI	SpM

TotalB (both) = only total landings for the state provided (both marine and freshwater together, not separated into artisanal and industrial);
GroupB (both) = landings per group (fishes, crustaceans, molluscs, mammals, chelonians) (both marine and freshwater together, not separated into artisanal and industrial);
SpRB (reduced/both) = landings only for a reduced number of main species (both marine and freshwater in the same table; not separated into artisanal and industrial);
SpHB (higher/both) = landings per species for a higher number of species, representing 75-80% of total landings (both marine and freshwater in the same table; not separated into artisanal and industrial);
SpB (both) = landings per species for a higher number of species (both marine and freshwater in the same table; separated into artisanal and industrial);
SpM (marine) = landings per species for a higher number of marine species (separated into artisanal and industrial);
SpMRp (marine/repetition): there was no system of data collection in Brazil during this period (except for a few main species for which there were working groups) and a mean for the previous four years was calculated for each of all other species and printed in the national bulletin (separated into artisanal and industrial);
SpMI (marine/industrial): landings per species for a higher number of marine species (only for industrial fleet);
None = there was no collection system in that state for those years and the Ministry of Fisheries and Aquaculture (MPA) published bulletins where a general estimation procedure was used to estimate total landings for each state, but no landing data per species was estimated. However, we were able to compile detailed data from local initiatives, including some supported by MPA.

Commercial landings

Commercial landings include those originating from both large-scale (industrial) and small-scale (artisanal) fleets. The boundary between these two fleets is blurry and traditionally 20 GT (gross tonnage) was considered as a cut-off point in Brazil. Landings were reported for each of these two fleet types from 1978 onwards. Thus, landings for previous years were split among them based on the proportion observed for 1978-1980 for each species. We also considered, based on the literature, information on the beginning of industrial operation for each species or group of species in each state. Most artisanal fisheries were reconstructed until 1950 unless we found any reference stating otherwise.

Landings have been reported in official national bulletins by common name. The correspondence between common and scientific names was established preferentially based on local references. Otherwise, we used information from an updated version of the national database of common names available for Brazilian marine fishes (Freire and Pauly 2005) and from the list of names provided by Freire and Carvalho Filho (2009). Our team included experts from most of the coastal states in an attempt to improve this correspondence. Unfortunately, some invited local experts were unable to contribute on time for this initiative and were not included here. With the help of local experts, local references or even interviews with fishers or data collectors, we were able to split landings reported for each common name among all species associated with that name. Whenever this was not possible, landings were attributed to a genus or a family. Based on more recent detailed landings data (species-specific), we managed to split earlier catches for “pescada” (weakfishes) or “vermelhos” (lutjanids), e.g., among species. However, this was not possible for all generic names or all states.

In the 1980s, two bulletins were released annually (with the exception of 1980). In these bulletins, there were records with zero landings (0), but with a monetary values associated with each entry. In those cases, each zero landings entry was replaced by 0.5 t. Thus, the following criteria were adopted in order to guarantee that even small landings show up in the reconstructed database:

0 and – (in two bulletins): replaced by 0.5 t;

0 and 0 (in two bulletins): replaced by 1 t;

10 and 0 (in two bulletins): 10 was retained.

For those years when only landings for major species were reported, we estimated landings for the other species based on their proportion in relation to total landings for the closest three years (and these were later subtracted from miscellaneous fishes). Whenever landings were missing for one or more years in the middle of the historical catches, they were estimated based on linear trends.

Values for the period 1990-1994 in the national bulletins were repeated and represent the average for the previous four years (1986-1989; CEPENE 1995a), except for some more important species that used to be studied by Permanent Study Groups (GPEs – *Grupos Permanentes de Estudos*): sardine, lobster, southern red snapper, etc. Those repeated values were replaced by estimated values using linear trends that also considered posterior values (1995 onwards). For 1995, two bulletins were released: one in March/1997 and other in May/1997. In the first bulletin, artisanal and industrial landings were combined in some cases and attributed to the wrong category in other cases. Landings were properly split between artisanal and industrial fleets in the second bulletin. Thus, we used the second bulletin here. For more recent years (2008-2010), due to the absence of catch data by species for each state, we used different data sources to complete the time series. For the state of Ceará, José Augusto Aragão provided a database for 2008 (artisanal and industrial). For Rio Grande do Norte, José Airton Vasconcelos contributed with a catch database for 2008-2009 (artisanal and industrial) and for 2010 (only industrial). For Sergipe, Mário Thomé de Souza (Universidade Federal de Sergipe/PMPDP) provided an unpublished manuscript with catch data for 2010. For the state of Rio Grande do Sul, there were local bulletins with recorded catch data from 1997 to 2010 (IBAMA/CEPERG 2011). For the remaining states, linear trends (when evident), average means or repeated values were used depending on each case.

As two co-authors are responsible for the collection system of catch data for the state of São Paulo, a different procedure was possible. Landing information was available for the years 1944 (Vieira *et al.* 1945), 1959-1965 (Braga *et al.* 1966), and 1969-2010 (ProPesq institutional database; Ávila-da-Silva *et al.* 1999). All fishery-related information available after 1959 was obtained through dockside interviews with fishers, using census, and through records from fishing industries. There has been no interruption in the data collection system in the state of São Paulo since 1969. Information gathered is forwarded to the federal government for the composition of the national fisheries statistics. Landing reconstruction for the period with missing values (1950-1958 and 1966-1968) was performed by species applying LOESS (locally weighted scatterplot smoothing) models or linear cubic spline interpolation on the available time series. Landings for 1950-1958 were estimated considering data for 1944 and 1959-1965, while landings for 1966-1968 were estimated based on 1959-1965 data and from 1969 onwards. Categorization into artisanal and industrial fleets was done considering fishing fleets and species caught.

For the state of Rio de Janeiro, most of the data previously estimated by Freire and Oliveira (2007) were used, but some corrections/inclusions were made. Landings data for each species for the period 2008-2010 were reconstructed through information provided in spreadsheets by municipality of coastal towns such as Angra dos Reis and Cabo Frio (unpublished data), spreadsheets and reports produced by the Fishing Institute of the state of Rio de Janeiro (FIPERJ/MPA/UFRJ undated; FIPERJ/Prefeitura Municipal de Cabo Frio, undated) and of São Paulo (PMAP/Instituto de Pesca de São Paulo, undated) and spreadsheets from monitoring programs of some oil and gas activities (Petrobrás, undated). For missing values of some species in the middle of the time series, linear interpolation was used as for other states.

Recreational catches

Brazil has no system of data collection for recreational catches. The reconstruction included catches from competitive events, based on an updated and extended version of the database compiled by Freire (2005). The second component of the reconstruction refers to daily recreational activities. We used data on human population size available in Table 1.4 from IBGE (2010) and fitted a Verhulst logistic equation in the format provided by Miranda and Lima (2010) to estimate the population each year. For each state, we used information from local studies that provided the percentage of recreational fishers interviewed that had a fishing license to extrapolate the total number of recreational fishers based on the number of licenses issued in 2009. For those states were such a ratio was not available, we considered a national mean value of 13.5% (Freire *et al.* 2012). To adjust the number of recreational fishers, we considered only the proportion of fishers fishing in marine waters (estuarine, coastal, and offshore). This information was collected in a questionnaire answered online in 2009, which is required to obtain the license. Finally, we estimated total catch multiplying the number of fishers by the number of days fishing and by the mean daily catch for each fisher. The latter information came from local studies, when available, or from neighboring states: Bahia (K.M.F. Freire, unpublished data), Espírito Santo (Chiappani 2006), Rio de Janeiro (Couto 2011), São Paulo and Paraná (Atlantic & Fishing Project), Santa Catarina (Schork *et al.* 2010) and Rio Grande do Sul (Peres and Klippel 2005).

The start of the time series was originally defined as the year when the first fishing club was established in each state (Freire *et al.* 2014a). Here, we followed the same procedure, but additionally assumed that in 1950 at least 20% of the catches observed in the year of establishment of the fishing club were caught by recreational fishers. Catches were then linearly interpolated in between those years. For those states where clubs were established very early (1950-1955), the same linear trend was used to estimate catches for the first five-six years (to avoid unrealistic sharp increase in catches).

For the sates of Rio de Janeiro, São Paulo and Paraná, the procedure was more complex as there was detailed information for different sectors. Thus, we used the proportion among A, B and C license categories (as described in Freire *et al.* 2012), where category A includes only coastal, shore-based fishers, and B and C categories operating from boats. Category C includes spearfishing. Catches were estimated separately for these categories (A and B/C) considering different number of fishing days per year and CPUE (g/fisher·day) and finally they were added to represent total recreational catch for each state.

Subsistence catches

The estimate of subsistence catches was obtained through the following two equations:

Total consumption (fresh and marine) = number of registered fishers * fecundity rate (+2) * consumption per capita

and;

Subsistence catch (marine) = total consumption * proportion of non-commercial 'fish' acquisition

where (+2) represents a fisher and his wife/partner.

The number of officially registered fishers by coastal state was obtained from statistical yearbooks (IBGE, 1955-1982), IBAMA (2003, 2004a, 2004b, 2005, 2007a), SEAP/IBAMA/PROZEE (2005), and MPA (2012, undated). In order to estimate the number of persons by family, the fecundity rate by region and decade was used (Table 3, IBGE 2010a). A *per capita* consumption rate (kg·person^{-1}·year^{-1}) by state was used, based on the 'fish' consumption typical of each region (Anon. 1963; Wiefels *et al.* 2005; Silva and Dias 2010; Sartori and Amancio 2012). 'Fish' includes fishes, crustaceans and molluscs.

Table 3. Official reported fecundity rate by decade and region used as anchor points to estimate the average number of persons in Brazilian fisher families.

	Total fecundity rate						
	1950	1960	1970	1980	1991	2000	2010
Brazil	6.2	6.3	5.8	4.4	2.9	2.4	1.9
North	8.0	8.6	8.2	6.5	4.2	3.2	2.5
Northeast	7.5	7.4	7.5	6.1	3.8	2.7	2.1
Southeast	5.5	6.3	4.6	3.5	2.4	2.1	1.7
South	5.7	5.9	5.4	3.6	2.5	2.2	1.8

The Household Budget Survey (*Pesquisa de Orçamentos Familiares*–POF) conducted by the Brazilian Institute of Geography and Statistics (IBGE) gathered data about the average *per capita* monetary and non-monetary acquisition of food in Brazil (IBGE 1967, 2004, 2010b). This survey provided information on how the population acquires food (including fishes) and also its average consumption, highlighting the profile of living conditions of the Brazilian population by region from the analysis of their household budgets. The POF survey was conducted in urban and rural areas including coastal regions and consumption of both marine and freshwater fishes were available separately (IBGE 2010b). Thus, we estimated subsistence catches by Brazilian State using the percentage of marine fish obtained by fishers through non-monetary acquisition. The non-monetary acquisition is that made without payment, being obtained through donation, removal from the business or own production (IBGE 2010b). Anchor points and a linear trend were used to estimate missing catches for the period of this study (1950-2010).

The taxonomic breakdown of subsistence catches was obtained by applying the reported proportions of each marine fish species (or group of species) (IBGE 2010b) over the estimated subsistence catches obtained. Reported common names were then associated with the lowest taxon possible.

Discards

The methodology for calculating discards was done separately for the artisanal and industrial sectors due to varying gear and discarding practices employed.

<u>Industrial sector</u>

In order to estimate discards for the industrial sector, we first allocated landings to gear type. Data on gear are available for Rio Grande do Sul from 1975 to 1994 in Haimovici *et al.* (1998) and from 1997 to 2010 in CEPERG (2011). Here, we assume this breakdown by gear is representative of the entire industrial sector because:

1. The fisheries and gears used in the southeastern and the southern regions are "quite similar" (FAO 2014); and
2. For the 1950-2010 time period, the southern and southeastern regions account for 93% of all industrial landings (and the southern region alone accounts for 53%).

Historically, in Rio Grande do Sul, the major industrial gears used since 1950 were trawlers (otter and pair) and purse seine. In the mid-1970s, the pelagic longline was introduced and the industrial fleet began using handline to target white grouper on the upper slope of the continental shelf. In later years, handline was replaced by vertical longline and bottom longline. Around 1990, there was a significant shift in the gear distribution as new gear types entered the industrial fleet. These new gears were the double-rig trawl, bottom gillnet, and pole and line gears (Haimovici *et al.* 1998).

For the time period between 1950 and 1974, we used landings by gear type from 1975 to 1979 (the earliest gear-based landings available). However, we excluded pelagic longline and demersal 'line' gears (handline, vertical longline, and bottom longline), as these gears were introduced in the mid-1970s. Thus, gear-based landings were adjusted to reflect this difference (Table 4). For the time period from 1975 to 1994, landing data from Haimovici *et al.* (1998) were used. Data from CEPERG (2011) were used for the year 2010 and earlier volumes for the years 1997–2009. We excluded landings from trap gears (targeting deep sea red crab) because there were only landings from 1988 to 1992 and this amount was very small. We applied the gear breakdown percentages for each year to total landings, e.g., the sum of reported and unreported industrial landings. Discard rates for the relevant gears were compiled from various sources (Table 5). These rates were then applied to the gear-specific total catch as reconstructed previously.

Table 4. Industrial gear breakdown (%) by time period for the south and southeastern regions of Brazil.

Time period	Otter trawl	Pair trawl	Double-rig trawl	Seine	Gillnet	Longline	Live bait[1]	Line[2]
1950–1974	28.0	58.9	0.0	13.1	0.0	0.0	0.0	0.0
1975–1989	23.0	65.6	0.0	7.3	0.0	3.7	0.0	0.4
1990–2010	4.1	30.6	8.0	7.1	34.6	1.6	13.7	0.3

[1] Rod and live bait gear targeting skipjack; [2] Line gear includes bottom longline, vertical longline, and handline used on the upper slope of the continental shelf by the industrial fleet

Table 5. Discard rate by industrial gears for the south and southeastern regions of Brazil.

Gear	Discard per total catch (%)[3]	Discard per landings, as applied (%)[4]	Source
Otter trawl	38.0	61.0	Haimovici and Mendonça (1996)[5]
Pair trawl	38.0	61.0	Haimovici and Mendonça (1996)[5]
Double-rig trawl	38.0	62.0	Haimovici and Mendonça (1996)[5]
Seine	1.0	1.0	Kelleher (2005)[6]
Gillnet	44.0	77.0	Kelleher (2005)[7]
Longline[1]	15.0	18.0	Kelleher (2005)[8]
Live bait	1.0	1.0	Kelleher (2005)[6]
Line[2]	5.3	6.0	Kelleher (2005)[9]

[1]Pelagic; [2]Includes handline, vertical longline, and bottom longline; [3]Discards as a percentage of total catch, not landings; [4]Discards as a percentage of landings; rate applied to landings; [5]Discard rate was obtained by averaging two discard rates for double-rig trawl with comparable landings: 52.3% for flatfish-directed and 23.9% for shrimp-directed; [6]Due to lack of data, Kelleher assumed 1% as a conservative estimate; [7]Discard rate for multi-gear (gillnet and hook) for the South of Brazil from Haimovici (1996); [8]Due to lack of data on longline discard rate for Brazil, rates for Uruguay (9.1%) and Argentina (20.5%) were averaged; [9]Discard rate came from data on the North (artisanal lines and demersal lines, gillnet, and traps) based on Isaac and Braga (1999).

Table 6. Derived taxonomic composition of industrial discards for south and southeastern Brazil based on Haimovici and Palacios (1981).

Scientific name	Common name	Discard (%)
Cynoscion guatucupa	Striped weakfish	10
Umbrina canosai	Argentine croaker	23
Macrodon atricauda[1]	Southern king weakfish	2
Prionotus spp.	Searobins	2
Paralonchurus brasiliensis	Banded croaker	3
Trichiurus lepturus	Largehead hairtail	10
Marine fishes nei	Marine fishes	4
Batoidea	Skates and rays	23
Mustelus schmitti	Narrownose smooth-hound	8
Mustelus spp.	Smoothhounds	8
Squalus spp.	Dogfishes	8

Macrodon ancylodon in the original source.

To disaggregate the estimated discards among relevant taxa, we used data from four research trawlers (two otter and two pair trawlers) fishing off Rio Grande do Sul in 1978 and 1979 (Haimovici and Palacios 1981), but pooled the data from the four trawlers to yield an average taxonomic composition (Table 6). For the state of Sergipe, the estimation of discards was based on Decken (1986) and only for the industrial fleet while operating in that state (until 1994).

Artisanal sector

Artisanal discards were estimated based on a year-long study of artisanal discards per gear in Paraná (southern region of Brazil). The local 'canoes' in the study were made either from single carved tree trunk or molded fiberglass, and averaged 10 m long with a small engine (Carniel and Krul 2012). Artisanal boats in the northern region were also described as "small, wooden boats, motor-powered or sail-propelled" (Isaac 1998). Although differences between the regions exist, we assumed that this study was representative for all of Brazil. Future investigations should improve this assumption and consider local differences. We believe this study is relatively conservative, as the 'canoes' are considered the "least technical and least powerful fishing effort on the inner shelf" (Carniel and Krul 2012).

The most common gear employed is driftnetting and shrimp fishing. Discards while driftnetting averaged 5 $kg \cdot boat^{-1} \cdot day^{-1}$, whereas shrimp fishing produced an average of 100 $kg \cdot boat^{-1} \cdot day^{-1}$ (Carniel and Krul 2012). Additionally, it was stated that in the sample area, shrimp fishing accounted for 64% of the total discards (Carniel and Krul 2012). We adjusted this proportion to the variation in discard rates of each gear, and derived the proportion of boats engaged in driftnetting (92%) and shrimp fishing (8%). We applied this breakdown to the total number of artisanal boats in Brazil.

Data on the number of boats in Brazil were generally available by region. In the southern region, which includes the states of Paraná, Santa Catarina, and Rio Grande do Sul, the artisanal sector was comprised of 23,000 small and medium capacity vessels (FAO 2001). For all states north of Rio de Janeiro, in addition to a very small portion of the northern coast of Rio de Janeiro state, Diegues *et al.* (2006) reported the number of artisanal boats at 37,812. The only gap in boat data was for the states of São Paulo and the majority of Rio de Janeiro. For this area, we took the proportion of artisanal catches in 2001 for Rio de Janeiro and São Paulo (i.e., 26,215 t) to all other coastal states (i.e., 258,590 t), which was just over 10%. We used catches in 2001 because all of the sources on boat data were dated around 2001. We lowered this estimate to 9% in order to account for the small portion of coast already considered, resulting in an estimate of 5,473 artisanal boats in Rio de Janeiro and São Paulo, and thus 66,285 artisanal boats for all of Brazil. We assumed that artisanal fishing takes place on 200 days per year.

As stated earlier, we assumed that 92% of these boats are engaged in driftnetting and the other 8% in shrimp fishing. We applied the discard rate of 100 $kg \cdot boat^{-1} \cdot day^{-1}$ for shrimp fishing boats and 5 $kg \cdot boat^{-1} \cdot day^{-1}$ for driftnet boats (Carniel and Krul 2012). Thus, the total discards for artisanal fishing in 2001 came to 169,095 t. Total artisanal catches in 2001 were 284,805 t, which gave us a discard rate of approximately 59% of landings. We assumed this rate was constant for all other years. Additionally, annual discards were disaggregated by state using artisanal catch.

Table 7. Taxonomic composition of artisanal discards in northern and northeastern Brazil (based on Araújo Júnior *et al.* 2005).

Scientific name	Common name	Discards (%)
Clupeidae	Sardine	24.00
Siluriformes	Catfish	9.00
Ariidae	Sea catfishes	2.60
Mugil spp.	Mullets	4.00
Anableps anableps	Largescale foureyes	1.00
Belonidae	Needlefishes	0.03
Carangidae	Jacks and pompanos	0.10
Genyatremus luteus	Torroto grunt	0.40
Macrodon ancylodon	King weakfish	21.00
Micropogonias furnieri	Whitemouth croaker	28.00
Sciaenidae	Drums or croakers	0.10
Chaetodipterus faber	Atlantic spadefish	0.20
Symphurus spp.	Duskycheek tonguefish	1.00
Achirus spp.	Soles	1.00
Tetraodontidae	Puffers	8.00

Table 8. Taxonomic composition of artisanal discards in south and southeastern Brazil (based on Coelho *et al.* 1986b).

Species name	Common name	Discards (%)
Paralonchurus brasiliensis	Banded croaker	17
Isopisthus parvipinnis	Bigtooth corvina	6
Stellifer brasiliensis	Drums or croakers	6
Stellifer rastrifer	Stardrums	18
Menticirrhus spp.	Kingcroakers	3
Micropogonias furnieri	Whitemouth croaker	2
Macrodon atricauda[1]	Southern king weakfish	2
Nebris microps	Smalleye croaker	3
Cynoscion virescens	Green weakfish	7
Ariidae	Sea catfishes	13
Pellona harroweri	American coastal pellona	4
Selene setapinnis	Atlantic moonfish	3
Symphurus spp.	Duskycheek tonguefish	7
Porichthys porosissimus	Porichthys porosissimus	4
Trichiurus lepturus	Largehead hairtail	6

[1] *Macrodon ancylodon* in the original source.

The taxonomic disaggregation of artisanal discards varies by region. For the northern and northeastern regions, we used a study on by-catch composition for the state of Maranhão (Araújo Júnior *et al.* 2005). Sixteen species were recorded in the by-catch. Although the weights by species were not given, the numbers of individuals along with average length were available. Using the length-weight relationships available in FishBase (Froese and Pauly 2014), we derived an average weight for each taxon. The proportions of taxa discarded by weight were then derived (Table 7). Some changes in the scientific names were proposed to accommodate variations among states.

