# Report on tropical Atlantic marine ecosystem dynamics in the last decades

## WP2 – D2.1

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# Outline





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# 1. Introduction

## 1.1. Foreword

With 625 million inhabitants, the coastal regions of the world –defined as "low-elevation coastal zone" (LECZ) with less than 10 m elevation above sea level (e.g., Neumann et al., 2015) host more than 8% of the world population – even 40% of the global population live within 100 km of the coastline. Taking into account only coastal countries, the LECZ comprises solely 2.3% of the total land area, but 10.9% of their population (year 2000: Neumann et al., 2015). On a global scale, 83% of the LECZ population live in the less advanced countries. Global demographic changes, migration and economic development (Hugo, 2011; Smith, 2011) and ever increasing population growth will increase the population size and density in coastal areas over the next decades, particularly in tropical and developing countries of Africa and Asia (Seto, 2011; Neumann et al., 2015). Under current scenarios of climate change and relative sea level rise, hence, more and more people will be at risk of being threatened and harmed by extreme weather events, natural hazards and disasters (McGranahan et al., 2007; Syvitski et al., 2009; Nicholls and Cazenave, 2010; Hanson et al., 2011; Hallegatte et al., 2013).

The corresponding increased use of natural resources of the coast and the adjacent seas, along with the increasing production and release of potentially polluting –including eutrophying– substances, will drive changes in coastal zones and generate ever growing pressure on coastal and marine ecosystems (Crossland et al., 2005; Patterson et al., 2008). The partly competing uses of resources and land or sea warrant conflicts among stakeholders. Marine Spatial Planning (MSP) aims at organizing and harmonizing multitude of human activities in the marine and coastal environment. Beyond exhaustively knowing the corresponding groups of stakeholders and comprehending their needs and requirements, spatially explicit information on the availability of the respective resources is key and of paramount relevance for effective spatial planning. Whereas this prerequisite of MSP is met across most of Europe's coasts and national EEZs, MSP is still in its infancy in most countries of the Tropical Atlantic. Often, awareness of natural resources and their exploitation versus availability is only fragmentary or restricted locally or –at best– regionally. Despite extensive long-term data sets of transatlantic processes between Africa and South America (e.g. "Prediction and Research moored Array in the Tropical Atlantic", www.pmel.noaa.gov/gtmba/pmel-theme/atlantic-ocean-pirata), a global view of tropical Atlantic coasts and coastal seas, and their natural resources, is essentially still lacking.

This report aims at gathering and summarizing, as a case study for Western (Brazil) and Eastern (Cape Verde, Senegal) tropical Atlantic countries, information on marine and coastal natural resources and their use and exploitation status.

## 1.2. Overall trends in oceanographic conditions in the Tropical Atlantic

The Tropical Atlantic is characterised by a belt of extremely warm sea surface temperature (SST) > 27°C centred at 5°N in the western portion. Fed by the North and South Equatorial currents as well as the outreaches of the Guinea Dome from the East Atlantic, the warm surface water masses extend to a range from 15°N to 15°S in the Western Atlantic thereby dominating the East and Northeast Brazilian coastal waters (Figure 1.1 left panel; Stramma et al., 2008; Servain et al., 2014). The Mauritanian and Senegalese regions, located in the southern part of the Canary Current upwelling system, has comparatively low average SST of < 19°C while the Cape Verde area shows SST of 25 to 26°C originating from the North Equatorial Counter Current/Mauritanian Current (Guinea Dome). The warming observed from 1985 to 2007 (Demarcq, 2009) in the western tropical Atlantic was strongly attenuated during the last 2 decades (Figure 1.1 right panel). A noticeable cooling in the



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Senegalese and Guinean regions due to an increase in the coastal upwelling intensity. The Cabo Frio upwelling in Brazil is also increasing. Other regions including Northeast Brazil present null or moderate warming (< +0.05°C per decade). The cooling observed in the upwelling areas for the same period correspond to higher phytoplankton biomasses (Figure 1.2 left panel). This positive trend in productivity was even stronger during the last 16 years (Figure 1.2 right panel). A moderate positive SST trend was observed in the equatorial region, where the eastern cooling is associated with a slight increase in Chlorophyll-c close to the equator. Finally, the temporal trend in productivity does not present a clear pattern along the coast of Northeast Brazil with a slight coastal increase when considering the full time period (1998-2018) but a moderate decrease during the last 16 years (2003-2018). Note that this discrepancy could be due to the use of two satellite sensors during the 1998-2018 period (Figure 1.2 left panel) versus the 2003-2018 period with a single sensor (MODIS).