For the southern and southeastern regions, we used a study on discarded fish in the artisanal shrimp fishery of São Paulo (Coelho *et al.* 1986a). As in the previous study, the number of fish and average length of fish were given, and were converted as above. Only the 15 major taxa were taken from this study (Table 8).

Ornamental (aquarium) fishery

No catch data originating from ornamental fisheries were included in the reconstructed database. Most of the Brazilian aquarium catches originate from inland waters, even though there has been an increasing interest in marine fishes from the 2000s onwards (Gasparini *et al.* 2005).

Results and discussion

Correspondence between common and scientific names

Two levels of loss in taxonomic resolution along the data reporting chain were observed: from the state level to the national level, and from the national to the international level (FishStat/FAO). One example of this loss could be observed for Elasmobranchii in the state of Rio Grande do Sul where in 2003 four species reported in the local bulletin IBAMA/CEPERG (2004) were eliminated from the national landing bulletins and added to the category "cações" (sharks): "cação-gato", "cação-moro", cação-vaca", and "machote". On the other hand, 10 tonnes originally reported for "cação-moro" (*Isurus oxyrinchus*) in the state bulletin were attributed to "cação-azul" (*Prionace glauca*) in the national bulletin (IBAMA 2004b). Another example was observed for mullets in the state of Sergipe. The state bulletin reported that 12.7 t of "curimã" (*Mugil liza*) and 63.5 t of "tainha" (*Mugil* spp.) in 2001 (CEPENE 2002). However, the national bulletin reported 76.0 t for "tainha" only (*Mugil* spp.), resulting in a taxonomic loss. For some taxonomic groups such as sharks, these problems are prominent in a regional scale. For instance, 24 common names were attributed to six biological shark species in the southern Bahia (Previero *et al.* 2013).

The detailed analysis of catch records indicated that there were also change in names throughout the period studied: "agulhão-azul" changed to "agulhão-negro" (*Makaira nigricans*), "coró" to "roncador" (*Conodon nobilis*), "paru" to "saberé" and back to "paru" (*Chaetodipterus faber*), etc. This was a pattern observed for most states. Besides, some names are associated to different species depending on the state. One of the most important cases is *Ocyurus chrysurus*. It represents one of the most important fish resources in the state of Espírito Santo, where is known as "cioba". However, this name is used for *Lutjanus analis* in all other states in Brazil. In some cases, catches reported as "cioba" may include *Lutjanus jocu* together with *L. analis* (K.M.F. Freire, personal observation in the state of Rio Grande do Norte). Another interesting case is "roncador" and "corcoroca", which were used as synonymous in the 1980s in Santa Catarina (IBGE 1985a). However, these names represent two different species according to the analysis of more recent bulletins for that state (UNIVALI, 2011): *Conodon nobilis* and *Haemulon aurolineatum*, respectively. The problems associated with correspondence between common and scientific names had been already pointed out in the 1950s and was later assessed by Freire and Pauly (2005).

In Rio de Janeiro, we noticed that landings for "sororoca", "serra" and "sarda" are confusing. Rocha & Costa (1999) established the following correspondence: *Sarda sarda* = "serra", *Scomberomorus brasiliensis* = "sororoca" or "sarda", and *Scomberomorus regalis* = "sororoca". But the complimentary character of the historical data in fact indicates that "sororoca" and "serra" should be the same species (*Scomberomorus brasiliensis* with some inclusions of *S. regalis*) and "sarda" would be a different species (*Sarda sarda*). "Xerelete" and "garacimbora" correspond to different species in different states. We decided to use, for Rio de Janeiro, "xerelete" as *Caranx latus*, according to Vianna (2009), as it was a name also used for São Paulo. Thus, garacimbora and its variations (garaximbora, graçainha, guaracimbora) were associated to *Caranx crysos*. However, this tentative correspondence should be revisited.

Problems with common names in the landing statistics do not occur only with fishes, but with crustaceans and mollusks as well. One of the most common problem with crustaceans in observed for shrimps, as names such as "camarão pequeno" (small), "médio" (medium) and "grande" (large) are used, or even worse, only "camarões" (shrimps). We tried to establish the correspondence of catches with each species based on local references, consulting local experts or using Dias-Neto (2011). For mollusks, we noticed that *Lucina pectinata* ("lambreta") does not even show up in the ASFIS/FAO list, even though it is caught in the state of Bahia and more recently in the state of Sergipe. The genus *Lucina* was included in the ASFIS/FAO list, but no common name was associated with it. Thus, catches for that species cannot be included in the FishStat/FAO database as it uses only common names.

In order to better compare the national and the international database, we decided to analyze in detail data reported in FishStatJ and IBAMA (2007b), the latest national bulletin with detailed information of catches by species for each state (Table 9). A total of 135 species (or group of species) are reported in FishStatJ against 160 in the national bulletin (IBAMA 2007b). Thus, this represents the second type of taxonomic loss in the process of reporting catch statistics in Brazil (and probably in other countries as well). Catches for "biquara" (*Haemulon plumieri*) and "cambuba" (*Haemulon flavolineatum*) were added and reported as "Grunts, sweetlips nei" in FishStatJ. Catches reported for "cioba" in IBAMA (2007b), representing *Lutjanus analis* and *Ocyurus chrysurus* were reported as "Snappers, jobfishes nei (Lutjanidae)" in FishStatJ. This is an unnecessary loss of taxonomic resolution as in most of Brazil (with the exception of the state of Espírito Santo) "cioba" refers to *Lutjanus analis*, which is not included in FishStatJ. Additionally, catches may also be attributed to the wrong FAO common name. For example, catches for "abrótea" should be reported in FishStatJ as *Urophycis* nei, but it was reported as Brazilian codling (*U. brasiliensis*) even though other species are also caught in Brazilian waters, such as *U. cirrata*, according to IBAMA (2007b), and possibly referring to *U. mystacea*, according to this study. Additionally, divergence in total landings reported for both databases are observed. See for example the case of blue marlin and Atlantic white marlin, where catches reported in IBAMA (2007b) are smaller. Detailed catches for shrimps and mollusks were lost in the global database. For some important resources such as lobsters, errors were also detected

Analysis of commercial catches

For those states where we had access to published or unpublished local databases (such as Rio Grande do Norte, Santa Catarina and Rio Grande do Sul), we noticed that local databases report landings in kilograms and national bulletins round landings to the closest tonne or half tonne. Data in FishStatJ are rounded to the closest tonne.

One important feature of the time series of catch statistics for Brazil is the interruption of the collection system in the earlier 1990s. Thus, as previously mentioned, values representing an arithmetic mean of catches for each species in 1986-1989 were repeated for 1990-1994, except for some species studied by Permanent Working Groups. These repeated values were replaced here by values estimated using linear trends considering values for later years. In other cases, there were local data available for that period and repeated values were replaced. In addition, two bulletins were published in 1995. The first one was released in March 1997 and values for artisanal and industrial fisheries were added or exchanged. The volume later released (in May 1997) contained separated reasonable values for artisanal and industrial fisheries. The second important feature is the interruption of the data collection system from 2008 onwards and estimates are based only on models (MPA 2012, undated).

Table 9. Comparison between common names and associated catches (tonnes) reported in FishStatJ/FAO database and IBAMA (2007b) for 2007. The order of common names as cited in IBAMA (2007b) may be slightly altered to place associated names together such as "albacora" and "atum" (true tunas nei). Differences between FishStatJ and IBAMA (2007b) are listed in bold. Asterisk indicates catch in number and do not add to total catch in tonnes.

Commn name – ASFIS/FishStatJ	Common name - IBAMA	Scientific name ASFIS	Scientific name - IBAMA	Comments	Catch FishStatJ	Catch IBAMA
Brazilian codling	Abrótea	*Urophycis brasiliensis*	*Urophycis brasiliensis* *U. cirrata*	Should be *Urophycis* nei but was reported as Brazilian codling (*U. brasiliensis*) in FishStatJ. This is incorrect as at least one other species is also caught (*U. mystacea*). The occurrence of U. cirrata in Brazil, although reported in our database, is not widely accepted.	6,579	6,579
Ballyhoo halfbeak	Agulha	*Hemiramphus brasiliensis*	*Hyporhamphus unifasciatus* *Hemiramphus brasiliensis*	Should be Hemiramphidae (Halfbeaks nei in FishStatJ) and not ballyhoo halfbeak (*Hemiramphus brasiliensis*).	2,081	2,080.5
Marlins, sailfishes,etc. nei	Agulhão	*Istiophoridae*	*Tetrapturus albidus* *Tetrapturus pfluegeri* *Makaira nigricans* *Istiophorus albicans*	May include catches for Belonidae, if originating from artisanal fishery. Total catches for all billfish species in FishStatJ (461.0 t) are smaller than in IBAMA, 2007 (760.5 t).	3	429
Atlantic white marlin	Agulhão-branco	*Tetrapturus albidus*	*Tetrapturus albidus*	Should be *Kajikia albida*.	70	142.5
Blue marlin	Agulhão-negro	*Makaira nigricans*	*Makaira nigricans*	None.	261	101.5
Atlantic sailfish	Agulhão-vela	*Istiophorus albicans*	*Istiophorus albicans*	Consider replacing by *Istiophorus platypterus* according to Eschmeyer (CofF vers. May. 2014), following Collette *et al.* (2006).	123	87.5
Longbill spearfish	–	*Tetrapturus pfluegeri*	–	This species is referred separately as "agulhão verde", but there was no catch value reported for this species. Thus, it is not known where this value was obtained from.	4	–
–	Albacora Atum	–	*Thunnus obesus* *Thunnus alalunga* *Thunnus albacores* *Thunnus atlanticus*	Correspondence of catches between FishStatJ and IBAMA (2007) should be checked. Total catches for all tuna species in FishStatJ (7,830 t) are smaller than in IBAMA, 2007 (10,529.5 t).	–	603.5 734.5 (1,338.0)
Bigeye tuna	Albacora-bandolim	*Thunnus obesus*	*Thunnus obesus*	Reported only as "Atum-cachorra" in the list of correspondence between common and scientific names in IBAMA (2007b).	1,595	1,596.5
Albacore	Albacora-branca	*Thunnus alalunga*	*Thunnus alalunga*	Difference in catches may be attributed to splitting catches reported under the generic name "Albacora" or "Atum".	534	591
Yellowfin tuna	Albacora-lage	*Thunnus albacares*	*Thunnus albacares*	Difference in catches may be attributed to splitting catches reported under the generic name "Albacora" or "Atum".	5,468	6,702
Blackfin tuna	Albacorinha	*Thunnus atlanticus*	*Thunnus atlanticus*	Difference in catches may be attributed to splitting catches reported under the generic name "Albacora" or "Atum".	233	302
Tuna-like fishes nei	–	*Scombroidei*	–	Check correspondence.	22	–
–	Bonito	–	*Auxis thazard* *Katsuwonus pelamis* *Euthynnus alletteratus*	Catches should be reported for each species separately.	–	1,696
Frigate and bullet tunas	Bonito cachorro	*Auxis thazard* *A. rochei*	*Auxis thazard*	National bulletin should report as *Auxis* spp.	203	1,212
Skipjack tuna	Bonito listrado	*Katsuwonus pelamis*	*Katsuwonus pelamis*	Difference in catches should be investigated.	24,191	24,390
Little tunny(=Atl. black skipj)	Bonito pintado	*Euthynnus alletteratus*	*Euthynnus alletteratus*	None	397	396.5
Amberjacks nei	Arabaiana, Olho-de-boi	*Seriola* spp.	*Seriola lalandi* *Seriola dumerili* *Seriola fasciata* *Elagatis bipinnulata*	"Olho-de-boi" should be Greater amberjack and "arabaiana" may include *Elagatis bipinnulata* together with *Seriola* spp.	904	729.5 174.0 (903.5)
Yellowtail amberjack	Olhete, Arabaiana, Olho-de-boi	*Seriola lalandi*	*Seriola lalandi* *Seriola dumerili*	These catches should be added to "Amberjacks nei". However, some effort should be put into separating them from *Elagatis bipinnulata*.	279	278.5
Jacks, crevalles nei	Aracimbora Garacimbora Guaraximbora Xaréu Xerelete, xarelete	*Caranx* spp.	*Caranx latus* *Caranx latus* *Caranx latus* *Caranx hippos* *Caranx latus*	Difference in catches should be checked. Taxonomic details are lost from national to global databases but they should be kept. Data for "guaraximbora" may have been entered twice in FishStatJ as it corresponds to the difference between FishStatJ and IBAMA.	6,971	74.0 98.5 132.5 2,391.5 4,142.0 (6,838.5)

Table 9 continued. Comparison between common names and associated catches (tonnes) reported in FishStatJ/FAO database and IBAMA (2007b) for 2007. The order of common names as cited in IBAMA (2007b) may be slightly altered to place associated names together such as "albacora" and "atum" (true tunas nei). Differences between FishStatJ and IBAMA (2007b) are listed in bold. Asterisk indicates catch in number and do not add to total catch in tonnes.

Commn name – ASFIS/FishStatJ	Common name - IBAMA	Scientific name ASFIS	Scientific name - IBAMA	Comments	Catch FishStatJ	Catch IBAMA
Carangids nei	Canguira Guaivira Timbira Galo, galo-de-penacho, peixe galo	Carangidae	– *Oligoplites* spp. *Oligoplites* spp. *Selene* spp.	"Guaivira" and "timbira" should be associated to Leatherjackets nei. "Galo" should be in a separate category for *Selene* spp., but there is no name in FishStatJ.	1,203	459.5 1,104.5 739.5 2,529.0 (4,832.5)
Atlantic moonfish	Galo de profundidade	*Selene setapinnis*	–	Should be *Zenopsis conchifer* (Silvery John dory in ASFIS) as it was reported only for Santa Catarina (UNIVALI/CCTMar 2008).	23	23
Blue runner	Garajuba	*Caranx crysos*	*Caranx crysos*	None.	1,384	1,383.5
Bigeye scad	Garapau	*Selar crumenophthalmus*	*Selar crumenophthalmus*	May also include *Chloroscombrus chrysurus*.	262	262
Rough scad	Xixarro, chicharro	*Trachurus lathami*	*Trachurus lathami*	May include other carangids: *Decapterus* spp., *Selar crumenophthalmus.*	2,291	2,291
Pompanos nei	Pampo	*Trachinotus spp.*	*Trachinotus* spp.	None.	152	152
Lane snapper	Ariacó	*Lutjanus synagris*	*Lutjanus synagris*	None.	2,036	2,036
Rays, stingrays, mantas Nei	Arraia	Rajiformes	None	Several species reported and detailed information lost in the national and global database.	5,279	5,279
Brazilian groupers nei	Badejo, sirigado Sirigado	*Mycteroperca* spp.	*Mycteroperca* spp.	Do not include two data entries: "badejo" and "sirigado".	1,781	1,238.5 542.5 (1,781.0)
Groupers nei	Cherne Mero	*Epinephelus* spp.	*Epinephelus* spp., *E. flavolimbatus,* *Polyprion americanus,* *Epinephelus itajara*	National bulletin should differentiate between "cherne" (*Epinephelus* spp.) and "cherne poveiro" (*Polyprion americanus*). *P. americanus* is listed as wreckfish in ASFIS/FAO, but there is no catch associated to this common name in FishStatJ. *Epinephelus flavolimbatus* changed to *Hyporthodus flavolimbatus*.	833	479.0 353.5 (832.5)
Sea catfishes nei	Bagre Bandeirado Cambeua Cangatá Gurijuba Jurupiranga	Ariidae	Ariidae	Probably includes more common names. Taxonomic details should not be lost: Bagre = Ariidae Bandeirado = *Bagre* spp. Cambeua = *Notarius grandicassis* (Thomas sea catfish) Cangatá = *Aspistor quadriscutis* (Bressou sea catfish) Gurijuba = *Sciades parkeri* Jurupiranga = *Amphiarius rugispinis* (Softhead sea catfish) Uritinga = *Sciades proops*	28,781	7,445.5 4,193.0 1,098.0 3,730.0 6,344.5 294.0 5,676.0 (28,781.0)
Puffers nei	Baiacu	Tetraodontidae	*Lagocephalus laevigatus*	Tetraodontidae	409	409
Tilefishes nei	Batata	Branchiostegidae	*Caulolatilus chrysops* *Lopholatilus villarii*	Branchiostegidae in ASFIS, but this should be Malacanthidae. However, this family is not in the ASFIS list. It includes two species: *Lopholatilus villarii* and *Caulolatilus chrysops*.	924	923.5
Cobia	Beijupirá	*Rachycentron canadum*	*Rachycentron canadum*	None.	635	634.5
Barracudas nei	Bicuda	*Sphyraena* spp.	*Sphyraena tome*	The national bulletin should use *Sphyraena* spp. as in FishStatJ.	375	375
Grunts, sweetlips nei	Biquara Cambuba Corcoroca Sapuruna Xira Golosa Peixe-pedra	Haemulidae	*Haemulon plumieri* *H. flavolineatum* *Haemulon spp., Pomadasys spp., Osthopristis ruber* – – *Genyatremus luteus* *Genyatremus luteus*	Even though IBAMA (2007) reports the species *Haemulon plumieri* as "biquara", it may include other species. Haemulidae is the best option if taxonomic details are not provided. *Genyatremus luteus* = "golosa" or "peixe-pedra", and it should be reported as Torroto grunt in FishStatJ.	3,792	1,286.5 20.5 259.5 208.5 4.0 0.5 2,012.5 (3,792.0)

Table 9 continued. Comparison between common names and associated catches (tonnes) reported in FishStatJ/FAO database and IBAMA (2007b) for 2007. The order of common names as cited in IBAMA (2007b) may be slightly altered to place associated names together such as "albacora" and "atum" (true tunas nei). Differences between FishStatJ and IBAMA (2007b) are listed in bold. Asterisk indicates catch in number and do not add to total catch in tonnes.

Commn name – ASFIS/FishStatJ	Common name - IBAMA	Scientific name ASFIS	Scientific name - IBAMA	Comments	Catch FishStatJ	Catch IBAMA
Parrotfishes nei	Budião	Scaridae	*Sparisoma* spp.	National bulletin should change to Scaridae.	135	135
Atlantic searobins	Cabra	*Prionotus* spp.	*Prionotus* spp.	None.	5,246	5,246
Sharks, rays, skates, etc. nei	Cação Tubarão	Elasmobranchii	Lamnidae, Carcharhinidae, Triakidae, Odontaspididae, Sphyrnidae, Alopiidae, Squalidae	National bulletin should provide catches by species. Taxonomic resolution should not be lost in the global database; thus, Various sharks nei should be used, which corresponds to Selachimorpha (Pleurotremata).	7,862	7,698.0 4,256.0 (11,954.0)
Bigeye thresher	–	*Alopias superciliosus*	–	Interesting case of resolution loss in the national bulletin and resolution recuperated in the global database.	69	–
Blue shark	–	*Prionace glauca*	–	Interesting case of resolution loss in the national bulletin and resolution recuperated in the global database.	2,318	–
Requiem sharks nei	–	Carcharhinidae	–	Interesting case of resolution loss in the national bulletin and resolution recuperated in the global database.	1,414	–
Scalloped hammerhead	–	*Sphyrna lewini*	–	Interesting case of resolution loss in the national bulletin and resolution recuperated in the global database. Other species are also caught, so it should be changed to *Sphyrna* spp. (Hammerhead sharks nei).	120	–
Shortfin mako	–	*Isurus oxyrinchus*	–	Interesting case of resolution loss in the national bulletin and resolution recuperated in the global database.	157	–
Tiger shark	–	*Galeocerdo cuvier*	–	Interesting case of resolution loss in the national bulletin and resolution recuperated in the global database.	6	–
Oceanic whitetip shark	–	*Carcharhinus longimanus*	–	None.	14	–
Tarpon	Camurupim Pirapema	*Megalops atlanticus*	*Tarpon atlanticus* –	National bulletin should report as *Megalops atlanticus*.	636	342.0 293.5 (635.5)
Snappers, jobfishes nei	Caranha (vermelho) Carapitanga Cioba Dentão Vermelho	Lutjanidae	*Lutjanus* spp., *Rhomboplites aurorubens* – *Lutjanus analis* and *Ocyurus chrysurus* *Lutjanus jocu* –	Carapitanga is not listed in IBAMA (2007); cioba = *Ocyurus chrysurus* only in Espírito Santo and *Lutjanus analis* in all other states; dentão = *Lutjanus jocu*. These specific details should not be lost in the global database.	7,875	154.0 297.5 3,025.5 1,168.0 3,229.5 (7,874.5)
Irish mojarra	Carapeba	*Diapterus auratus*	*Diapterus auratus, Eugerres brasilianus, Eucinostomus argenteus*	Should be "Mojarras, etc. nei" in the global database (Gerreidae).	2,074	2,074
Argentine croaker	Castanha	*Umbrina canosai*	*Umbrina canosai*	May include *U. coroides* in some states.	11,164	11,163.5
Largehead hairtail	Catana Espada	*Trichiurus lepturus*	– *Trichiurus lepturus*	"Catana" should be in the list of common names in IBAMA (2007b). Only "Espada" was included.	3,390	31 3,359 (3,390)
King mackerel Wahoo	Cavala	*Scomberomorus cavalla* *Acanthocybium solandri*	*Scomberomorus cavalla, Acanthocybium solandri*	Not sure how catches for "cavala" in IBAMA (2007b) were split between two species (wahoo and king mackerel) in FishStatJ. Besides, they do not add to 3,706 t reported.	33 76 (109)	3,706
Serra Spanish mackerel	Serra Sororoca	*Scomberomorus brasiliensis*	– *Scomberomorus brasiliensis*	Includes a smaller proportion of *S. regalis* (Cero). Difference between FishStatJ and IBAMA should be better investigated.	563	7,887 445 (8,832)
Atlantic bonito	Sarda (serra)	*Sarda sarda*	*Scomberomorus maculatus, Sarda sarda*	National bulletin should correct to *Scomberomorus brasiliensis, S. regalis* and *Sarda sarda*, and provide catches separately for each species.	334	334
Chub mackerel	Cavalinha	*Scomber japonicus*	*Scomber japonicus*	Should be *Scomber colias*.	8,262	8,262

Table 9 continued. Comparison between common names and associated catches (tonnes) reported in FishStatJ/FAO database and IBAMA (2007b) for 2007. The order of common names as cited in IBAMA (2007b) may be slightly altered to place associated names together such as "albacora" and "atum" (true tunas nei). Differences between FishStatJ and IBAMA (2007b) are listed in bold. Asterisk indicates catch in number and do not add to total catch in tonnes.

Commn name – ASFIS/FishStatJ	Common name - IBAMA	Scientific name ASFIS	Scientific name - IBAMA	Comments	Catch FishStatJ	Catch IBAMA
Red grouper	Garoupa	*Epinephelus morio*	Epinephelus spp.	Includes other species besides *E. morio*. Thus, Groupers nei should be used.	863	862.5
Argentine conger Cusk-eels, brotulas nei	Congro Congro-rosa	*Conger orbignyanus* Ophidiidae	– *Genypterus brasiliensis*	Could be *Conger orbignianus, Genypterus brasiliensis* or *Ophichthus* spp. More detail should be provided in national bulletin and taxonomic detail improved in FishStatJ, using *Genypterus brasiliensis* for "congro rosa".	12 626	12 626
Barred grunt	Coró Roncador	*Conodon nobilis*	*Conodon nobilis* *Conodon nobilis*	None.	161	51.0 109.5 (160.5)
Whitemouth croaker	Corvina Cururuca	*Micropogonias furnieri*	*Micropogonias furnieri* –	None.	44,374	44,053.5 320.0 (44,373.5)
Common dolphinfish	Dourado	*Coryphaena hippurus*	*Coryphaena hippurus*	Includes a small proportion of *Coryphaena equisetis* (Pompano dolphinfish), but these two species are never reported separately in landing ports.	8,873	8,872.5
Guyana dolphin	–	*Sotalia guianensis*	–	Not reported in the national bulletin (IBAMA, 2007).	114*	–
Bluefish	Enchova	*Pomatomus saltatrix*	*Pomatomus saltatrix*	None.	3,926	3,926
–	Enguia	–	–	Not located in FishStatJ or in the taxonomic list provided in IMABA (2007b).	–	35
Swordfish	Espadarte	*Xiphias gladius*	*Xiphias gladius*	Unknown reasons for difference in catches.	4,243	4,201.5
Jamaica weakfish	Goete	*Cynoscion jamaicensis*	*Cynoscion jamaicensis*	Should be analyzed carefully as it may be *Macrodon ancylodon* in northeastern Brazil. Thus, correct correspondence should be established before national compilation.	2,776	2,776
Yellowtail snapper	Guaiúba	*Ocyurus chrysurus*	*Ocyurus chrysurus*	None.	3,717	3,717
Bastard halibuts nei	Linguado	*Paralichthys* spp.	Paralichthyidae Bothidae Achiridae	Should be changed to Pleuronectiformes (Flatfishes nei) in FishStatJ.	2,566	2,566
Argentine hake	Merluza	*Merluccius hubbsi*	–	Even though the correspondence is correct, one should consider recent catches reported for *Macruronus magellanicus* (merluza de cola) and *Dissostichus eleginoides* (merluza negra) in southern and southeastern Brazil, respectively.	2,075	2,074.5
Moray	Mororó	Muraenidae	–	Should be *Gymnothorax* spp., but there is no common name in ASFIS.	–	51.5
Argentinian sandperch	Namorado	*Pseudopercis semifasciata*	*Pseudopercis* spp.	Two species occur in Brazil: *P. semifasciata* and *P. numida*. It should be *Pseudopercis* spp. (but there is no common name in ASFIS for it). Catches for northeastern Brazil should be better investigated.	687	687.5
Bigeyes nei	Olho de cão	*Priacanthus* spp.	*Priacanthus* spp.	According to Froese & Pauly (2014), there is only one species in Brazil: *Priacanthus arenatus*. However, there is some possibility that *Heteropriacanthus cruentatus* is also caught. This should be better investigated.	398	398
Shorthead drum	Oveva	*Larimus breviceps*	*Larimus breviceps*	None.	254	254
Bocon toadfish	Pacamão	*Amphicthys cryptocentrus*	*Amphicthys cryptocentrus*	Should be corrected to *Amphichthys cryptocentrus*. It may include *Batrachoides surinamensis*. In this case, it should be changed to Batrachoididae (Toadfishes, etc. nei) until proper identification of both species and separate catch reporting.	311	310.5
Atlantic bumper	Palombeta Pilombeta	*Chloroscombrus chysurus*	*Chloroscombrus chysurus* –	Catches reported as "pilombeta" (Engraulidae) originating from Sergipe are also included with "palometa" (Carangidae). However, it should not as it may include *Anchovia clupeoides, Anchoviella lepidentostole, Anchoviella vaillanti,* and *Lycengraulis grossidens*. As this is a resource locally important for Sergipe, it should be reported separately. However, as it includes four species (not easy to identify on site), their catches should be added to Anchovies, etc. nei.	2,868	2,759.5 108.0 (2,867.5)

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Commn name – ASFIS/FishStatJ	Common name - IBAMA	Scientific name ASFIS	Scientific name - IBAMA	Comments	Catch FishStatJ	Catch IBAMA
Kingcroakers nei	Papa-terra, betara	*Menticirrhus* spp.	*Menticirrhus* spp.	Only two species occur in Brazil: *Menticirrhus littoralis* and *M. americanus.*	1,948	1,948
–	Papuda	–	–	Was not included in the taxonomic list of IBAMA (2007b). We were not able to associate with any scientific name, even though there are catches reported for the states of Pernambuco and Bahia (0.5 to 51.5 $t \cdot year^{-1}$).	–	–
Southern red snapper	Pargo, pargo verdadeiro	*Lutjanus purpureus*	*Lutjanus purpureus*	None.	3,694	3,694
Red porgy	Pargo-rosa	*Pagrus pagrus*	*Pagrus pagrus*	May include *Lutjanus vivanus* or *Pagrus pagrus,* depending on the state. This should be clarified when obtaining and reporting data locally.	2,051	2,050.5
Spadefishes nei	Parú, enchada, sabara	Ephippidae	*Chaetodipterus faber*	Could include also *Pomacanthus paru* (Pomacanthidae). To be investigated on site (easy distinction).	198	198
Silversides(=Sand smelts) nei	Peixe-rei	Atherinidae	*Atherinella brasiliensis, Odontesthes argentinensis*	Includes *Odontesthes argentinensis, Atherinella brasiliensis* (Atherinopsidae) and possibly *Elagatis bipinnulata*. Data should be properly reported and checked before national compilation.	1	0.5
Blackfin goosefish	Peixe-sapo, diabo, pescador, rape	*Lophius gastrophysus*	*Lophius gastrophysus*	None.	2,508	2,508
Flyingfishes nei	Peixe-voador, voador holandês	Exocoetidae	*Cheilopogon cyanopterus, Hirundichthys affinis*	May include 'falso voador' (*Dactylopterus volitans*). This should be investigated locally.	1,256	1,255.5
–	Voador	–	–	Should be included in Flyingfishes nei.	–	37
Triggerfishes, durgons nei	Peroá, cangulo, peixe porco	Balistidae	*Balistes capriscus, Aluterus monoceros*	*Aluterus monoceros* belongs to the family Monacanthidae. Thus, the name used in FishStatJ should consider this. Besides, *Balistes vetula* is also caught in Brazilian waters and has been replacing *B. capriscus* in landings off Espírito Santo after its commercial extinction (Freitas-Netto and Madeira di Beneditto 2010).	3,787	3,787
Weakfishes nei	Pescada Pescadinha-gó	*Cynoscion* spp.	*Cynoscion* spp., *Macrodon* spp. –	Catches for each genus should be reported separately and more detail for catches of Cynoscion could be provided based on local data. Pescadinha-gó is caught in northern Brazil, where it is associated to *Macrodon ancylodon*. Thus, its catches should be added to King weakfish.	19,239	7,987.5 11,252.0 (19,239.5)
Acoupa weakfish	Pescada-amarela	*Cynoscion acoupa*	*Cynoscion acoupa*	None.	20,411	20,411
Smooth weakfish	Pescada-branca	*Cynoscion leiarchus*	*Cynoscion leiarchus*	May include three other species besides *C. leiarchus: C. guatucuba, C. jamaicensis,* and *C. virescens*.	692	692
Green weakfish	Pescada-cambuçu, pescada-cururuca	*Cynoscion virescens*	*Cynoscion virescens*	"Pescada cambuçu" may include *Macrodon* spp.	331	330.5
Stripped weakfish	Pescada-olhuda	*Cynoscion guatucupa*	*Cynoscion guatucupa*	Note some bulletins are still using *C. striatus*, which was considered nomen dubium by Figueiredo (1992).	3,050	3,049.5
King weakfish	Pescadinha-real	*Macrodon ancylodon*	*Macrodon ancylodon*	Should consider *M. atricauda* for southeastern/southern Brazil and *M. ancylodon* otherwise (Carvalho-Filho et al. 2010).	3,651	3,651
Sea chubs nei	Pirajica	Kyphosidae	*Kyphosus* spp.	Should be changed to *Kyphosus* sea chubs nei in FishStatJ.	44	44
Tripletail	Prejereba	*Lobotes surinamensis*	*Lobotes surinamensis*	None.	14	13.5
Snooks(=Robalos) nei	Robalo	*Centropomus spp.*	*Centropomus* spp.	None.	3,947	3,946.5
Goatfishes, red mullets nei	Saramonete Trilha	Mullidae	*Pseudupeneus maculatus*	Catches are associated to three species: *Mulloidichthys martinicus, Mullus argentinae,* and *Pseudupeneus maculatus.* Thus, national bulletin should properly attribute catches to the correct species based on the state catches originate from.	1,388	322.5 1,065.5 (1,388.0)
Atlantic thread herring	Sardinha-lage, sardinha-chata, sardinha-bandeira	*Opisthonema oglinum*	*Opisthonema oglinum*	None.	13,252	13,252

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Brazilian sardinella	Sardinha verdadeira, maromba	*Sardinella brasiliensis*	*Sardinella brasiliensis*	None.	55,940	55,939.5
Scaled sardines	Sardinha cascuda	*Harengula* spp.	–	None.	226	226
Anchovies, etc. nei	Manjuba	Engraulidae	Engraulidae Engraulidae	None.	4,374	4,374
Clupeoids nei	Arenque Sardinha	Clupeoidei	–	Detailed catches should be provided by species.	18,190	48.5 18,141.5 (18,190.0)
Brazilian menhaden	Savelha	*Brevoortia aurea*	*Brevoortia* spp.	Catches are associated to *Brevoortia aurea* (Brazilian menhaden) and B. *pectinata (*Argentine menhaden). Besides, it may include *Harengula* spp. Thus, Brazilian menhaden should be replaced by Menhaden (*Brevoortia* spp.), however, no such category exists in FishStatJ.	1,078	1,077.5
Mullets nei	Tainha, saúna, curimã, cacetão, tainhota	Mugilidae	*Mugil* spp.	There is no common name associated to *Mugil* spp. in ASFIS, but it should be included to accommodate catches associated to "tainha". Each local name is associated to different species and the proper correspondence should be established in each state.	21,864	21,864
Brazilian flathead	Tira-vira	*Percophis brasiliensis*	*Percophis brasiliensis*	None.	941	940.5
Bigtooth corvina	Tortinha	*Isopisthus parvipinnis*	*Isopisthus parvipinnis*	None.	16	16
Marine fishes nei	Uricica Cabeçudo Outros peixes	– – Osteichthyes	– – –	Taxonomic resolution lost. More effort should be put to increase resolution. Uricica should be included in Sea catfishes nei. Cabeçudo = *Stellifer* spp. (no name in ASFIS).	60,823	1,200 231 38,587.5
Marine crabs nei	Caranguejo-uçá	Brachyura	*Ucides cordatus*	Should be reported in FishStatJ as Swamp ghost crab (according to ASFIS). It may consider a more adequate name for the species "mangrove crab" (Palomares and Pauly 2014).	6,818	6,818
Southwest Atlantic red crab	Caranguejo-de-profundidade, caranguejo-real, caranguejo-vermelho	*Chaceon notialis*	*Chaceon ramosae* *Chaceon notialis*	Should be reported in FishStatJ as *Chaceon geryons* nei (*Chaceon* spp.) as two species are caught.	1	0.5
Dana swimcrab	Siri	*Callinectes danae*	Callinectes spp.	Should be reported as "Callinectes swimcrabs nei" in FishStatJ (*Callinectes* spp.) as it includes several species.	1,461	1,461
Penaeid shrimps nei	Camarão Camarão-barba-ruça, camarão-serrinha, ferrinho Camarão branco Camarão-santana	Penaeidae	*Penaeidae* *Artemesia longinaris* *Litopenaeus schmitti* *Pleoticus muelleri*	Species should be separated, as taxonomic resolution was lost: Camarão-barba-ruça = *Artemesia longinaris* should be reported as Argentine stiletto shrimp in FishStatJ. Camarão branco = *Litopenaeus schmitti* = Southern white shrimp Camarão-santana = *Pleoticus muelleri* = Argentine red shrimp	12,244	3,861.5 3,467.0 4,099.5 816.0 (12,244.0)
Redspotted shrimp	Camarão-rosa	*Penaeus brasiliensis*	*Farfantepenaeus brasiliensis* *Farfantepenaeus paulensis* *Farfantepenaeus subtilis*	Should be "Penaeus shrimps nei" (*Penaeus* spp.). AFSIS does not consider *Farfantepenaeus* as a valid genus.	8,238	8,237.5
Atlantic seabob	Camarão-sete-barbas	*Xiphopenaeus kroyeri*	*Xiphopenaeus kroyeri*	None.	15,060	15,060
Caribbean spiny lobster	Lagosta	*Panulirus argus*	*Panulirus argus,* *P. laevicauda, P. echinatus*	Taxonomic resolution should be kept considering three species ("lagosta-vermelha", "lagosta-verde", and "lagosta-pintada").	6,479	6,478.5
Marine crustaceans nei	Aratu Guaiamum Lagostim Outros crustáceos	– – – –	*Goniopsis cruentata* *Cardisoma guanhumim* *Metanephrops rubellus* –	Note that purple mangrove crab = *Goniopsis cruentata* in SealifeBase but to *Goniopsis pelii* in ASFIS. *G. pelii* may be a synonym for *G. cruentata*. It should be changed to *Cardisoma guanhumi* = Giant land crab. Taxonomic resolution lost for "lagostim". Effort should be put to clarify, as it may also include *Scyllarides brasiliensis*.	484	57.5 89.5 156.5 180.5 (484.0)

Table 9 continued. Comparison between common names and associated catches (tonnes) reported in FishStatJ/FAO database and IBAMA (2007b) for 2007. The order of common names as cited in IBAMA (2007b) may be slightly altered to place associated names together such as "albacora" and "atum" (true tunas nei). Differences between FishStatJ and IBAMA (2007b) are listed in bold. Asterisk indicates catch in number and do not add to total catch in tonnes.

Commn name – ASFIS/FishStatJ	Common name - IBAMA	Scientific name ASFIS	Scientific name - IBAMA	Comments	Catch FishStatJ	Catch IBAMA
Common squids nei	Calamar-argentino Lula	Loligo spp.	Ommastrephidae Loliginidae	More taxonomic detail needed and change in FishStatJ is required.	2,160	344 1,816 (2,160)
Octopuses, etc. nei	Polvo	Octopodidae	*Octopus* spp. *Eledone* spp.	None.	2,195	2,195
Cupped oysters nei	Ostra	*Crassostrea* spp.	*Crassostrea* spp.	None.	800	800
Triangular tivela	Maçunim	*Tivela mactroides*	*Tivela mactroides*	None.	1,820	1,819.5
Sea mussels nei	Berbigão Sarnambi Sururu	Mytilidae	*Anomalocardia brasiliensis* *Mytilus falcata,* *Mytella* spp.	"Berbigão" and "sarnambi" = West Indian pointed venus (Veneridae) = *Anomalocardia brasiliana* "Sururu" = *Mytella charruana* and *Mytella guyanensis* (Mytilidae)	1,348	58.0 0.5 1,289.5 (1,348.0)
Marine molluscs nei	Mexilhão Vieira Outros moluscos	Mollusca	*Perna perna* *Euvola ziczac* –	Mexilhão = *Perna perna* = South American rock mussel Vieira = *Euvola ziczac* = Zigzag scallop	5,389	5,361.5 1 25.5 (5,388.0)
Total	-	-	-	None.	539,966.5	539,967.0

Another feature of the national bulletins is data reporting for the states of Rio de Janeiro and Guanabara separately until 1975. These two states were united in 1975, but in the 1976 bulletin, data were presented twice under the state of Rio de Janeiro. One of them was considered as originating from Guanabara and both data were added and reported for Rio de Janeiro in our database. It is also important to point out that São Paulo was considered as part of the southern region until 1968 and changed to southeastern Brazil from 1969 onwards. It is worth to consider this change when analyzing historical trends among regions. IBGE is responsible for defining the regional division of Brazil. In 1950, Brazil was divided into north, northeast, east, center-west, and south (the latter including the state of São Paulo). In 1970, São Paulo was considered part of the southeastern region. The current regional division (north, northeast, center-west, southeast, and south) with all their states was established in 1990.

It is mentioned in IBGE (1976, 1977) that shrimp and its by-catch caught by foreign fleets from Barbados, United States of America, Suriname and Trinidad & Tobago based on fishing agreements were not included in those bulletins. These catches are not included in this version of our database either. Catches included in those bulletins only accounted for 75-80% of the total landings (main species). We hope that our procedure of estimation of missing values have been able to raise these percentages to 100%. A source of underestimation of catches is the usage of weight of eviscerated fishes and of crustaceans without the cephalothorax. No attempt was made here to correct this source of underestimation, although FAO data are generally corrected to whole wet weight.

Some of the most important detailed observations about data reported for some groups will be discussed in the next sections. This will not be an exhaustive analysis but rather intended to point out some discrepancies to make the reader aware of their existence. Thus, they should compare national bulletins with local bulletins whenever possible.

Fisheries for "mero" (*Epinephelus itajara*) were banned in 2002 in Brazilian waters (Legal instrument: Portaria IBAMA N. 121, September 20, 2002). However, in all regions of Brazil, there are states where there are still catches officially reported for "mero" (0.5 to 1,130 t per year according to the state). Either this represents one more case of ill-defined relation between common name and scientific name, or threatened species continue to be openly exploited. Gerhardinger *et al.* (2006) had already called attention to the fact that non-consideration of local names in the legal instrument does not allow for its proper implementation in some regions.

A similar case was observed for billfishes. IN SEAP N. 12 (14 July 2005) obliges fishers to return to the sea all white and blue marlin (*Kajikia albida* and *Makaira nigricans*) that are still alive after being caught, and their commercialization is prohibited. However, for the years 2006 and 2007, we noticed that 0.5-69 t of Atlantic white marlin were reported annually for the states of Rio Grande do Norte, Paraíba, Espírito Santo, Rio de Janeiro and Paraná, and 1.5 to 103.5 t of blue marlin in the first three states. This may represent only landings of dead specimens or non-compliance to a legal instrument. Catches for sailfish (*Istiophorus platypterus*) may contain a small proportion of *Tetrapturus pfluegeri* (K.M.F. Freire, personal observation).

Some examples of over-reporting were observed in the national bulletins. In the state of Rio Grande do Sul, for example, 1,841.5 t of "bonito-listrado" were reported for the industrial fleet in 2007 by IBAMA (2007b), but only 0.28 t were reported as "bonito" (which includes *Auxis thazard*, *Euthynnus alleteratus*, *Katsuwonus pelamis*) in the state bulletin (IBAMA/CEPERG 2008). "Bonito-listrado" was not even mentioned separately. In this volume it was also mentioned that there was no record of live bait fishery for "bonitos" in Rio Grande do Sul in 2007. Additionally, some boats could be landing in the state of Santa Catarina. Catches for shrimps reported in Valentini *et al.* (1991) for the state of Rio de Janeiro are much smaller than officially reported. In some years, catches reported for Rio de Janeiro alone in the national bulletins were close to the total catch for all southeastern-southern regions in Valentini *et al.* (1991). Also artisanal (1978) and industrial (1979) catches for shrimps were mixed, resulting in unrealistic high values. Thus, we decided to keep the data reported in the Valentini *et al.* (1991) data.

Problems with landings originating from fresh and salt water were also observed. The first bulletins presented data from both water bodies together until the early 1970s. From 1978 onwards, they were properly separated (Freire and Oliveira 2007). Mangrove crab (*Ucides cordatus*) was reported in some years as originating from fresh water and from salt water in others in all states. Here we considered all records as marine catches (Palomares and Pauly 2014). For the state of Rio Grande do Sul, in some years catches for marine guitarfishes (Rhinobatidae) were reported together with freshwater species (Antero-Silva 1990), but it was not possible to correct this problem in this version of the database.