Oceanic upwelling along the northwest African coastline stretches from 12°N to 33°N. Between 20°N and 25°N, off West-Sahara and Mauritania, upwelling occurs year-round (Mittelstaedt, 1991; Cropper et al., 2014). The sea off Mauritania and Senegal represents a transition zone between the relatively cool water masses of the Canary Current upwelling system coming from the North and the outreaches of the warm tropical waters of the Guinea Current from the South. The boundary between these water masses varies seasonally between the Cap Blanc (northern edge of Banc d'Arguin) and the region Cap Vert to Cabo Roxo (see Figure 3.1. for details on geographic locations).

The waters off northern Mauritania are among the most productive marine areas in the world (11 µg $l^{-1}$ Chl-a [chlorophyll-a]; Quack et al., 2007; primary production = 2.5 g C $m^{-2}$ $d^{-1}$, seaaroundus.org) and are important fishing grounds (Binet et al., 1998). Oceanic upwelling causes elevated concentrations of nutrients on the shelf (up to 1.3 and 18 mmol $l^{-1}$ in the surface waters, respectively; Quack et al. 2007), and influx of eolian dust is thought to result in elevated iron concentrations (e.g., Ohde and Siegel, 2010). The narrow (65 km) shelf of NW Africa broadens offshore northern Mauritania to the Golfe d'Arguin, with a width of some 150 km. This extensive gulf hosts the shallow Banc d'Arguin (ca. 15,000 $km^2$ mostly <10 m water depth; Piessens, 1979; Sevrin-Reyssac, 1993; Wolff et al., 1993) where upwelled waters warm to subtropical–tropical temperatures exceeding 25°C in summer and not dropping below 18°C in winter (Sevrin-Reyssac 1993; Quack et al. 2007).

Senegal waters are reported to have an average primary production of 1.4 g C $m^{-2}$ $d^{-1}$ (seaaroundus.org 29.06.2014). The Sine Saloum estuary is in the transition zone from dry arid landscape into mangrove fringed tropical humid coastal ecosystem and represents an important nursery for fish. The shelf is wide and provides a fertile habitat and feeding ground for bottom dwelling and small pelagic fish important for the coastal fisheries.

The tropical belt as such is seen as the most vulnerable area on earth facing the challenges of climate change. While on land, decrease of precipitation has been observed e.g. for Northwest Africa and the Northeast coast of Brazil (IPCC, 2014, p61), at the same time observed ocean warming is expected to continue in large parts of the tropical Atlantic. This shift in habitats will force many species moving polewards or into deeper waters to survive, or to significantly change their behaviors. Winners in this transformation will be adaptable species that are able to expand their ranges, while specialists will be the losers. These changes will deeply impact the ecosystems' trophic structures and their surplus production available for fisheries.



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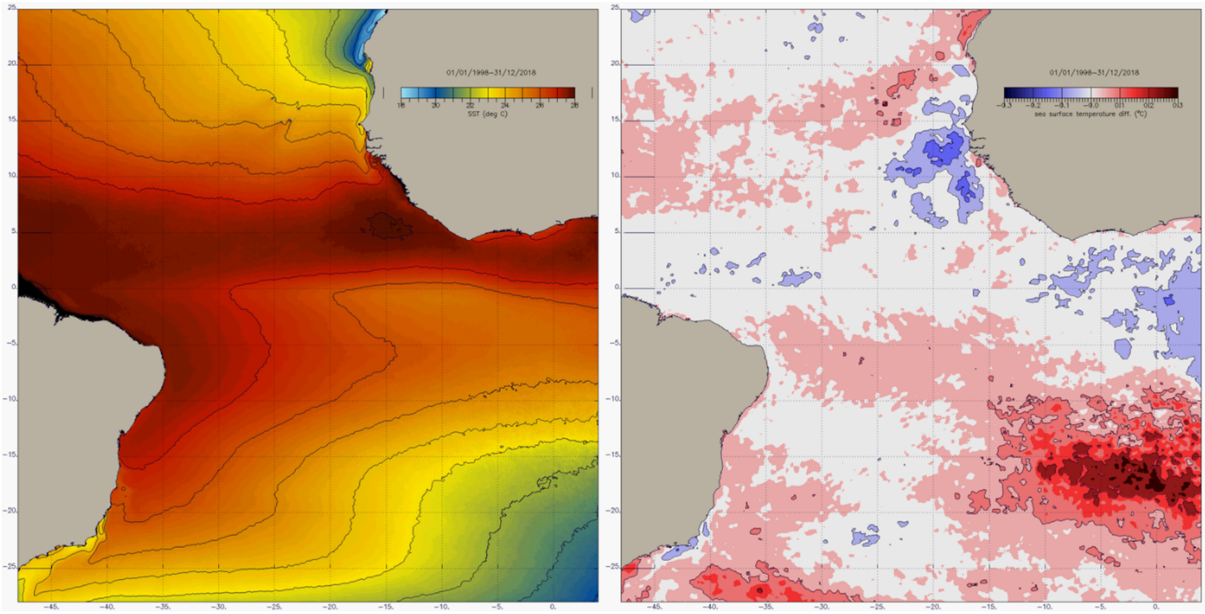