The start of lobster fisheries in Brazil is not known precisely. According to Fonteles-Filho (1992), these fisheries began in 1955 (place not mentioned). According to Santos & Freitas (2002), it was in 1950 in the state of Pernambuco. However, lobster was already cited in Schubart (1944) as one of the species caught off Pernambuco and by Oliveira (1946) as consumed in the state of Rio de Janeiro. In 1955, a lobster fishery would have been introduced in the state of Ceará and, in 1961, in the states of Rio Grande do Norte and Espírito Santo. In the 1970s, a lobster fishery started in Piauí, Maranhão, Pará, Amapá, and Bahia. Finally, in the 1980s, it reached the state of Alagoas. Nowadays lobster fisheries are also found in the state of Rio de Janeiro (Tubino *et al.* 2007). In our database, we considered the beginning in 1950. Main species caught are *Panulirus argus* and *P. laevicauda*, but smaller catches are observed for *Panulirus echinatus* and *Scillarides brasiliensis*. The

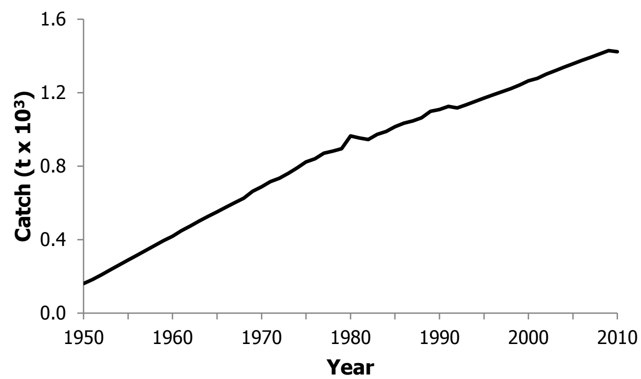

Figure 2. Catches originating from Brazilian recreational marine fisheries (daily activities and competitive events).

highest catches are for *Panulirus argus*, but with the overexploitation of this resource, catches of *P. laevicauda* are increasing, as well as for *P. echinatus* and *S. brasiliensis*. However, in FishStat/Brazil there are only records for Caribbean spiny lobster (*P. argus*) and Tropical spiny lobsters nei (*Panulirus* spp.).

We would like to point out that problems are not restricted to minor landings. *Goniopsis cruentata* ("aratu") is the sixth most important resource exploited in marine waters off the state of Sergipe (northeastern Brazil), with 115 t landed in 2010 and 139 t in 2011 (Souza *et al.* 2012; Souza *et al.* 2013). Additionally, landings are reported from all states between Rio Grande do Norte and Bahia (with the exception of Paraíba). However, landings for this species are not reported in FishStatJ and the species name is not even listed in ASFIS/FAO (2013 or 2014 versions).

Finally, we observed that FishStatJ includes catches for Guyana dolphin, *Sotalia guianensis* (in number). A total of 114 individuals were caught in 2007 (Table 9), followed by 22, 22, and 60 in 2008, 2009 and 2010, respectively. These catches are not reported in IBAMA (2007) even though there was footage obtained by IBAMA and broadcast on July 16, 2007, showing 83 carcasses of this species that were probably used as bait in shark fisheries (Secchi, 2012). However, as the *Sea Around Us* does not consider catches of marine mammals, reptiles or marine plants, we did not include these data in our database.

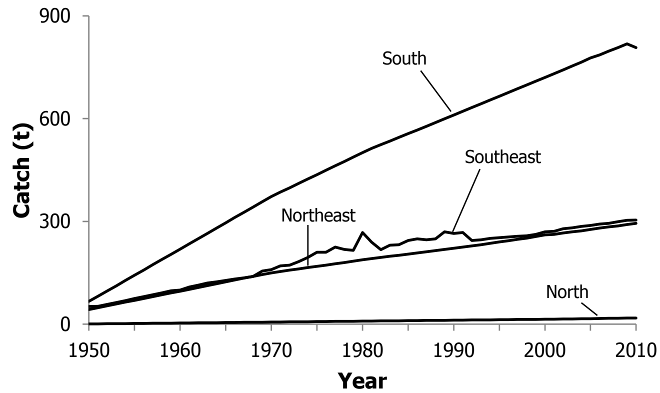

Figure 3. Catches originating from Brazilian recreational marine fisheries by region (daily activities and competitive events).

Recreational catches

Total estimated catches indicated an increase throughout the period analyzed (Figure 2). Freire (2005) indicated that results of competitive events are lost and earlier results are probably missing. Other sources of error include absence of information on the proportion of license holders in relation to total number of anglers. For many states, a national estimate had to be used (Freire *et al.* 2012). The same occurred with estimates of daily catch per recreational fisher, as values for neighbor states were used when local data were unavailable. Catches were higher for the southern region, which are dominated by the state of Santa Catarina. The estimates of CPUE may be overestimated and results should be revisited when more local data become available. Finally, for competitive events, there is no national database with catches originating from those events. Thus, there are many missing values that have been only recently reconstructed in other small projects (see, e.g., Freire *et al.* 2014b). However, for most of the states, this reconstruction is not complete at this point and only results readily available were used.

The national trend was defined mostly by values estimated for southern Brazil (Figure 3). This trend was mainly defined by catches estimated for the state of Santa Catarina where local data available indicated high catch rates for recreational fishers of category B (boat-based) (Schork *et al.* 2010). Catches for the north region were the lowest, even though it is known that many fishing events are promoted in the state of Pará (Frédou *et al.* 2008). However, for that region it is expected that most recreational fisheries are practiced in fresh waters. No detail on catch composition was provided, as this information is not available yet for most states, with some exceptions, such as select regions in the states of Bahia, São Paulo, Santa Catarina, and Rio Grande do Sul (Peres and Klippel 2005; Nascimento 2008; Schork *et al.* 2010; Barcellini *et al.* 2013).

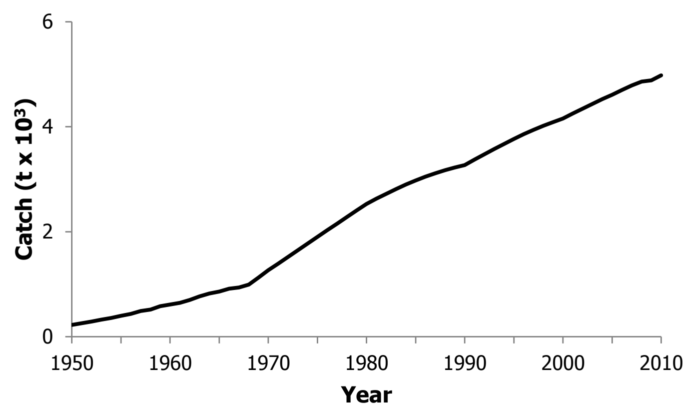

Figure 4. Subsistence catches from "nonmonetary marine fish acquisition" (marine fish catches for food purposes) based on the household budget survey for the Brazilian waters from 1950 to 2010.

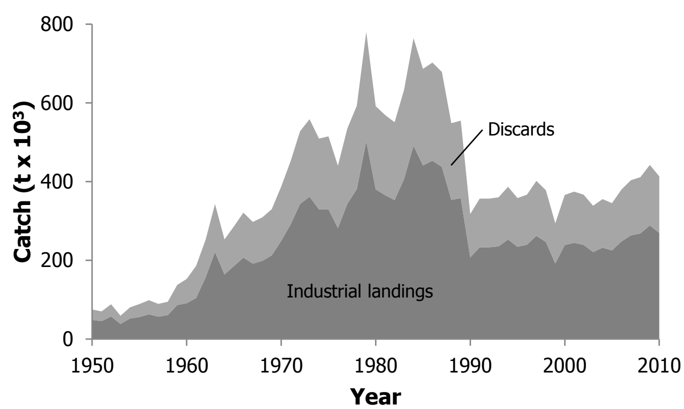

Figure 5. Discards and catches in the industrial sector of Brazilian fisheries.

Subsistence catches

The overall estimated marine subsistence catches, based on the "nonmonetary marine 'fish' acquisition" provided by the Household Budget Survey, reached about 5,000 t in 2010 (Figure 4). The number of registered fishers rose from 11,000 in 1950 to 72,000 in 2010 and the state that presented the higher number of fishers was Pará (in northern Brazil) with about 31%, while Pernambuco (in northeastern Brazil) accounted for less than 2%. The fish consumption rate (kg·capita·year^{-1}) by geographic region also varied considerably: north (38.1), northeast (14.6), southeast (5.4) and south (3.1). The average number of persons by family in fishing communities ranged from 4 to 9 for the study period, which has a direct influence on subsistence fish consumption (including fresh and marine fishes), along with social and economic changes. The most representative 'fish' families consumed were: Sciaenidae (28% of total estimated catches), followed by Mugilidae (27%), Clupeidae (10%) and Ariidae (5%) (Table 10). Elasmobranchs and shrimps also had some participation in the subsistence consumption of marine fish (1% and 12%, respectively). The remaining 17% encompassed different marine fish families.

Table 10. Proportion of the taxonomic breakdown used to estimate catches by species (or group of species) reported as subsistence catches in each region. The Household Budget Survey (POF) reported these values in kg·person^{-1}·year^{-1} (non-monetary acquisition for both urban and rural areas), which were here calculated as a proportion within each region (Based on IBGE 2010b).

Item	North	Northeast	Southeast	South
Anchova fresca (fresh bluefish)	–	–	–	0.023
Bacalhau (codling)	–	0.009	0.008	–
Bagre fresco (fresh marine catfish)	0.060	0.018	–	–
Cação fresco (fresh shark)	–	0.056	–	0.134
Camarão fresco (fresh shrimp)	0.152	0.023	0.041	–
Corvina fresca (fresh whitemouth croaker)	0.007	0.051	0.063	0.046
Merluza em filé congelado (frozen hake fillet)	–	0.004	0.008	–
Merluza em filé fresco (fresh hake fillet)	–	–	0.086	–
Parati fresco (fresh mullet)	0.026	–	–	–
Pescada fresca (fresh weakfish)	0.286	0.140	–	0.090
Pescadinha fresca (fresh king weakfish)	0.006	0.027	0.008	–
Sardinha em conserva (preserved sardine)	0.006	0.023	0.219	0.046
Sardinha fresca (fresh sardine)	0.108	0.037	0.041	0.090
Tainha fresca (fresh mullet)	0.293	0.145	–	0.468
Outros pescados em filé fresco (other fresh fish fillet)	–	0.013	0.019	0.012
Outros pescados frescos (other fresh fish)	0.047	0.455	0.508	0.068
Outros pescados salgados (other salted fish)	0.007	–	–	0.023

Discards

Industrial discards were estimated at 26,000 t·year^{-1} in the early 1950s, increasing nearly tenfold throughout the next few decades to peak in the mid-1980s at approximately 250,000 t·year^{-1} (Figure 5). Thereafter, industrial discards declined to 110,000 t in 1990 and for the next two decades averaged approximately 130,000 t·year^{-1}. This decline was largely driven by a shift in the use of industrial gear types, away from pair- and otter-trawls towards an increase in gillnets (Figure 6). The vast majority of discards were from the south and southeastern regions, namely Paraná, Santa Catarina, Rio Grande do Sul, Espírito Santo, Rio de Janeiro, and São Paulo (Figure 7). The average discard rate from 1950 to 2010 was 55% of industrial landings.

In 1950, artisanal discards amounted to around 42,000 t (Figure 8), increasing throughout the next few decades to peak in 1985 of 172,000 t. Discards dropped in the 1990s, averaging 120,000 t·year^{-1}, but then increased in the 2000s to nearly 170,000 t·year^{-1}. Artisanal discards occurred primarily in the northeastern region (Figure 9). The average discard rate from 1950 to 2010 was 59% of artisanal landings.

Total discards averaged 57% of industrial and artisanal landings. In 1950, around 69,000 t were discarded (Figure 10). Discards increased to over 400,000 t·year^{-1} in the mid-1980s, and then dropped to nearly half this level in the early 1990s. Since then, discards have slowly increased again, reaching almost 310,000 t of discards in 2010.

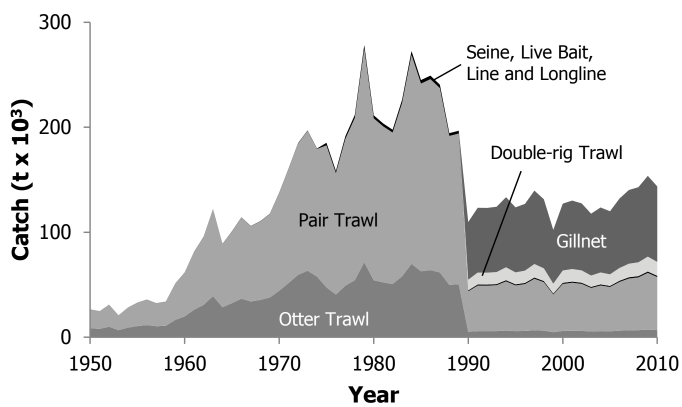

Figure 6. Discards in the Brazilian industrial sector by fishing gear.

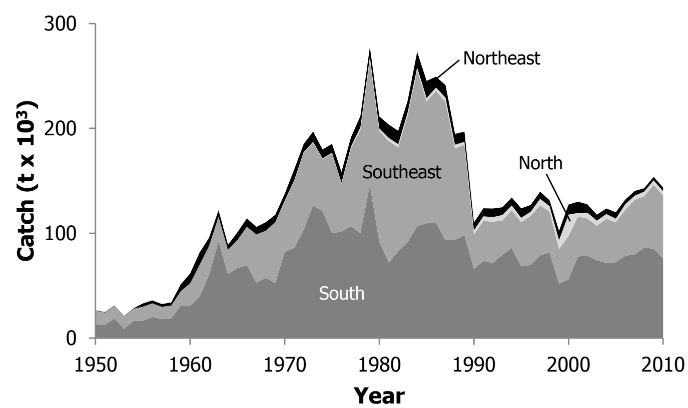

Figure 7. Discards in the Brazilian industrial sector by region.

As seen by the gear breakdown of discards in the industrial sector (Figure 6), the shift in gear in 1990 corresponded to a significant drop in discards. There is a parallel trend in landings, where industrial catch dropped 42% from 1989 to 1990. This resulted from the collapse of the main Brazilian industrial fishery (including sardine), which was followed by targeting previously unexploited species with new gears or expanding existing fisheries. Indeed, many commonly targeted species that were heavily fished by pair and otter trawlers in the 1970s and 1980s are currently heavily exploited (Haimovici 1998; FAO 2011).

We believe that our discard estimates on trawling activities are very conservative. According to Conolly (1992), "*361,000 tonnes per year of accompanying fauna are incidentally by-caught in trawling activities in Brazil, of which over 80% are discarded*". This totals 288,800 tonnes in annual discards. Our calculations suggest that approximately 198,000 tonnes were discarded annually by trawlers from 1950 to 1992, the year of publication of Conolly (1992). The estimate given in 1992 is about 46% higher than what is estimated in the present study.

Additionally, the discard rate used for industrial shrimp trawling activities (23.9% of total catch by the double rig trawl gear) is very low compared to other studies done on shrimp trawling. This discard rate corresponds to 31.4% of reported landings. Comparatively, discard studies done in southeastern Brazil directed at pink shrimp list discard rates at 3130% of landings (Keunecke *et al.* 2007). Discard rates in northern Brazil are also high, with trawling directed at southern brown shrimp producing discards in the order of 500% of landings (Isaac 1998). These preliminary estimates should be revised by local experts with the inclusion of more local information. Important references such as Santos (1996), Tischer & Santos (2001), and Vianna & Almeida (2005) were not included here.

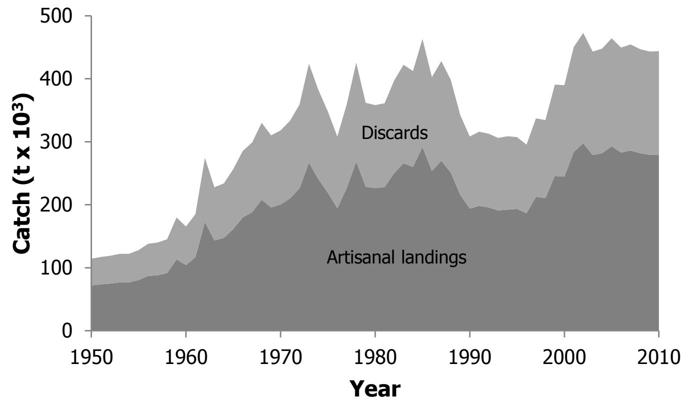

Figure 8. Discards and catches in the artisanal sector of Brazilian fisheries.

Reconstructed total catches (commercial, recreational, subsistence and discards)

Reconstructed total catches, aggregated to national level (but omitting Brazil's oceanic islands), averaged to 192,000 t·year^{-1} in the early 1950s, peaked at 1,181,000 t in 1984, at the height of the industrial fishery for Brazilian 'sardine' (*Sardinella brasiliensis*), and returned to lower levels after this fishery collapsed, averaging 873,000 t·year^{-1} in the late 2000s (Figure 11a). The reconstructed catches were 1.8 times the reported landings baseline determined for Brazil, and dominated by demersal fishes and sardine from the southeastern and southern regions (Figure 11b).

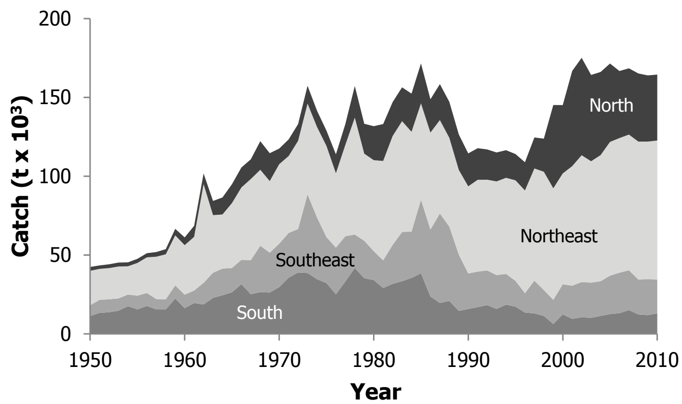

Figure 9. Discards in the artisanal sector by Brazilian region.

Conclusion

It is crucial for Brazil to resume its data collection system for all Brazilian fisheries, considering all local initiatives that continue working in some states of Brazil. Landings data are fundamental to effective fisheries policy and management. In addition, the inclusion of other components of fisheries (recreational, subsistence, and discards), based on local data, is very important to properly access the total impact of fisheries on Brazilian marine ecosystems. The first step was taken in this study, which, however, must be viewed as preliminary. The data should be revised by local experts to improve the local database and hence the national database. Making this resulting database openly available online is a fundamental condition for transparent and accountable public resource use.

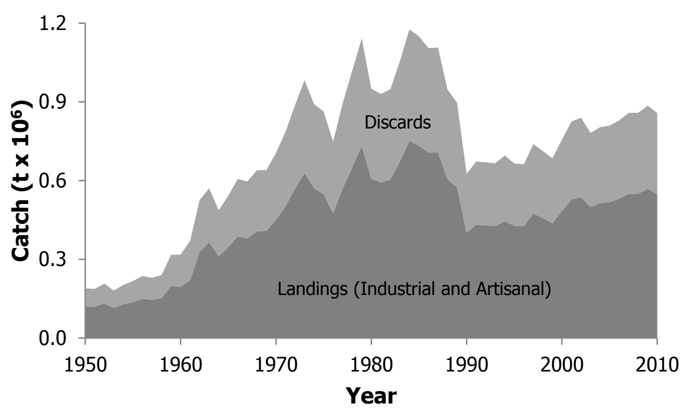

Figure 10. Discards and catches in the industrial and artisanal Brazilian fisheries.

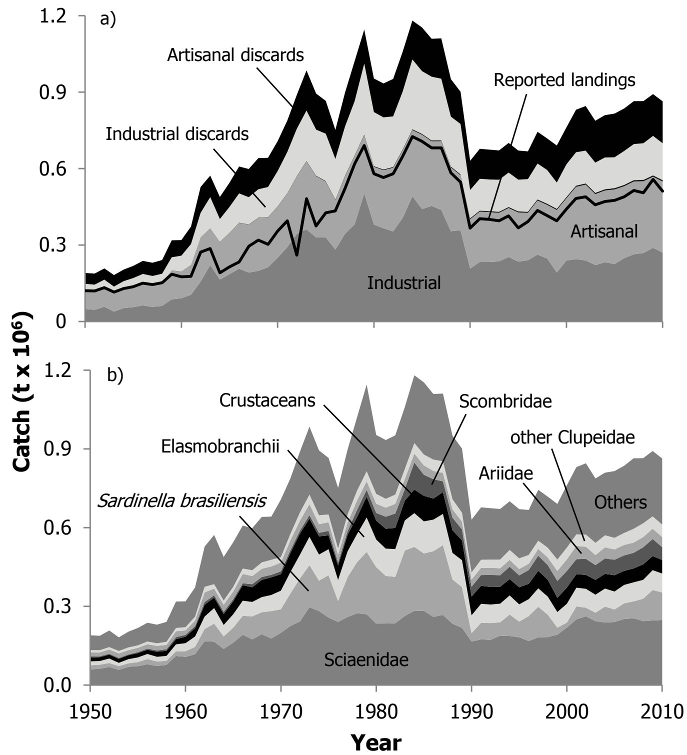

Figure 11. Total reconstructed marine catches of Brazil (1950-2010), a) by sector, including commercial, recreational, and subsistence fisheries, with discards show separately, and the reported landings overlaid as a line graph (note that recreational and subsistence fisheries are too small to be visible); and b) by taxonomic group. 'Others' represents approximately 300 minor taxonomic categories.

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Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector, with discards shown separately, for Brazil mainland, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Recreational	Discards
1950	120,534	190,000	48,700	71,900	230	160	68,900
1951	119,158	188,000	45,600	73,700	260	180	68,200
1952	132,268	208,000	57,400	74,900	290	210	75,200
1953	115,107	182,000	38,400	76,800	320	240	66,100
1954	128,977	203,000	52,200	76,800	360	260	73,700
1955	136,416	218,000	55,900	80,500	400	290	80,600
1956	149,667	238,000	62,800	86,900	440	320	87,100
1957	144,999	230,000	56,900	88,200	490	340	84,400
1958	152,175	241,000	60,800	91,400	520	370	87,700
1959	184,880	318,000	86,400	113,200	580	400	117,800
1960	174,846	319,000	91,000	104,200	610	420	122,900
1961	176,553	372,000	104,400	116,600	640	450	150,100
1962	271,921	528,000	156,400	172,700	700	480	197,500
1963	286,173	572,000	221,000	143,500	770	500	206,300
1964	190,986	488,000	164,200	147,300	820	530	175,500
1965	214,123	544,000	185,400	161,600	860	550	195,900
1966	232,863	608,000	206,900	179,800	920	580	219,700
1967	295,421	598,000	191,600	188,300	940	600	216,700
1968	319,183	641,000	198,500	207,900	990	630	232,800
1969	302,379	642,000	212,500	195,600	1,130	660	232,200
1970	354,045	707,000	249,700	200,500	1,270	690	255,200
1971	394,691	788,000	291,400	210,000	1,390	720	284,200
1972	260,175	890,000	343,300	226,000	1,520	730	318,100
1973	481,946	985,000	361,500	266,700	1,650	760	354,400
1974	374,037	894,000	329,600	240,600	1,770	790	321,400
1975	426,145	866,000	329,700	219,100	1,900	820	314,200
1976	433,381	752,000	281,900	194,500	2,030	840	272,300
1977	521,703	898,000	343,600	226,600	2,150	870	324,600
1978	619,225	1,021,000	380,900	268,400	2,280	880	369,000
1979	689,962	1,145,000	502,500	228,600	2,400	900	410,900
1980	579,119	953,000	380,300	226,500	2,530	960	343,100
1981	564,673	934,000	365,500	228,000	2,630	950	336,800
1982	579,634	952,000	353,200	250,000	2,720	950	344,700
1983	647,866	1,059,000	406,700	265,900	2,810	970	383,000
1984	725,337	1,181,000	491,300	259,900	2,900	990	425,500
1985	707,048	1,154,000	441,100	291,700	2,980	1,010	416,900
1986	681,462	1,109,000	453,100	253,800	3,050	1,030	398,200
1987	681,281	1,111,000	437,400	269,700	3,120	1,050	399,600
1988	582,819	951,000	353,700	250,900	3,170	1,060	341,900
1989	546,655	901,000	357,900	215,700	3,230	1,100	323,500
1990	365,768	630,000	207,300	193,900	3,270	1,110	224,700
1991	403,167	677,000	233,000	198,200	3,370	1,130	241,600
1992	400,640	674,000	233,200	195,800	3,480	1,120	240,600
1993	394,629	671,000	235,500	191,000	3,580	1,130	239,800
1994	414,429	700,000	252,800	192,300	3,670	1,150	250,600
1995	366,853	671,000	234,500	193,300	3,770	1,170	237,800
1996	391,796	667,000	239,800	186,600	3,860	1,190	235,900
1997	435,171	744,000	262,200	212,500	3,940	1,200	264,300
1998	415,011	718,000	246,800	210,700	4,020	1,220	255,300
1999	394,640	690,000	191,900	245,600	4,090	1,240	247,400
2000	440,914	761,000	238,900	244,600	4,160	1,270	272,400
2001	482,316	831,000	244,400	283,800	4,250	1,280	297,000
2002	488,527	845,000	239,300	297,600	4,340	1,300	302,600
2003	457,480	787,000	220,900	278,800	4,440	1,320	282,000
2004	470,292	809,000	232,000	281,900	4,530	1,340	289,700
2005	475,063	816,000	225,300	292,800	4,610	1,360	291,500
2006	489,190	836,000	247,900	282,800	4,700	1,380	298,800
2007	514,328	864,000	263,300	286,100	4,790	1,390	308,700
2008	505,030	865,000	268,300	281,900	4,860	1,410	308,100
2009	557,671	892,000	288,700	279,300	4,880	1,430	317,700
2010	511,311	864,000	269,700	279,400	4,980	1,420	308,100

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxonomic categories, for Brazil mainland, 1950-2010. Others represent approximately 300 additional taxonomic categories.

Year	Sciaenidae	*Sardinella brasiliensis*	Elasmobranchii	Crustacea	Scombridae	Ariidae	Other Clupeidae	Others
1950	59,800	15,900	14,700	15,000	3,370	15,300	9,230	56,600
1951	62,200	15,500	14,000	14,700	3,220	15,100	8,200	54,800
1952	69,000	15,100	17,000	15,000	3,270	16,100	9,170	63,300
1953	58,000	14,200	12,600	15,400	3,160	17,400	9,270	51,800
1954	69,500	13,400	15,800	15,200	2,980	16,200	10,390	59,900
1955	72,100	15,400	17,900	16,500	3,580	16,500	9,400	66,300
1956	79,400	19,900	19,200	16,200	4,330	16,700	10,280	71,400
1957	72,600	17,300	17,900	19,300	4,710	17,500	10,020	70,900
1958	77,100	15,500	18,600	19,400	5,930	16,900	11,550	75,900
1959	111,100	17,600	26,500	19,900	7,750	22,300	12,430	100,800
1960	107,600	21,400	30,800	24,500	7,010	16,900	12,460	98,400
1961	117,500	28,100	39,500	32,300	7,590	21,400	14,550	111,200
1962	167,100	46,500	47,400	45,200	9,800	37,100	21,420	153,100
1963	165,400	68,800	59,400	40,000	8,820	25,100	16,980	187,500
1964	137,900	47,500	43,900	41,700	8,140	27,400	15,680	166,200
1965	161,600	57,300	50,900	49,600	7,630	29,500	17,860	169,900
1966	191,700	72,100	57,800	59,200	7,280	35,600	20,530	163,800
1967	174,200	87,800	55,000	55,800	11,740	31,000	22,240	160,500
1968	193,700	83,900	57,700	65,700	10,850	31,300	24,410	173,300
1969	177,200	104,700	61,500	67,200	9,340	32,000	25,510	164,500
1970	199,200	89,600	71,000	62,700	11,100	33,500	20,550	219,700
1971	225,200	124,100	81,600	72,500	10,680	37,600	24,620	211,500
1972	242,300	163,700	90,900	80,200	11,460	37,900	31,470	231,700
1973	296,700	160,400	107,800	69,200	13,130	42,400	36,110	259,100
1974	282,100	115,800	99,400	69,500	13,290	32,900	34,080	247,000
1975	257,300	161,200	99,300	52,700	17,040	33,100	29,750	215,400
1976	240,600	79,900	80,300	54,900	11,330	30,400	22,610	231,600
1977	259,600	151,900	98,500	63,000	13,890	32,500	31,090	247,400
1978	273,800	194,900	107,400	64,800	27,400	35,700	37,640	279,800
1979	269,800	237,900	130,600	79,400	26,360	33,000	37,880	330,500
1980	234,300	215,100	105,300	72,000	29,250	35,000	37,530	224,900
1981	234,500	181,500	104,000	75,700	46,050	34,400	33,880	223,900
1982	235,700	176,700	106,000	80,600	54,710	36,900	35,320	225,700
1983	263,600	249,200	114,600	75,300	43,920	38,200	38,430	236,000
1984	283,000	243,600	128,800	89,800	102,980	34,100	40,070	258,200
1985	283,000	218,600	122,200	97,500	80,070	35,900	41,170	275,200
1986	259,900	250,300	120,400	80,200	73,680	31,400	43,460	249,800
1987	267,200	266,000	119,100	82,700	41,430	32,500	44,030	258,000
1988	233,900	168,600	101,300	86,500	47,750	32,000	38,410	242,400
1989	218,000	155,600	102,300	75,600	41,580	29,900	34,060	244,400
1990	166,000	31,900	68,000	71,600	37,050	27,900	26,830	201,000
1991	174,000	63,500	72,000	68,900	40,730	27,700	30,700	199,700
1992	172,500	63,600	70,900	66,600	46,040	27,300	31,240	195,800
1993	188,200	51,100	70,800	64,500	44,000	26,500	33,100	192,700
1994	186,900	81,900	72,700	62,400	47,070	26,200	37,720	185,500
1995	182,200	59,500	66,000	65,000	45,280	24,300	40,630	187,600
1996	167,800	95,300	64,200	58,700	52,460	23,900	33,700	171,200
1997	182,000	116,500	70,200	66,600	57,480	26,200	31,260	193,800
1998	182,900	85,200	69,000	64,400	55,580	29,100	37,300	194,600
1999	191,900	27,000	59,600	54,000	64,360	38,200	43,550	211,800
2000	219,200	19,000	71,700	61,800	63,190	44,100	44,940	237,600
2001	250,300	49,500	71,300	51,600	57,120	50,500	44,160	256,200
2002	262,000	32,900	72,100	52,800	61,290	46,100	46,430	271,700
2003	243,700	32,000	68,700	56,500	56,110	38,500	46,600	245,300
2004	238,500	60,500	68,900	55,900	58,700	42,300	45,980	238,700
2005	240,400	47,700	68,500	62,100	59,030	39,200	44,360	254,300
2006	251,700	59,800	70,200	53,400	59,110	39,900	45,600	256,000
2007	254,800	64,200	72,500	52,900	59,490	39,100	52,510	268,700
2008	243,500	85,300	72,100	59,000	65,030	38,900	52,800	248,000
2009	246,100	116,200	75,600	53,700	65,200	39,300	46,860	249,100
2010	248,100	104,700	72,300	51,700	48,510	38,800	47,630	251,900

Oceanic islands of Brazil: catch reconstruction from 1950 to 2010[1]

Esther Divovich and Daniel Pauly

Sea Around Us, Fisheries Centre, University of British Columbia
2202 Main Mall, Vancouver, V6T 1Z4, Canada

e.divovich@fisheries.ubc.ca; d.pauly@fisheries.ubc.ca

Abstract

This catch reconstruction encompasses the waters within the 200 nautical mile Exclusive Economic Zones (EEZ) of three Brazilian oceanic island clusters: Fernando de Noronha (FN), Saint Peter and Saint Paul Archipelago (SPSPA), and Trindade Island and Martim Vaz Archipelago (TMV). Two industrial multi-gear fleets operate within the waters of these islands, one targeting yellowfin tuna, wahoo, and flying fish in the waters of SPSPA, and the other targeting various reef species in the waters of TMV. Artisanal and subsistence catches were also estimated within the waters of Fernando de Noronha, in addition to bait usage and discards at sea for all fleets. Reported data were only present for some years for SPSPA, where total estimated removals were twice as high as reported data from 1950 to 2010. Total removals from all islands increased from approximately 220 t·year^{-1} in the 1950s to a peak of over 770 t in 2004, before slightly declining by 2010. Only 40% of this catch was reported. Actual catches within their EEZs are even higher if one considers effort exerted by domestic and foreign pelagic longlining, which is not considered in the present reconstruction. Oceanic islands are especially vulnerable to overfishing, and this, paired with Brazil's inability to enforce the jurisdiction of these islands, have resulted in illegal fishing by foreign fleets, especially Asian fleets targeting pelagic species.

Introduction

The oceanic islands of Brazil consist of three major clusters remote from the Brazilian mainland, i.e., Fernando de Noronha Island (FN), Saint Peter and Saint Paul Archipelago (SPSPA), and Trindade Island and Martim Vaz Archipelago (TMV). Although each island cluster has a distinct history and is surrounded by its own Exclusive Economic Zone (see Figure 1), the common factors that link them are a fragile ecosystem paired with their importance to various species which rely on these islands as sanctuary, feeding, and spawning ground (Viana *et al.* 2010). While the Brazilian large-marine ecosystem is considered to have a low productivity, areas with seamounts, including all three oceanic islands covered here, are considered 'hot spots' of biodiversity (Campos *et al.* 2006). Yet due to their isolation, any type of exploitation or alteration can easily lead to extinction and threaten insular reef fish, especially as is being done by targeting top predators, which has a "*cascade effect on other species, including endemic species*" (Pinheiro *et al.* 2010). In such fisheries, commercial exploitation can drive the fishery to extinction in just five to ten years (Pinheiro *et al.* 2010).

Given this vulnerability, it is extremely important to obtain and study accurate catch statistics and monitor the biological status of species on the islands. Currently, commercial catches are not reported to FAO with the level of detail necessary to evaluate the total withdrawals from these waters. In this reconstruction, we estimated domestic commercial and artisanal catch, including bait usage and discards at sea using the same methodology as the catch reconstruction for the Brazilian mainland (Freire *et al.* 2014). Additionally, for the island of Fernando de Noronha, which unlike the other two islands has a small population of permanent residents, subsistence catches were calculated.

Fernando de Noronha (FN), Arquipélago de Fernando de Noronha

The Fernando de Noronha complex (03°50'S and 32°25'W) is composed of six islands, with the main island being Fernando de Noronha proper, comprising 91% of the archipelago, along with 14 remote islets (Castro 2010; Dominguez *et al.* 2013). It is located in the South Atlantic ocean, 350 km from Natal, Rio Grande do Norte (Castro 2010), and due to its closer proximity to the Brazilian mainland than the other oceanic islands, its history has been more intertwined with human development.

Discovered in the early 1500s by navigator Amerigo Vespucci, FN was originally a trading post, later a prison, although its beauty and wildlife often attracted many naturalist and researchers, including Charles Darwin in the 19th century (Castro 2010). According to historian Marietta Borges, in the time of the prison, fishing activity was performed by prisoners who had the duty to return from the sea with fish, otherwise they would be punished (IOPE 2010). The prison was disbanded after World War II, when the island served as a strategic military outpost (Anon 1978), and shortly thereafter a population of approximately 1,000 established itself, subsisting on agriculture and fishing.

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In 1988, the archipelago was declared a National Park (Parnamar – FN), which consequently restricted fishing activities, which to this day can only engage in more offshore waters at depths beyond 50 m (Silva Jr 2003). This, along with its transition to a civil government, was the impetus for a dramatic increase in tourism (Souza and Vieira Filho 2011). Currently, Fernando de Noronha has a substantial community of residents and a constant presence of tourists, whereby tourism is the main economic activity, which has generated multiple transformations of island life, including changes to preexisting economic activities such as agriculture, livestock and fisheries (Souza and Vieira Filho 2011).

Saint Peter and Saint Paul Archipelago (SPSPA), Arquipélago de São Pedro e São Paulo

Saint Peter and Saint Paul Archipelago is composed of six major islands, four smaller ones, and various rockheads located close to the equator at 00°55’N, 29°20’W, 533 nautical miles from Natal – RN and 985 miles from Guinea-Bissau, Africa (Viana *et al.* 2010). Due to its strategic location in the middle of the Atlantic Ocean, it is a key component in the life cycle of various migratory species (fish, crustaceans, and birds) that use this region as a sanctuary for food, spawning grounds, and shelter (Viana *et al.* 2010). Of the 123 known taxa of fish, 70 are pelagic fish (the other 52 are reef fishes) – this abundance of predators such as tunas, billfish, and sharks is explained by the aggregations of flying fish who are the main prey for species like yellowfin tuna and wahoo (Viana *et al.* 2010). Indeed, the CPUE of yellowfin tuna was cited in the 1980s to be four times higher than that of adjacent ocean areas (Hazin 1993).

Such factors undoubtedly attracted fishing, starting in the late 1950s by leased Japanese boats operating from the port of Recife, PE and once again briefly in the mid-1960s (Hazin *et al.* 1998). However, only in 1988 was more significant fishing effort exerted by national fishing boats based out of Natal, Rio Grande do Norte, mainly targeting species are yellowfin tuna (*Thunnus albacares*), wahoo (*Acanthocybium solandrii*) and flying fish (*Cypselurus cyanopterus*) (Viana *et al.* 2010). This fleet employed numerous gears, including handline, longline, dipnets, and trolling where flying fish is commonly used as bait (Vaske Jr. *et al.* 2006). In 1998, the ‘Research Station of the Archipelago’ (ECASPSP) was established, which has since supported a small staff of fisheries researchers and other biologists (Vaske Jr. *et al.* 2006).

Trindade Island and Martim Vaz Archipelago (TMV), Arquipélago de Trindade e Martim Vaz

The Island of Trindade (20°30’S and 29°20’W) and the Arquipélago Martim Vaz (20°28’S and 28°50’W) are the only emerged portions of extinct underwater volcanoes formed over three million years ago (Pinheiro *et al.* 2010; Serafini *et al.* 2010). Discovered in 1502 by Vasco de Gama, the islands were claimed by Portugal; however, with the independence of Brazil, they were transferred to Brazilian control. Approximately 1,160 km from the Brazilian state of Espírito Santo, the islands have their own distinct Exclusive Economic Zone (EEZ) of 200 miles, enforced mostly by a small but permanent Brazilian Navy base established in 1957.

Besides the 32 military personnel stationed there, the islands remain isolated and uninhabited (Pinheiro *et al.* 2010). Nonetheless, the islands are fished from the mainland, and perhaps even overfished as evidenced by the relatively low density of large carnivorous fishes (Pereira-Filho *et al.* 2011).

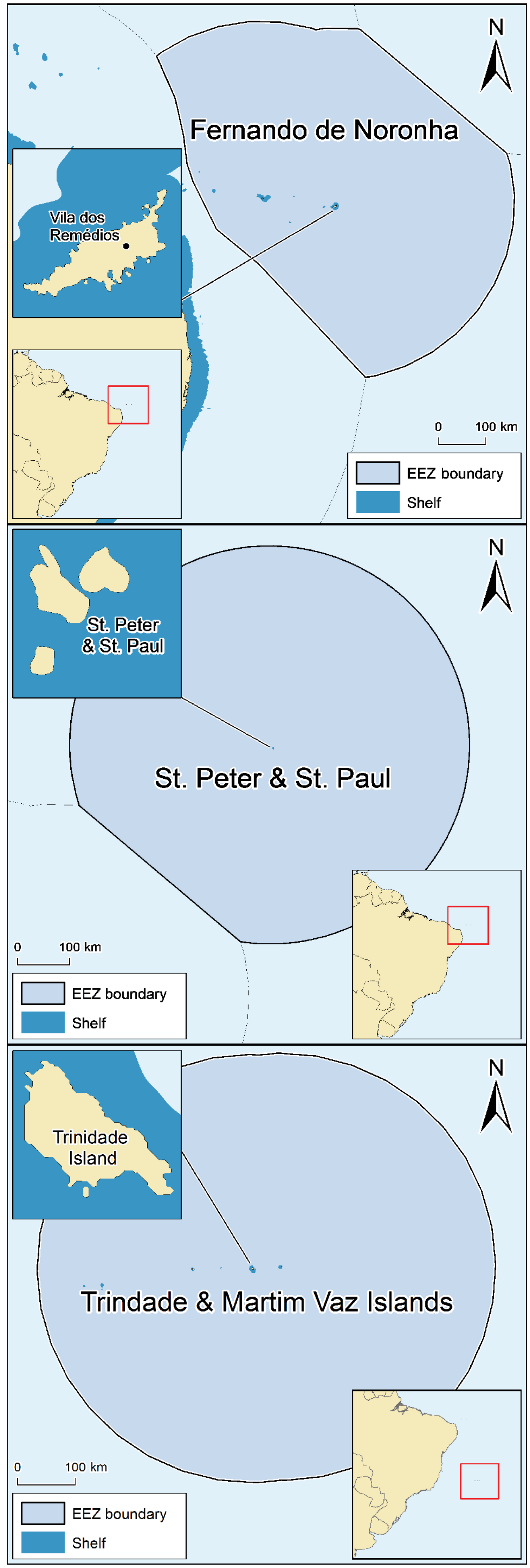

Figure 1. Oceanic islands of Brazil with their respective Exclusive Economic Zones (EEZs).

Like many other islands, the ecosystem is fragile due to few shallow areas and small reef area. Recent research found about 100 fish species in the reefs of Trindade, which is low compared to the Islands of Guarapari (the south coast of Espírito Santo), which has over 300 species. This is common for isolated tropical islands of the Atlantic Ocean (Gusmão *et al.* 2005) as are the high occurrence of endemic species; in this case there are six.

Methods

1. Industrial fisheries

In the two (mostly) uninhabited islands of TMV and SPSPA, there are Brazilian fleets that travel from the mainland to fish. The main fleet fishing in the waters of SPSPA is the multi-gear fleet based in Natal, state of Rio Grande do Norte, which is considered an industrial fleet. The waters of TMV are fished by an 'artisanal' fleet, based out of Vitoria, state of Espírito Santo, mainly targeting reef species. Although this fleet is considered artisanal by Brazil, the *Sea Around Us* considers this industrial, as artisanal catches are only those that are less than 50 km from inhabited shore or 200 m in depth. Since the islands are uninhabited, any fishing by non-inhabitants was considered industrial.