*Figure 1.1. Sea surface temperature mean (left panel) and temporal trend (right panel) in the Tropical Atlantic for the period ranging from 1998 to 2018. Data source: AVHRR SST (pathfinder v5.3), night SST and day SST data combined.*

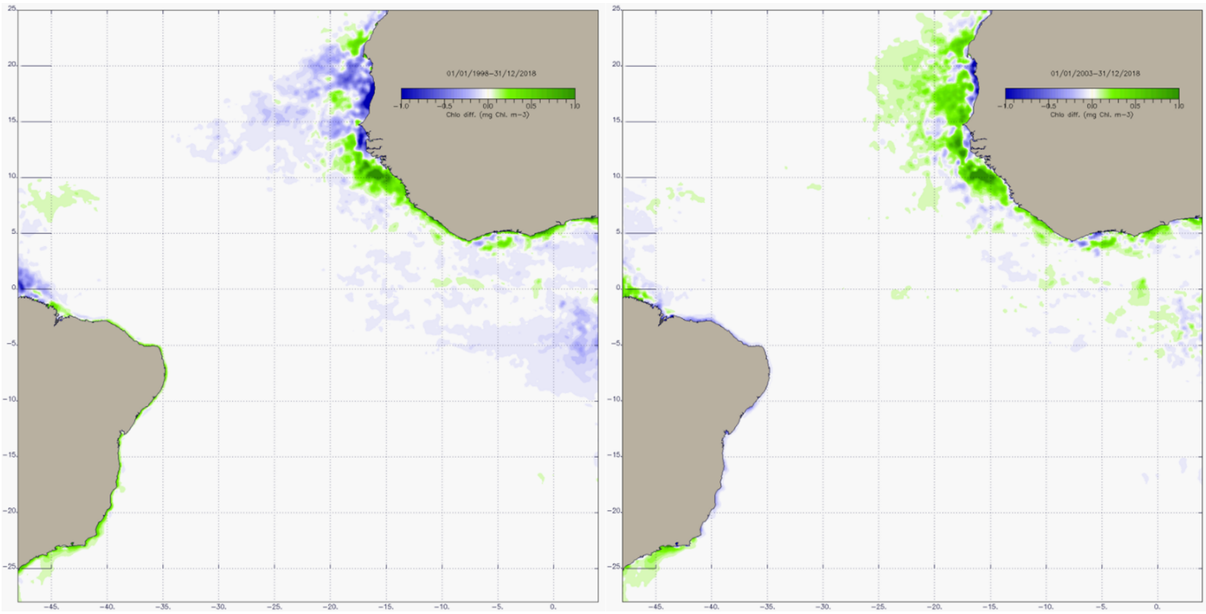

*Figure 1.2. Trend in chlorophyll-a concentration in the Tropical Atlantic during 1998-2018 (left panel) and 2003-2018. Data source: SeaWiFS (1998-2007 period) and MODIS (2003-2018 period).*