1.1 TMV – Multi-gear line fleet (handline, bottom longline, and trolling) targeting reef species

The use of hook and line is one of the few gears that allows fishers to access areas of rugged oceanic topography such as coral reefs and rocky bottoms where fish can hide (Martins *et al.* 2005).Targeting reef fish was practiced by the Espírito Santo fleet for many decades, but did not extend to the waters of TMV until there was a decline in catch rates of large reef fish in the coastal water of Espírito Santo in the 1980s (Martins *et al.* 2005). During the 1980s, the Vitória fleet (ES) began to search for more abundant fishing grounds, and in "*large movements*" established the Trindade and Martim Vaz seamounts as their destination (Pinheiro *et al.* 2010). Thus, this is a clear sign of spatial expansion of fishing fleets driven by unsustainable fishing effort (Swartz *et al.* 2010).

To estimate catch for the Vitória fleet in Trindade and Martin Vaz, we used the CPUE and effort data in (Martins *et al.* 2005) and made some adjustments to account for the specific CPUE, effort, and species distribution of Trindade and Martin Vaz in (Pinheiro *et al.* 2010). To calculate effort, which from here on will be represented as the number of trips per year, we obtained three anchor points from different periods of time from 1950 to 2010 and interpolated between them. From 1950 to 1980, we assumed that effort was zero, as the catch rates near to the coastal areas of Espírito Santo were still high and there were no cases of fishing cited within the waters of TMV by this fleet.

From 1990 to 1997, the fleet had established its fishing destinations around the islands and there was an effort of 3.9 trips per year, calculated from Martins *et al.* (2005) by using the effort of the entire bottom longline and handline Vitória fleet targeting reef species in 1997 as the baseline. That year, there were 84 boats and an effort of 434 trips taken. Furthermore, the spatial location of these trips was mapped and only three trips out of the 336 trips sampled, were within the EEZ of Trindade and Martin Vaz. This corresponds to 0.9% of all trips by the Vitória fleet, and by extending this sample proportion to the entire fleet, we can deduce that in 1997 there were approximately 3.9 trips per year into the EEZ.

After 1997, there is evidence of a dramatic increase in effort by the Vitória fleet due to the collapse of the coastal shrimp and Peroá (*Balistes capriscus*) populations, whereby these fishers shifted their efforts to target reef species. According to (Martins *et al.* 2005), between the late 1990s to 2002, the effort of the Vitória fleet as a whole increased by 50%. There is evidence, however, that effort within the waters of Trindade and Martim Vaz increased nearly fivefold.

During a 2007 scientific expedition, (Pinheiro *et al.* 2010) reported that around Trindade, there was a "*constant presence of fishing boats from Vitória*". The 1997 level of effort hardly fits this description, as four trips a year, at 20 days each means that there was a presence of one vessel only 22% of the year, rather than several vessels the entire year as described. For there to be a "*constant presence*" within the two month period of the expedition, there must be at least six trips within this time frame, which means that the entire 60 days there were about two boats present. Extending this to the entire year would yield 36 trips annually. In order to remain conservative and include the possibility that the two months of the survey were busier than most, we assumed that half of this amount, i.e., 18 trips were made in 2007. We also assumed that this effort stayed constant from 2007 to 2010. Since the effort for the entire Vitória fleet grew by at least 50% as stated, 18 trips a year is still quite small, amounting to less than 4% of all trips made by the Vitória fleets.

We interpolated between zero effort from 1950 – 1980 to an effort of 3.9 trips per year from 1990 – 1997, the transition period representing when the Vitória fleet was steadily exploring new fishing areas. Thereafter we interpolate to 18 trips in 2007 – 2010.

The CPUE of TMV was calculated by using the effort of the Vitória fleet targeting reef fish as a baseline, at 2.65 t per trip. However, the CPUE was undoubtedly higher, as fishers were leaving the Vitória coastal areas to find spots with higher catch rates. Specifically, a vessel bound for the Martim Vaz Islands Trinidad from Vitória had to travel five days at sea to arrive and five days to return, while trips lasted a maximum of 20 days at sea (Fundação Promar 2005). Using simple economics, in order for fishers to double their effort, losing 50% of the time on commuting, the CPUE for TMV must have been at least twice as high to offset their losses. Since the average CPUE for the Vitória fleet in 1997 was 2.65 t per trip, we assumed that the CPUE for the TMV islands was twice as high at 5.3 t per trip from 1950 to 2003. This is conservative, as it does not account for fuel cost.

There is evidence that this CPUE has declined since then, but this has varied by species. Caribbean reef shark (*Carcharhinus perzii*) and yellowfin grouper (*Mycteroperca venenosa*) have been exploited for a number of years by bottom longline fleet in shallow waters around TMV; captains and crews confirmed that population of these species declined over time (Pinheiro *et al.* 2010). According to one of the boat captains who has been fishing there for 12 years, yellowfin grouper visibly declined: from 1997 to 2003 they caught on average 600 kg per trip, whereas in 2007, they only caught one to three specimens per trip. Taking this statement at face value, this implies that the CPUE decreased from 600 kg to 4 kg per trip in just four years, the latter of which was calculated by estimating the average weight of yellowfin grouper using the length-weight function in Fishbase (www.fishbase.org) and multiplying this by the average of two specimens per trip.

We compared the 1997 CPUE of yellowfin grouper in at 0.6 t per trip to the overall CPUE of 5.3 t per trip, which yielded 11.3% contribution to the entire catch. We used this estimate as a baseline to estimate the contribution of other species, as no exact disaggregation was available, only a list of common species caught. Yellowfin grouper is caught using the handline hear, which is used both day and night when longlines soaking. This gear targets other serranids like misty grouper (*Epinephelus mystacinus*) and rock hind (*Ephinephelus adscensionis*), each of which were also assigned a contribution of 11.3% by weight. Likewise, the gear targets large carangids like black jack (*Caranx lugubris*), horse-eye jack (*Caranx latus*), rainbow runner (*Elagatis bipinnulata*) and various *Seriola* species (Pinheiro *et al.* 2010). The sum contribution of the serranids, 34%, was also applied to large carangids, split equally between the four species.

Bottom longline is also a common gear, at least two of which are deployed at the end of the afternoon in the shallow reef habitats of the islands a few meters from shoreline and retrieved the following morning. The bottom longline targets reef sharks, specifically Caribbean reef shark and nurse shark (*Ginglymostoma cirratum*), which were each assumed to contribute 11.3% to catch. The remaining 9% of catch was evenly distributed among the three remaining taxonomic groups caught occasionally with hand line: bigeyes or catalufas (Priacanthidae), snake mackerels (Gempylidae) and moray eels (Muraenidae).

To calculate CPUE for 2007, we assumed the same CPUE for all species as from 1950 – 2003, except for yellowfin grouper, as mentioned previously, and the Caribbean reef shark. The latter was reported to be overexploited, as the TMV insular complex is a nursery for Caribbean reef sharks and catches of juvenile species were common (Pinheiro *et al.* 2010). Therefore, we assumed that the CPUE of Caribbean reef shark decreased by 25% between 2003 and 2007, from a CPUE of 0.6 t per trip to 0.45 t per trip.

The total CPUEs of all species was added in 2007, assuming that all species except yellowfin grouper and Caribbean reef shark had constant CPUEs over time, resulting in a total CPUE of 4.6 t per trip in 2007. We assumed that the CPUE declined linearly between 5.3 in 2003 to 4.6 in 2007, and then remained constant thereafter. Please refer to Table 1 for a summary of the CPUE values and species disaggregation.

Bait usage in TMV

The use of live bait was common in the fisheries of all three islands. We estimated the bait usage per trip for the fleet fishing in the waters of TMV at approximately 429 $kg{\cdot}boat^{-1}{\cdot}trip^{-1}$, which was an average of the bait usage of the two most common gears used, bottom longline and hand line as sampled by (Martins *et al.* 2005) for the Vitoria fleet. Trolling was used to catch bait-like small scombrids *(*Scombridae*)* and other local reef fish such as coney (*Cephalopholis fulva*), squirrelfish (*Holocentrus adscensionis*), glasseye (*Heteropriacanthus cruentatus*) and spotted moray (*Gymnothorax moringa*) (Pinheiro *et al.* 2010). We multiplied the rate of bait catch per trip by the effort already calculated and assigned 20% of the catch to each of the five taxa.

1.2 SPSPA – Multi-gear fleet targeting tunas and wahoo

The present-day fishing operations off the waters of Saint Peter and Saint Paul Archipelago began in 1988 with vessels based Rio Grande do Norte (Hazin *et al.* 1998), and due to the high productivity of the island, a constant presence of boats has been there ever since. The catch is mostly comprised of yellowfin tuna, wahoo, and flying fish targeted with various gears such as handline, trolling, pelagic longline, dip net, and traps (Vaske Jr. *et al.* 2006; Viana *et al.* 2008; Viana *et al.* 2010). According to (Vaske Jr. *et al.* 2006), fishing near the islands is carried out year-round with at least one and at most four vessels operating on site.

Except for the pelagic longline fleet, which is not considered in the present analysis, no literature is available on a domestic multi-gear fishery prior to 1988. However, personal communication with José Airton Vasconcelos, a member of IBAMA previously involved in the experimental fishery on the DIADOROM from 1977 to 1981, suggests otherwise. While the experimental fishery J.A. Vasconcelos was involved in was located mostly off the oceanic banks of Ceará and Rio Grande do Norte, the captain Manel Murrão of the Pernambuco-based vessel RIO NEGRO would regularly communicate with their team via radio about their trips to SPSPA. The reported fishing effort was one trip per month and the fishing methods were the same as is common in the present time period (J.A. Vasconcelos, pers. comm.). Furthermore, José Airton Vasconcelos provided catch data reported to the Brazilian state of Rio Grande do Norte from 1995 to 2010 (Appendix Table A1). This implies that any catches prior to 1995 were unreported.

Thus, to reconstruct catches, we generated a time series of CPUE and effort data using representative anchor points and multiplied these values for reconstructed catch. We then compared the reported data with reconstructed catch and made appropriate adjustments.

CPUE (Catch Per Unit of Effort)

Our CPUE for the earlier time period was obtained from the research vessel DIADORIM in 1977 and 1978 which spent some time near the islands of Saint Peter and Saint Paul Archipelago. The CPUE calculated for SPSPA was 60 kg·hour^{-1} by trolling, employed on average 6 hours per day, 74.1 kg·hour^{-1} for dipnet, employed on average 2.2 hours per day during the survey, and 74.8 kg·hour^{-1} by handline, with on average 2.9 hours fished per day for the survey (Oliveira *et al.* 1997). Cumulatively, the CPUE was 0.74 t·fishing day^{-1}.

Table 1. CPUE and relative proportion of catch by taxon for the Vitória multi-gear fleet.

Species name	Common name	Gear	Species group	Years 1950–2003		Years 2007–2010	
				CPUE (t/trip)	(%)	CPUE (t/trip)	(%)
Carcharhinus perzii	Caribbean reef shark	Bottom longline	Reef shark	0.60	11	0.450	10
Ginglymostoma cirratum	Nurse shark	Bottom longline	Reef shark	0.60	11	0.600	13
Caranx lugubris	Black jack	Handline	Large carangid	0.45	8	0.450	10
Caranx Latus	Horse-eye jack	Handline	Large carangid	0.45	8	0.450	10
Elagatis bipinnulata	Rainbow runner	Handline	Large carangid	0.45	8	0.450	10
Seriola	Amberjacks	Handline	Large carangid	0.45	8	0.450	10
Epinephelus mystacinus	Misty grouper	Handline	Serranid	0.60	11	0.600	13
Mycteroperca venenosa	Yellowfin grouper	Handline	Serranid	0.60	11	0.004	0.1
Epinephelus adscensionis	Rock hind	Handline	Serranid	0.60	11	0.600	12.9
Priacanthidae	Bigeyes or catalufas	Handline	-	0.17	3	0.170	4
Gempylidae	Snake mackerels	Handline	-	0.17	3	0.170	4
Muraenidae	Moray eels	Handline	-	0.17	3	0.170	4
Total	-	-	-	5.30	100.0	4.560	100.0

For the later time period, we used the sample data from (Viana *et al.* 2010) where a total of 2171 t of fish were caught, 20% wahoo, 12% flying fish, 60% tunas, 4% sharks, and 4% other species. Furthermore, it was stated that the CPUE for wahoo was 115 kg·fishing day^{-1} and for yellowfin tuna it was 450 kg·fishing day^{-1} (Viana *et al.* 2010). We determined the sample effort in fishing days using catch and CPUE estimates for both wahoo and albacore tuna, which was 3,775 fishing days and 2894 fishing days, respectively. We averaged the two to obtain an estimate of 3335 fishing days for the entire time period, and divided the total sample catch by effort exerted to obtain a CPUE of 0.65 t·fishing day^{-1}.

We assumed that from 1950 to 1977, the CPUE was 0.74 t·boat^{-1}·fishing day^{-1}, interpolated to 0.65 t·boat^{-1}·fishing day^{-1} in 1998, and then remained constant at this level until 2010.

Effort

As stated previously, the reported fishing effort for fishery in the 1970s was one trip per month, which needed to be converted to days at sea to apply the appropriate CPUE. Due to the similarity in fishing methods during the earlier and later time periods (J.A. Vasconcelos, pers. comm.), we converted the number of trips to the equivalent number of days at sea using a representative value of 11 days at sea per trip. This was calculated by comparing two independent measures of CPUE for yellowfin tuna, each with varying units of effort. The first measurement was official catch reported to Rio Grande do Norte from 2006 to 2010, divided by the number of trips taken annually (Appendix 1). The second measurement was the CPUE in (Viana *et al.* 2010) for yellowfin tuna for the equivalent years, which was in terms of kg·boat^{-1}·fishing day^{-1}. We assumed these two measurements were equal and consequently obtained that one trip is, on average, equivalent to 11 days at sea.

Thus, effort from 1977 to 1981 was 12 trips annually, or 132 days at sea. There is no clear way of knowing when the fishery truly began or ended, but in order to stay conservative we assumed these years are the peak years of the fishery. To account for the realistic scenario that fishing had gradually increased to this level (and conversely, waned after the peak of the fishery), we assumed half this effort for the years 1976 and 1982.

Next, we estimated the effort for the present fishery as described by (Vaske Jr. *et al.* 2006), who reported that fishing was carried out year-round with at least one and at most four vessels operating on site (Vaske Jr. *et al.* 2006), or an annual average of 2.5 boats operational for 912.5 fishing days cumulative, assuming each boat operated year-round as was stated. To be conservative, we estimated effort as the midpoint between this average, and the minimum fishing effort of one boat operating there annually, or 365 fishing days. In summary, our estimate of fishing effort during the later time period (starting with 1998) was 639 fishing days. For the years prior, effort was interpolated from 0 in 1987 to 639 fishing days in 1998.

Reconstructed catch

Effort and CPUE were multiplied to obtain an estimated reconstructed catch. Since the CPUE and effort values were constant from 1998 to 2010 (due to the aggregation of CPUE and catch data over the sample years), the catch for the later time period was constant. We compared this to the reported data from 1995 – 2010 (Appendix Table A1), which was more variable, and hence felt it was appropriate to follow the trend line of the reported data. Total reconstructed catch estimated at 416 t·year^{-1} from 1998 to 2010, while reported landings in this same time period averaged 261 t·year^{-1}. The unreported component for this time period was approximately 60% of reported landings. We applied this percentage to all reported landings from 1995 to 2010 assuming the same species composition as the reported portion.

Prior to this, we utilized the product of CPUE and effort data for the years 1976 to 1982, and then interpolated between zero catch in 1987, to the catch estimated in 1995 at 175 t. We utilized the species composition from the last two years of reported data for any catches from 1950 to 1994, i.e., we averaged the species compositions from 1995 and 1996.

The only taxon that we did not include in the species distribution was the brown spiny lobster (*Panulirus echinatus*), which has a small contribution by weight to overall catch, yet is a very economically important species. Thus, we modeled the catch separately for this species.

Brown spiny lobster

Spiny lobsters, which are one of the most highly valued resources in northeastern Brazil, have been heavily targeted and thus resulting in dramatic depletion due to illegal and predatory activities (Pinheiro *et al.* 2003). While most species of spiny lobster are well-studied and regulated by fisheries legislation, brown spiny lobster is the only species not considered in such management regulation, likely due to the fact that it prefers offshore rocky regions like Saint Peter and Saint Paul Archipelago, and thus has not been heavily targeted until the other lobster species closer to the mainland were depleted. While traps were originally used to target this species in the 1980s, by the 2000s this method was replaced by diving, which had significantly higher yields.

According to a sample of 15 research expeditions where traps were placed around SPSPA, 1494 lobsters were caught and sampled, each weighting an average of 200 g. We assumed that one research expedition was equivalent to two fishing days, or at least 1 day to set up traps and the following day to analyze and record findings. This results in a CPUE for traps of approximately 10 kg per fishing day. Since trap gear was known for yielding small catches, we assumed that CPUE for diving was twice as high, at 20 kg per fishing day. We modelled that traps were used until 1990, at which point the diving linearly replaced traps until 2003, when the only gear employed was diving. We also assumed that only 50% of the fishers, and thus 50% of the effort was directed at brown spiny lobster, especially since diving is a rather skilled endeavor.

Bait usage in SPSPA

Since the gears that used live bait for fishing in SPSPA were pelagic longline, hand line, and trolling, we took the average of the bait usage for these three gears in (Martins *et al.* 2005) and arrived at 293 kg ·boat^{-1}·trip^{-1}. Since the effort for SPSPA was represented in terms of days at sea, we adjusted the bait catch by dividing the estimate by 11, which was the average number of days at sea per trip as calculated previously. Thus, the bait usage was estimated at approximately 15 kg·boat^{-1}·fishing day^{-1}. This was multiplied by the effort previously calculated. In SPSPSA, dipnets were used to capture flying fish, which are used as live bait (Vaske Jr. *et al.* 2006). Sometimes shark skin was cut in the shape of a fish for bait, but most accounts focus on flying fish as the most common bait used (Vaske Jr. *et al.* 2006).

2. Artisanal fisheries

2.1 Fernando de Noronha artisanal fishery

The only artisanal fishery present is located on the island of Fernando de Noronha, which has a small-scale fishery active since 1950, where effort is exerted by artisanal fishers living on the island (Barros 1963; Lessa *et al.* 1998; Dominguez *et al.* 2013). In the early years of the fishery, after World War II, there was no strict control or oversight, so fishers freely brought fish to the beaches, often leading to the food poisoning of residents. This encouraged stricter measures, including beheading and gutting at sea along with storing fish in crushed ice (Barros 1963). By the mid-1950s and early 1960s, fishing took place along the entire coastline during the entire year by a solid base of artisanal fishers, working on four motorized boats (two with steel hulls and two with wood), ranging from 8 to 11.5 meters in length (Barros 1963). These fishers employed mostly hook and line gear, the most common of which were trolling and 'deep line' with line lengths between 5 to 100 fathoms and up to four hooks per line (Barros 1963; de Moura and Paiva 1965). On average, fishing took place eight to ten hours a day, starting in the early morning, employing between four to ten men on board, depending on the size of the boat (Barros 1963).

While the artisanal fleet continued using the same fishing gear and navigation techniques from 1950 to 2010, effort exerted changed significantly over time. Although the population did not grow significantly prior to the establishment of the island as a National Park in 1988, the number of fishing boats, and thus fishing effort increased substantially. After 1988, however, fishing effort declined as the tourist industry expanded. While the number of boats remained high, fishers "*were attracted by the income and began to work full or part-time in tourism, which gradually absorbed much of the labor force*" (IOPE 2010). Thus, during this later period of time, fishing effort declined.

Throughout the entire time period, fishing generally took place within a radius not exceeding 5 nautical miles from shore (Lessa *et al.* 1998), and congregating near the '*parede*', or 'wall' where the depth dramatically drops off to 800

– 1200 meters and creates an upwelling leading to nutrient enrichment (Dominguez *et al.* 2013). After 1988, when the PNM was established, fishing was no longer allowed within 50 m of shore, although on occasion the PNM allows fishing inside its limits for species "*of passage*", especially barracuda (Lessa *et al.* 1998).

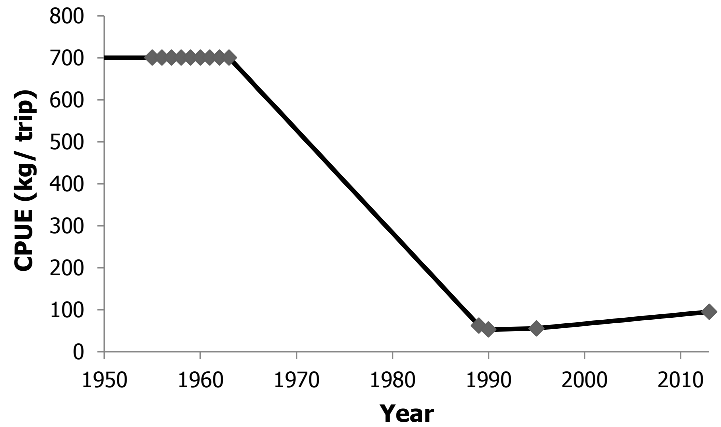

Figure 2. CPUE in kg per trip of the artisanal fishery in Fernando de Noronha.

In order to estimate catches by this fleet, we took the product of CPUE and fishing effort from 1950 to 2010. Annual effort was represented as the sum of the efforts of all boats, with the effort of a boat equal to the number of fishing trips (Lessa *et al.* 1998). One trip was equivalent to one day of fishing averaging eight to ten hours at sea (Lessa *et al.* 1998; Dominguez *et al.* 2013), and the CPUE was denoted in kg of catch per trip per year.

According to (Barros 1963), in the mid-1950s up until 1963 commercial catch was estimated between 150 to 200 t, derived from the fact that when the four boats of the fleet are in operation, they export to Recife about 3 to 4 tonnes weekly, for approximately 50 weeks per year. Additionally, Barros (1963) cites that on average, the CPUE was 700 kg·boat^{-1}·day^{-1}, i.e., 700 kg·boat^{-1}·trip^{-1}. We conservatively used the lower bound of 150 tonnes annually as our baseline and using the CPUE derived an average of 214 trips annually.

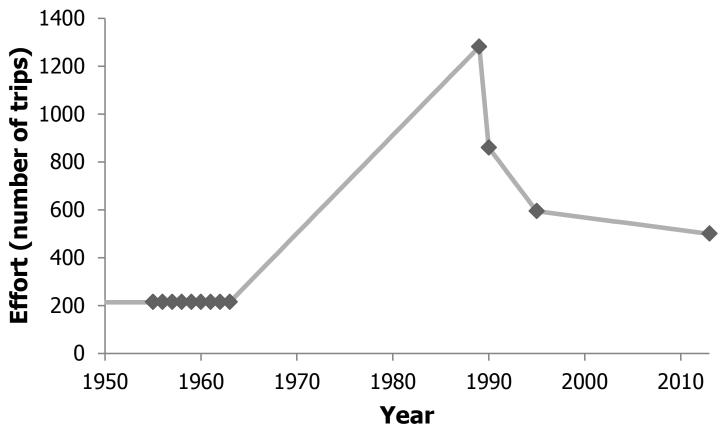

Figure 3. Effort in number of trips of the artisanal fishery in Fernando de Noronha.

For the years 1989 and 1990, Lessa *et al.* (1998) estimated a significantly lower CPUE at 62 kg per trip and 52.5 kg per trip, respectively, but also a significantly higher effort with 1281 and 859 trips taken in the respective years. Additionally, Lessa *et al.* (1998) stated that the CPUE in 1995 recorded by IBAMA was on average 55.5 kg per trip and the effort in the mid-1990s was shared between nine boats each taking an average of 5.5 trips monthly. Thus, we estimated an effort of 594 trips in 1995.

Finally, during a six-month trip from April to September in 2013, Dominguez (2013) sampled 23.75 t of landings obtained by an effort of 250 trips, thus resulting in a CPUE of 95 kg per trip and an annual effort of 500 trips. We compiled all estimates of CPUE (Figure 2) and effort (Figure 3) and multiplied the quantities to obtain total catch. As a quick verification, we compared our results to some "*scarce records*" (Lessa *et al.* 1998) that were compiled from non-systematic catch statistics. The general trend marked that of the one calculated here, with catches peaking in the mid-1970s and declining thereafter. The only data point available in the 1970s was in 1974 where the catch was reported at 280 t. Our estimate resulted in a total of 286 t of catch in that year, which is remarkably similarly given an independent methodology.

In order to disaggregate the catch by species, we used the composition of catch from each of the three studies and interpolated the proportions over time (see Table 2). From 1950 to 1963, we used the description from (Barros 1963) to assign species composition. Although (Lessa *et al.* 1998) for the years 1988 to 1990 had more specific data about species composition than (Barros 1963), we hesitated to use it for the earlier time period later studies took place after the establishment of the Arquipélago as a National Park, which in consequence restricted the fishing activity until this day to outside 50m from the coast (Silva Jr 2003; IOPE 2010). Indeed, of the thirteen major commercially significant species or species groups listed in (Barros 1963), four were not included in (Lessa *et al.* 1998) at all. Furthermore, of the ones included in (Lessa *et al.* 1998), approximately half had a minuscule contribution to overall catch.

It was stated in (Barros 1963) that during a sample taken over seven days, the top catches were predominantly of red porgy pargo (*Pagrus pagrus*), barracudas (Sphyraenidae), and the group of species of tuna known by the Portuguese common name of 'albacora'. For these three species or taxonomic groups, we estimated a contribution of 20% each to catch by weight. In order to be consistent with the species classifications for later time periods in (Lessa *et al.* 1998) and (Dominguez *et al.* 2013), we assumed that the main barracuda species referred to was the great barracuda (*Sphyraena barracuda*), and that the species referred to as 'albacoras' were the yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*), blackfin tuna (*Thunnus atlanticus*), and albacore (*Thunnus alalunga*), each of which contributed 5% by weight to catch. (Barros 1963) also mentioned 11 other species that were significant to the fishery, each of which we assumed contributed equally to the remaining 40% of catch, or 3.6% each. The species classification of jacks and groupers were further divided into more specific species so to have a comparable level of detail with (Lessa *et al.* 1998) and (Dominguez *et al.* 2013).

For the time period 1988 – 1990, studied by (Lessa *et al.* 1998), the taxonomic composition by weight was based on the family of fish, with further clues in the text as to the particular contribution of each species. When there was no particular description in the text, all species for that family received an equal contribution to the percentage assigned for that taxonomic family. The majority of catch in (Lessa *et al.* 1998) was attributed to great barracuda (*Sphyraena barracuda*), yellowfin tuna (*Thunnus albacares*), blackfin tuna (*Thunnus atlanticus*), albacore (*Thunnus alalunga*), and black jack (*Caranx lugubris*). (Dominguez *et al.* 2013) also reported on the species composition of sampled catch by percentage and all but two of the 14 species listed were also in (Lessa *et al.* 1998). In order to have a comparable level of detail to that of (Lessa *et al.* 1998), we split the more general designation of *Caranx* species into horse-eye jack (*Caranx latus*) and blue runner (*Caranx crysos*). Further details can be seen in Table 2.

Table 2. -Species composition of catch by the artisanal fleet in FN, by time period.

Species name	English common name	Portuguese c. name	1950–1963 (%; Barros 1963)	1988–1990 (%; Lessa et al 1998)	2013 (%: Dominguez 2013)
Thunnus albacares	Yellowfin tuna	Albacora-laje	5.0	10.0	30.1
Thunnus obesus	Bigeye tuna	Albacora-bandolim	5.0	5.8	-
Thunnus alalunga	Albacore	Albacora-branca	5.0	10.0	-
Thunnus atlanticus	Blackfin tuna	Albacorinha	5.0	10.0	-
Acanthocybium solandri	Wahoo	Cavala-aipim, cavala	3.6	6.8	7.6
Katsuwonus pelamis	Skipjack tuna	Bonito-rei	3.6	0.5	-
Sphyraena barracuda	Great barracuda	Barracuda, bicuda	20.0	40.0	6.6
Sphyraena picudilla	Southern sennet	Barracuda-corona	-	2.0	-
Caranx lugubris	Black jack	Xaréu-preto	1.8	5.0	16.1
Caranx hippos	Crevalle jack	Xaréu-branco	1.8	0.2	0.3
Caranx crysos	Blue runner	Xaralete	-	0.2	2.2
Caranx latus	Horse-eye jack	Xixarro-preto	-	0.2	2.2
Decapterus spp.	Scads	Xixarro-branco	-	0.2	-
Elagatis bipinnulata	Rainbow runner	Peixe-rei	-	0.2	24.5
Seriola dumerili	Greater amberjack	Arabaiana	-	0.2	1.3
Selene vomer	Lookdown	Galo-de-penacho	-	0.2	-
Alectis ciliaris	African pompano	Galo-de-alto	-	0.2	-
Trachinotus ovatus	Pompano	Pampo-garabebel	-	0.2	-
Coryphaena hippurus	Common dolphinfish	Dourado	-	0.6	3.4
Istiophorus albicans	Atlantic sailfish	Agulhão-Vela	-	0.6	-
Xiphias gladius	Swordfish	Agulhão-roliço	-	0.6	-
Lutjanus jocu	Dog snapper	Dentão	-	0.6	2.0
Lutjanus purpureus	Southern red snapper	Pargo	20.0	0.6	-
Lutjanus analis	Mutton snapper	Cioba	3.6	0.6	-
Hyporthodus niveatus	Snowy grouper	Serigado-cherne	1.8	0.0	-
Mycteroperca bonaci	Black grouper	Serigado-badejo	1.8	0.0	-
Anisotremus surinamensis	Black margate	Pirambu	-	0.0	-
Epinephelus morio	Red grouper	Garoupa	3.6	0.6	-
Cephalopholis fulva	Coney	Piraúna	-	0.6	0.1
Melichthys niger	Black triggerfish	Cangulo-bandeira	-	0.6	2.2
Balistes vetula	Queen triggerfish	Cangulo-listrado	-	0.6	-
Holocentrus adscensionis	Squirrelfish	Mariquita	-	0.6	-
Lactophrys spp.	Cowfishes	Baiacu-caixão	-	0.6	-
Carcharhinus spp.	Sharks	Tubarão-sucuri, cacão	3.6	0.6	-
Carangoides bartholomaei	Yellow jack	Guarajuba	3.6	-	0.5
Makaira nigricans	Blue marlin	Marlin azul	-	-	0.7
Epinephelus itajara	Goliath grouper	Mero	3.6	-	-
Pomatomus saltatrix	Bluefish	Enchova	3.6	-	-
Clupeidae	Herrings and shads and sardines and menhadens	Sardinha	3.6	-	-

Octopus (Octopus vulgaris) fishery

Up until 1988, we believe, octopus fishing was purely subsistence in nature, carried out by residents, as there was no mention of this fishery prior to the 2000s. With increased tourist activity after 1988, there was an intensified exploration of activities related with the marine environment such as recreational diving and boating, as well as the gradual migration and adaption of fishing vessels towards the tourist industry (Lessa *et al.* 1998; Leite *et al.* 2008; IOPE 2010). Since octopus was caught via diving and a majority of octopus fishers were also involved in the tourist industry, it follows that octopus fishing grew proportionally with the tourist industry.

However, the base of octopus fishers themselves changed little, as more than 80% of the octopus fishers interviewed in 2003 to 2005 learned to fish with their parents and have been involved with octopus fishing since childhood or adolescence (Leite *et al.* 2008), implying that it was a tradition carried down in the family. In 2004, an average octopus fisher has been fishing for 14 years, which is further evidence that these fishers had been fishing prior to the explosion of tourism.

Between 2003 to 2005 (Leite *et al.* 2008) stated that there were 45 octopus fishers, mostly operating part-time, and that 80% of them, or 36, were the stable base of octopus 'traditional' fishers from 1988 to 2010. We assumed that the other 20% of fishers began fishing as a result of the increase in tourism, so that these 'non-traditional' fishers numbered 0 in 1987 and increased linearly to 9 in 2004 when the study was done and continued to increase following the same trend to 12 in 2010.

From 2003 to 2005 an average fisher consumed 1.35 kg and sold 6.55 kg of octopus on a weekly basis (Leite *et al.* 2008). For subsistence activity, we will assume they are active all 52 weeks of the year, while for commercial activity it was stated in (Leite *et al.* 2008) that fishers were most active 32 weeks of the year. Subsistence was thus a product of the weekly consumption by 52 weeks by the total number of fishers from 1988 to 2010, both traditional and nontraditional.

As for the 6.55 kg sold to restaurants, hotels, and local residents, we separated out the amount sold to local residents, as this was related with subsistence, while the amount sold to restaurants and hotels was related to the growth in tourism. This was done by first calculating the total amount sold in 2003 to 2005, using 2004 as a base year, which we estimated at 9.4 t annually (a product of 6.55 kg weekly by 45 fishermen for 32 weeks in a year). According to (Leite *et al.* 2008) the amount provided to hotels and restaurants from the small-scale local fishery was 11% of their yearly consumption, or 0.9 t, which was subtracted from the total of 9.4 t. Thus, in 2004, 8.5 t of octopus went to local residents for consumption.

We varied these estimates over time from 1988 to 2010 by assuming that the total amount sold to restaurants and hotels increased linearly from 0 in 1987 to 0.9 t in 2004, and then we extrapolated the linear trend to 1.3 t in 2010. We inferred the amount sold to local residents as a proportion of the growth in resident population (see section on Consumption for resident population methodology). This was equivalent to 3.3 t in 1987, increasing linearly to the aforementioned 8.5 t in 2004, and culminating at 8.7 t in 2010.

We believe these estimates are conservative, because even though the number of fishers is small, the total number of people involved in recreational fishing for octopus is high, as seen by the interviews conducted with non-fisher residents, 41.3% already fished octopus sometime in their life.

Bait usage in FN

In 1978, one of the locals exclaimed, "*throw a net, and come dragging 300, 400, 500 sardines!*" (Anon 1978). Residents and fishers alike used 'tarrafas', a conical- shaped net cast out by hand, to target the abundant schools of sardines on beaches and in shallow waters. Sardines were the most common live bait used by fishers to target commercial species from 1950 to 2010 (Lessa *et al.* 1998; Dominguez *et al.* 2013).

In order to calculate the number of sardines used as bait, we adjusted estimates of bait usage in (Martins *et al.* 2005) for various gears of the Espírito Santo (ES) fleet, to represent the bait usage for the Fernando de Noronha fleet. Since trolling and pargueira, or 'deep line,' were the predominant gears of the Fernando de Noronha fleet, (Lessa *et al.* 1998), we averaged the bait usage per trip for these gears as presented in (Martins *et al.* 2005) at 215 $kg \cdot boat^{-1} \cdot trip^{-1}$. In (Martins *et al.* 2005), the maximum days at sea per trip was 20, while for Fernando de Noronha the duration of one trip was equivalent to one day. Thus, we divided the estimated by 20, to obtain 11 $kg \cdot boat^{-1} \cdot trip^{-1}$, which was multiplied by the total effort previously calculated.

Lastly, we considered that from 1950 to 1990, it was reported that 100% of the hooks used sardines as live bait (Barros 1963; Lessa *et al.* 1998), while a report in 2013 by (Dominguez *et al.* 2013) stated that live sardine was most commonly used while artificial bait was used for 7.2% of landings. Thus we adjusted the amount calculated accordingly, assumed that sardines were used 100% of the time from 1950–2000, and for the years after the proportion of bait used linearly decreased to 92.8% in 2013.

3. Discards

Discards were applied to industrial and artisanal landings, except for the species of octopus and brown spiny lobster, as these species were generally caught by diving or traps, and thus would have little to no discards associated with them. For discard rates, we referred to the same proportions as those assumed by Freire *et al.* (2014), i.e., 5.3% of catch for the 'line' gear, which includes hand-line, vertical longline, and bottom longline gears, and 14.8% for pelagic longline gears. The discard rates and species proportions for each island follow.

Saint Peter and Saint Paul Archipelago

Since fishermen in SPSPA employ mostly handline and pelagic longline gears, we averaged the two discard rates for line gear, 5.3%, and pelagic longline, 14.8%, and obtained a rate of 10.1% of catch, or 11.2% of landings. This fishery mostly targets tuna, a highly prized fish, and there is evidence that almost all catches of tuna were juvenile (Vaske Jr. *et al.* 2006). Thus, we believe very little tuna was discarded. We also assumed there were no discards of spiny lobster. The remaining 23 species were assigned a contribution of discards proportional to landings.

Fernando de Noronha

While describing the artisanal fishery, (Barros 1963) mentioned that small juvenile species, or '*peixes miúdos*,' were "*constantly hooked*" on various hooks. Since it was implied that these fish were not commercially desirable, we assumed they were discarded. We assumed a discard rate of 5.3% of catch, or 5.6% of landings. The Portuguese common names of ten species were given, however only eight of them were identifiable: coney (*Cephalopholis fulva*), grunts (*Haemulon*), spotted goatfish (*Pseudupeneus maculatus*), squirrelfish (*Holocentrus adscensionis*), doctorfish (*Acanthurus chirurgus*), greater soapfish (*Rypticus saponaceus*), parrotfishes (*Scaridae*), and a species in the family of jacks and pompanos (*Carangidae*). The two unidentifiable species had the common names of '*manteguinha*' and '*lingua de negro'*. We equally distributed the discards amongst these eight identifiable species.

Trindade Island and Martim Vaz Archipelago

For this fishery, there is the least amount of certainty regarding discards, which are not mentioned. Also, the species composition was derived from interviews with fishers, who, likely mentioned only commercially desirable fish. Nonetheless, we assumed the discard rate for the line fishery, 5.6% of landings, and applied this rate to all landings. Since there was uncertainty as to the species composition, we assumed the same proportion of contribution to discards for all the species, including bait fish that must be alive, and thus any dead fish were likely discarded.

<u>Subsistence fisheries</u>

Although there are several dozen military personel residing in TMV and researchers in SPSPA, catches from their consumption are likely not important enough to warrant study. FN on the other hand has had a population ranging from approximately 800 residents 1950 to 2,600 in 2010, and thus we have estimated consumption for this fishery.

According to (Barros 1963), any estimations for catch were incomplete, as fishing was also done almost daily by inhabitants for personal consumption without ever reporting catch. Species specifically mentioned by (Barros 1963) that were fished for by inhabitants were '*agulhões*,'or needle fishes (Beloniformes*)*, lobster (Decapoda), crab (Portunidae). It was also stated that octopus and squid (*Loligo*) were very common in the waters of Noronha, although he did not mention any fishing for them (Barros 1963). Additionally, an account by a tourist visiting Fernando de Noronha in 1978 mentions several cases of consumption and fishing by islanders, notably, sardines (Clupeidae), yellow jack (*Carangoides bartholomaei*), jacks and pompanos (Carangidae), octopus, and the aforementioned needle fishes and lobster (Barros 1963).

To calculate subsistence fishing, we assumed that as a minimum, each person consumed one serving daily. A three ounce cooked serving of most fish or shellfish provides about one-third of the average daily recommended amount of protein (Seafood Health Facts 2012). The logical maximum bound to our estimates would be three portions of fish daily per person, but to make this leap we would have to assume that fish is the only source of protein. This is not unreasonable, as historically, the primary activites of the island were fishing and agriculture (IOPE 2010). However, since this cannot be verified, we will conservatively assume consumption of one serving a day per inhabitant.

A three ounce serving is equivalent to 85g of edible fish. We assigned an equal split, in edible weight, between the seven species mentioned: lobster, crab, needle fishes, sardines, yellow jack, jacks and pompanos, and octopus. In order to convert to whole weight, we used estimates of edible weight as a percentage of whole weight, i.e., 44% of lobster, 31.5% of crab (Waterman 2001), 56% of species in the Carangidae family, 65% of sardines and needlefishes (Barros 1963; FAO 1989), and 100% of octopus is edible, as it is commonly eaten whole. Overall, this was equivalent to 159 g per serving of whole fish, which resulted in an annual per capita consumption of 58 kg. This is reasonable for an island society during the 1950s and 1960s when store-bought food was not common.

For population figures from 1950 to 2010, we compiled several anchor points and interpolated linearly between them. According to (SAE 2014) in the 1960s the population was constant ranging from 1,200 to 1,300, in the 1970 census the population was 1244, and in the 1980 census it was 1,266. Population after this time period grew dramatically, from 1,342 in 1990 to 2,520 in 2003 (Leite *et al.* 2008). The final anchor point was a population of 2,605 in (Souza and Vieira Filho 2011), who states that this is the population during the time of writing (i.e., between 2009 – 2011). For the decade preceding 1960, we assumed that the population in 1945 was 625, as this was the year the prison was shut down and the island became a place hospitable for settlers. We assumed a linear growth from 625 residents in 1945 to 1250 residents in 1960.

As seen by the fairly constant population up until 1988 and the insular nature of island environments, we assumed that consumption patterns did not change until 1988 with the establishment of the national park. Thus, for these early years we used the constant per capita consumption by specie and multiplied it by the population from 1950 to 1987.

Once the National Park was established in 1988 and tourism exploded (Silva Jr 2003; Leite *et al.* 2008; Souza and Vieira Filho 2011), there were dramatic changes in fishing and consumption patterns. Firstly, the water 50 m around the entire island were considered restricted to fishing, meaning that inhabitants could not easily access these fishing waters to fish by themselves. Although subsistence consumption undoubtedly continued, we believe that nearly all the catch was absorbed into the catch already calculated for commercial fishing by the artisanal fishers. This is supported by a 2008 survey of fishers in Fernando de Noronha, which found that 52% of catch is sold directly to consumers (IOPE 2010). Thus, we assumed that after 1988, 52% of artisanal catches already calculated actually support the livelihoods of island residents and are therefore considered subsistence.

Results

Industrial fisheries (landings and bait)

Catches (discards not included here) for the industrial fleet operating in the waters of TMV began in 1981 with 2 t of catch and increased to 90 t by 2010, bait accounting for approximately 8.6% of this. Catches from within the waters of SPSPA began in 1976 with an average catch of 86 t·year^{-1} until 1983 when the catches dropped to zero until rebounding in 1988. Thereafter, removals increased to 432 t in 1997 before slightly declining and then peaking at 564 t in 2004, subsequently dropping to 351 t in 2010 (Figure 4). For SPSPSA, bait accounted for about 4% of catch.

Artisanal fisheries (landings and bait)

Artisanal catches (discards not included here; Figure 5) were constant in the 1950s and early 1960s at 152 t·year^{-1} of catch, but as effort climbed, catches increased to 294 t in 1975, at which point increasing effort was offset by a decreasing CPUE and catches decreased to 146 t in 1987, the year before the National Park was built. Thereafter, catches declined dramatically, averaging 26 t·year^{-1} in the 1990s and 2000s. On average, baitfish was 11% of the annual catch, which was mostly due to later years when effort was still relatively high but catch was low.

Discards

Discards for the artisanal fleet in Fernando de Noronha were stable at 9 t·year^{-1} from 1950 to the early 1960s, at which point they increased proportionally with catch to 16 t in 1975, and then declined to about 1.5 t·year^{-1} in the 1990s and 2000s (Figure 6). Industrial discards in the waters of TMV were low for the entire period, starting at 0.1 t in 1981 and increasing to about 5 t in 2010. Discards for the SPSPA fleet were the highest, averaging 10 t·year^{-1} from 1976 to 1982, zero for the years after until 1988 when discards climbed to 48 t in 1997 and thereafter oscillated around 49 t·year^{-1} in the 2000s.

Subsistence

Subsistence catches grew proportionally with population for the years prior to 1988, increasing from 48 t in 1950 to approximately 73 t·year^{-1} from 1960 to 1988 (Figure 7). With the creation of the National park, subsistence consumption was bought directly from fishers, and thus catches changed proportional to artisanal activity, dropping to 26 t in 1995, and then increasing to 37 t by 2010. Coinciding with this drop in fish consumption, was a drastic change in the distribution of species consumed as catches of lobster, crab, sardines, and needlefishes dropped to zero in 1988 when residents were no longer legally allowed to fish from shore.

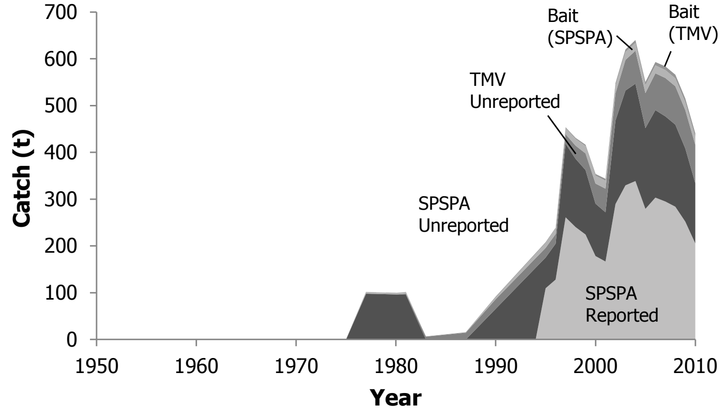

Figure 4. Industrial catch and baitfish for Saint Peter and Saint Paul Archipelago (SPSPA) and Trindade and Martim Vaz Archipelago (TMV).

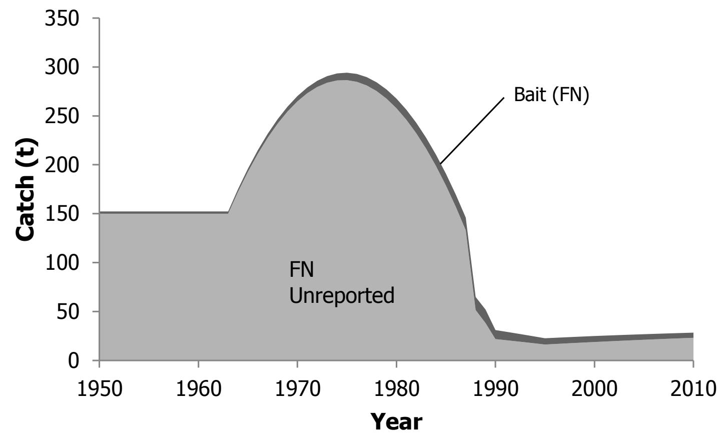

Figure 5. Artisanal catch and baitfish for Fernando de Noronha (FN).

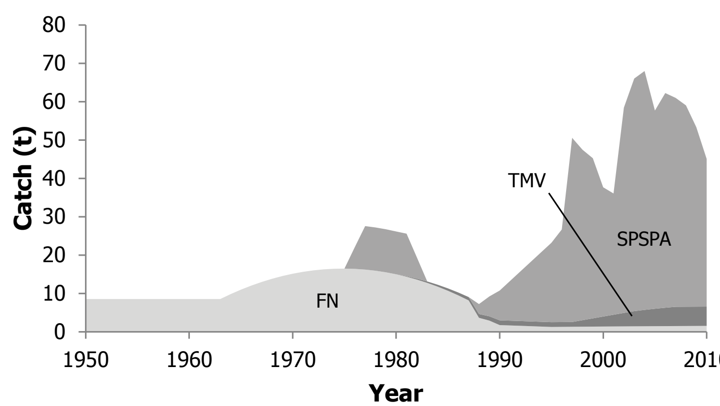

Figure 6. Discards for of industrial and artisanal catch for SPSPA, TMV, and FN.

Reconstructed total catch by sector

Altogether, removals increased from 209 t in 1950 to 492 t in 1977, declined to a minimum of 165 t in 1990, and then peaked twice in 1997 and 2004 with 555 t and 770 t of catch, respectively (Figure 8). Total removals decreased by 2010 to 550 t, most of which was caught in the waters of SPSPA.

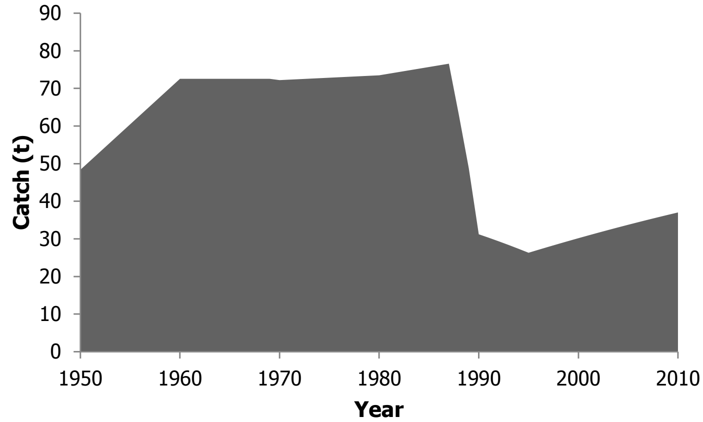

Figure 7. Subsistence catch for Fernando de Noronha (FN).

Reconstructed total catch by species

Catch was composed of a total of 71 species, most of them varying from island to island due to their unique ecosystems. Barracuda, sardines, and tunas were common in the early years of the fisheries, which in the later years the most common species were flying fish, wahoo, and yellowfin tuna (Figure 9).

Discussion

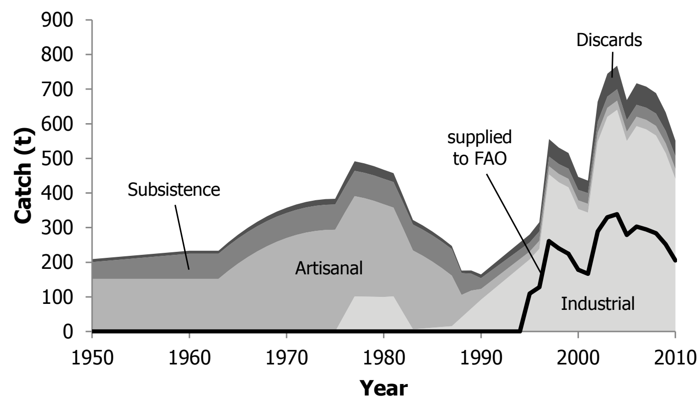

Figure 8. Catch by sector for SPSPA, TMV, and FN.

Total catches for the industrial fleets operating in Trindade and Martim Vaz Archipelago and Saint Peter and Saint Paul Archipelago began in 1976 and by the 2000s, were averaging 580 t·year^{-1}. Currently there are no quotas for optimal catch or measurements for the health of fishery, although some inferences can be made. In the waters of TMV, five shark species are threatened, two of which, the blue shark and nurse shark are targeted by the Espírito Santo fleet in the TMV complex (Pinheiro *et al.* 2010). Likewise, in St Peter and St Paul Archipelago, historical records point that shark populations, notably the reef sharks are already extinct (Luiz and Edwards 2011). Indeed, due to SPSPA's important role in the lifecycle of many species, extra caution must be taken while fishing, especially for species of silky shark for whom the Archipelago is a place to give birth (Oliveira *et al.* 1997). The targeting of yellowfin tuna also must be careful, as this is the primary target of fishing activities in SPSPSA, yet nearly all catch in the archipelago was shown to be immature (Vaske Jr. *et al.* 2006). The 'cascade effect,' previously mentioned, forewarns that the extinction of predatory species can cascade onto other species of lower trophic levels. As seen by the rapid decline of the yellowfin grouper in TMV waters, extinction or overexploitation can be very swift in such remote island ecosystems. As stocks fail closer to the mainland, and effort is increasingly exerted on new unexploited grounds, fishing pressure is only expected to increase.

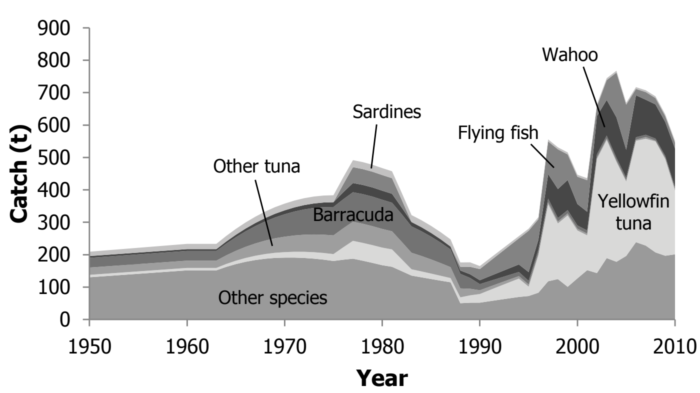

Figure 9. Catch by taxon for SPSPA, TMV, and FN.

Fernando de Noronha is unique from the other islands in that fishing effort by the artisanal fleet has actually declined over time. Catches for Fernando de Noronha were 209 t in 1950, peaking in 1975 with 383 t, and stabilizing at 59 t·year^{-1} as tourism expanded in the 1990s and 2000s. This is especially peculiar given that the resident population over doubled as catches declines, and this does not even consider the waves of tourists that stay on the island. The decline in catches was largely a result of the artisanal fisher labor force being absorbed by tourism. Additionally, as the number of tourists expanded and demand for fish increased, the seasonal variation in the domestic supply of fish "forced owners of restaurants and hotels to import fish from Recife and Natal" (IOPE 2010). A striking example of this is octopus, of which only 11% of what is served in local restaurants and hotels in in the mid-2000s was from the island itself (Leite *et al.* 2008), even though they are extremely abundant around the islands (Barros 1963). While tourism has been lucrative in some ways, it has also had several negative repercussions for the residents of the islands. One example is the establishment of National Park, which caused residents to be unable to fish from shore. Thus, along with the decline in artisanal fisheries, this caused the consumption of fish by local residents to decrease substantially, as seen by the fact that approximately 30% of the residents have developed a metabolic syndrome due to poor diet and lack of exercise (Marinho 2014). Thus, the result of modernization has had both pros and cons for the residents of Fernando de Noronha (Souza and Vieira Filho 2011).

The catches reconstructed in the present research are not all inclusive, as both national and foreign pelagic longline fleets operate in waters of all three islands, exerting substantial effort (Mazzoleni and Schwingel 2010). Furthermore, due to the limited to non-existent ability of Brazil to enforce its jurisdiction over its entire EEZ (Kalikoski and Vasconcellos 2006), particularly in SPSPA and TMV due to their distance from the mainland, illegal fishing activities are rampant, especially by foreign distant water fleets targeting pelagic species the 1990s; e.g., "vessels from Japan, Korea, Spain, and Taiwan frequently called Brazilian ports in the northeastern region for services and it is suspected that such vessels were targeting tuna in Brazilian waters (Weidner and Hall 1993). The same pattern is seen in TMV, where all domestic pelagic longline boat captains interviewed in (Pinheiro *et al.* 2010) "reported the presence of large Asian vessels operating clandestinely in Brazilian water".

It is possible that the oceanic islands of Brazil are out on a limb; on the edges of what is considered to be 'Brazil', they are isolated and lack the surveillance necessary to keep foreign presence at bay. This is compounded by the inherently fragile ecosystems of oceanic islands in the Atlantic, which puts them more at risk to overfishing than other regions of the world.

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Appendix Table A1. Total reported and reconstructed catch by sector for the oceanic islands of Brazil.

Year	Reported landings	Total reconstructed catch	Industrial	Artisanal	Subsistence	Discards
1950	-	209	-	152	48	9
1951	-	212	-	152	51	9
1952	-	214	-	152	53	9
1953	-	216	-	152	56	9
1954	-	219	-	152	58	9
1955	-	221	-	152	60	9
1956	-	224	-	152	63	9
1957	-	226	-	152	65	9
1958	-	229	-	152	68	9
1959	-	231	-	152	70	9
1960	-	233	-	152	73	9
1961	-	233	-	152	73	9
1962	-	233	-	152	73	9
1963	-	233	-	152	73	9
1964	-	258	-	175	73	10
1965	-	280	-	196	73	11
1966	-	300	-	215	73	12
1967	-	317	-	232	73	13
1968	-	333	-	247	73	14
1969	-	347	-	259	73	15
1970	-	358	-	270	72	15
1971	-	367	-	279	72	16
1972	-	374	-	286	72	16
1973	-	379	-	291	73	16
1974	-	383	-	293	73	16
1975	-	383	-	294	73	16
1976	-	439	51	293	73	22
1977	-	492	102	290	73	28
1978	-	486	101	284	73	27
1979	-	478	100	277	73	27
1980	-	467	100	268	73	26
1981	-	457	102	256	74	26
1982	-	391	54	243	74	19
1983	-	322	7	228	75	13
1984	-	307	9	210	75	12
1985	-	289	11	191	76	11
1986	-	269	13	169	76	10
1987	-	247	16	146	77	9
1988	-	176	41	65	63	7
1989	-	176	66	52	49	9
1990	-	165	92	31	31	11
1991	-	188	115	29	30	13
1992	-	211	138	28	29	16
1993	-	234	162	26	28	18
1994	-	257	185	24	27	21
1995	110	280	208	23	26	23
1996	128	316	239	23	27	27
1997	261	556	454	24	28	51
1998	240	531	431	24	29	47
1999	224	516	416	25	29	45
2000	178	447	354	25	30	38
2001	167	436	344	25	31	36
2002	290	664	548	26	32	58
2003	330	745	620	26	32	66
2004	339	768	640	26	33	68
2005	279	669	550	27	34	58
2006	303	717	593	27	34	62
2007	295	707	584	27	35	61
2008	284	689	566	28	36	59
2009	252	633	515	28	36	53
2010	205	551	441	28	37	45

Appendix Table A2. Data reported to the Brazilian state of Rio Grande do Norte for catches taken within the waters of Saint Peter and Saint Paul Archipelago (SPSPA).

Species name	*Thunnus albacares*	*Thunnus alalunga*	*Thunnus obesus*	*Istiophorus albicans*	*Tetrapturus albidus*	*Makaira nigricans*	*Xiphias gladius*	*Alopias superciliosus*	*Sphyrna lewini*	*Carcharhinus falciformis*	*Prionace glauca*
Portuguese c. name	**Albacora-laje**	**Albacora-branca**	**Albacora-bandolim**	**Agulhão-vela**	**Agulhão-branco**	**Agulhão-negro**	**Meka; Espadarte**	**Cação-raposa**	**Cação-panam**	**Cação-branco***	**Cação-azul**
Year											
1995	15.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	8.1	0.1
1996	69.2	0.0	0.1	0.0	0.0	0.1	0.2	0.0	0.1	4.1	0.0
1997	145.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0
1998	103.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.0
1999	134.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0
2000	88.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.2	0.0
2001	62.7	0.0	0.0	0.1	0.1	1.4	5.0	0.0	3.7	9.8	7.7
2002	215.7	0.1	0.0	0.2	0.0	0.6	3.8	0.1	0.9	5.0	0.9
2003	223.2	0.0	0.0	0.1	0.0	0.4	2.5	0.1	2.1	9.8	5.6
2004	187.5	0.0	0.0	0.0	0.0	0.2	0.4	0.1	0.7	4.2	0.7
2005	137.8	0.1	0.1	0.1	0.2	0.2	3.9	0.2	2.0	7.8	3.1
2006	189.7	0.0	0.0	0.2	0.0	0.6	4.5	0.3	1.0	9.1	2.9
2007	199.9	0.0	1.5	0.0	0.0	0.0	1.9	0.0	0.6	6.0	1.6
2008	207.6	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.8	1.8	1.2
2009	179.5	1.2	0.0	0.1	0.0	0.0	4.1	0.0	0.5	3.1	0.9
2010	115.3	1.2	1.0	0.0	0.0	0.1	0.2	0.0	1.1	1.2	0.6

* In original data source, stated that this refers to catch of 'cação tuninha' e 'cação lombo preto'. We assumed these catches mostly referred to the former (silky shark), a very common taxon in this region

Appendix Table A2 continued. Data reported to the Brazilian state of Rio Grande do Norte for catches taken within the waters of Saint Peter and Saint Paul Archipelago (SPSPA).

Species name	*Isurus oxyrinchus*	*Galeocerdo cuvier*	*Coryphaena hippurus*	*Acanthocybium solandri*	*Cheilopogon cyanopterus*	Marine fishes not identified	Number of trips
Portuguese c. name	**Cação-cavala**	**Cação-jaguara**	**Dourado**	**Cavala**	**Voador**	**Outros**	
Year							
1995	0.1	0.0	0.2	13.5	64.5	7.4	
1996	0.0	0.0	0.2	13.7	25.8	14.6	
1997	0.0	0.0	1.8	36.3	43.7	19.5	
1998	0.0	0.0	2.0	45.2	56.3	26.8	
1999	0.0	0.0	0.5	43.9	30.7	9.3	
2000	0.0	0.0	1.0	32.1	34.2	7.7	
2001	0.7	0.0	0.4	29.0	42.3	3.9	
2002	0.1	0.0	0.3	49.7	5.5	6.7	
2003	0.4	0.1	1.1	49.4	20.4	14.2	
2004	0.7	0.0	0.4	60.6	60.4	22.8	
2005	0.4	0.1	2.1	42.3	62.3	16.6	
2006	0.2	0.0	3.4	60.5	1.2	29.6	37
2007	0.3	0.0	3.5	48.2	3.1	28.5	36
2008	0.3	0.0	1.6	44.7	1.1	22.7	38
2009	0.3	0.0	2.0	45.0	0.5	14.7	35
2010	0.3	0.0	4.0	57.3	0.7	22.5	32

* In original data source, stated that this refers to catch of 'cação tuninha' e 'cação lombo preto'. We assumed these catches mostly referred to the former (silky shark), a very common taxon in this region

Appendix Table A3. Total reconstructed catch by taxon for the oceanic islands of Brazil.

Year	*Thunnus albacares*	Other tunas	Barracuda	*Acanthocybium solandri*	*Cheilopogon cyanopterus*	Clupeidae	Other species
1950	8	23	30	5	0	13	130
1951	8	23	30	5	0	14	132
1952	8	23	30	5	0	14	135
1953	8	23	30	5	0	14	137
1954	8	23	30	5	0	15	139
1955	8	23	30	5	0	15	141
1956	8	23	30	5	0	15	143
1957	8	23	30	5	0	15	145
1958	8	23	30	5	0	16	147
1959	8	23	30	5	0	16	150
1960	8	23	30	5	0	16	152
1961	8	23	30	5	0	16	152
1962	8	23	30	5	0	16	152
1963	8	23	30	5	0	16	152
1964	9	27	36	6	0	17	162
1965	10	31	42	7	0	18	171
1966	12	34	48	8	0	19	178
1967	13	38	54	9	0	20	184
1968	15	42	59	10	0	20	187
1969	16	45	64	11	0	21	190
1970	17	48	69	12	0	21	191
1971	18	50	74	13	0	21	191
1972	19	53	78	13	0	21	190
1973	20	55	82	14	0	21	188
1974	21	56	85	14	0	22	185
1975	21	58	88	15	0	22	181
1976	38	59	90	22	25	22	184
1977	55	59	91	28	49	22	188
1978	55	59	91	28	49	22	181
1979	55	59	91	28	49	22	175
1980	54	58	90	28	48	21	168
1981	54	56	88	27	48	21	163
1982	37	54	85	20	24	21	149
1983	19	51	81	13	0	22	135
1984	18	48	76	12	0	22	130
1985	17	44	70	11	0	22	125
1986	15	39	63	10	0	22	120
1987	13	34	55	9	0	22	115
1988	18	28	45	10	11	13	50
1989	23	20	33	11	23	14	52
1990	27	12	19	12	34	9	52
1991	34	11	17	15	46	9	56
1992	42	10	16	18	57	8	61
1993	49	9	14	20	69	8	65
1994	57	8	13	23	80	7	70
1995	29	7	11	27	128	6	72
1996	116	7	11	30	64	6	83
1997	238	6	11	75	101	6	118
1998	172	6	11	89	123	6	125
1999	221	6	10	93	79	6	101
2000	148	5	10	66	84	6	127
2001	108	5	10	58	97	6	152
2002	352	5	9	118	30	6	143
2003	365	5	9	110	61	6	189
2004	308	4	8	125	138	6	178
2005	230	4	8	86	139	6	196
2006	313	3	7	130	19	6	239
2007	330	5	7	108	24	6	228
2008	343	2	6	105	20	5	207
2009	298	4	6	105	18	5	197
2010	197	5	5	120	18	5	201