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# 2. Northeast Brazil

## 2.1. Context/Situation


*Figure 2.1. Northeast Brazil.*

As compared to highly productive upwelling areas (see above), the Northeast Brazilian coast (Figure 2.1) is characterized by a low level of productivity mainly due to the influence of oligotrophic tropical waters. The southern branch of the South Equatorial Current originating from the Angola and Benguela currents and heated up while crossing the tropical Atlantic, dominates the region and bifurcates between 5°S and 20°S into the North Brazil Current of Brazil, which moves towards Guyana, and the Brazil Current moving the southern direction. The influence of the oligotrophic Equatorial Surface Water (ESW) was found to reach up to the area between the 10 and 20 m isobath, representing 5 to 15 km from shore. This restricts the fertilisation effect by nutrient and POM export from the estuaries to a very nearshore band of sandstone reefs off Pernambuco and adjacent coasts (Ekau and Knoppers, 1999, Medeiros et al., 1999; Schwamborn et al. 1999). Also, the permanent presence of a thermocline along the entire Northeastern water contributes significantly to the impoverishment of the oceanographic environment. Since the thermal gradient is also a density gradient (pycnocline), the thermocline hinders the occurrence of vertical movements by mixing, inhibiting, consequently, the transport of nutrients to the euphotic zone. From the biological point of view, therefore, northeast Brazil is an oligotrophic region, with low primary productivity (<100 mgC $m^{-2}$ $d^{-1}$) and zooplankton biomass (< 200 mg $m^{-3}$), and a high sea surface temperature (SST) during the whole year between 26°C and 30$^{o}$C (Ferreira and Hazin, 1997). This region is dominated by sandy and rocky bottoms (Ekau and Knoppers, 1999; Vasconcelos et al., 2011) and a mostly narrow continental shelf, varying from 45 to 60 km wide in Ceará and Rio Grande do Norte; being relatively narrower in Pernambuco coasts, and wide again in the south of Bahia (200 km) (Maida and Ferreira, 1997). Coral reef formations are very important in this region and fisheries associate to this area concentrate on the reef formations distributed along the continental shelf up to the continental slope and over oceanic banks (Ferreira et al., 1998; Ferreira and Maida, 2001). However, as synthesised by Bertrand et al. (2018), Brazilian reefs might suffer a massive coral cover decline in the next 50 years and may go extinct in less than a century (Francini-Filho et al., 2008). Rhodoliths, which are non-geniculate



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nodules of coralline algae that occur in shallow waters (less than 150 m depth), are important ecosystem engineers that could also be affected. Ocean acidification could cause tropical coralline algae to stop growing by 2040 and subsequently to start dissolving (Doney, 2009).

Estuaries are preeminent ecosystems along the 9200 km of the Brazilian coast (Lana and Bernadino, 2018). As nurseries and feeding grounds for many important coastal fish species, they provide the basis for livelihood of numerous fishermen along the coast. The weather in Northeast Brazil is mainly divided into the rainy season (March- June) and the dry season (September- December). The weather conditions, although much rougher during July- August, due to the intensification of the Southeast Trade Winds, do allow fishing throughout the entire year.

Marine aquaculture activities are concentrated in Ceará and Rio Grande do Norte accounting for almost 80% of the total production in Northeast Brazil, with productions in 2007 of 21,500 t and 27,000 t, respectively. The only marine species cultivated is the *Litopenaeus vanamei*. Attempts to commercially cultivate cobia (*Rachycentron canadum*) and other reef fish species were of limited success.

## 2.2. Physical dynamics

The western tropical Atlantic Ocean is an area of prime importance to global climate change. It is an area through which oceanic signals, from intra-seasonal to decadal scales and multidecadal scales, must pass (Dengler et al., 2004; Schott et al., 2005). Moreover, this region is subjected to cyclonic and anticyclonic gyres strongly controlled by surface winds (Stramma and Schott, 1999; Lumpkin and Garzoli, 2005). These gyres drive the divergence of the southern branch of the South Equatorial Current (sSEC) (Rodrigues et al., 2007; Silva et al., 2009), which is partially at the birth site of several current systems that flow along the Brazilian coastline (Figure 2.2). The northern portion of the sSEC termination flows northward, forming the North Brazil Undercurrent/North Brazil Current (NBUC/NBC) system. This powerful western boundary current contributes to the northward Guyana Current (Bourlès et al., 1999; Stramma et al., 2005) and seasonally to the eastward North Equatorial Counter Current (NECC). It also feeds its associated complex retroflection system (Goes et al., 2005), as well as the eastward Equatorial Undercurrent (EUC). It is believed that NBC accounts for approximately one-third of the net warm-water flow transported across the equatorial tropical gyre boundary into the North Atlantic; this compensates for the southward export of North Atlantic Deep Water (NADW) through the Deep Western Boundary Current (DWBC) (Dengler et al., 2004; Schott et al., 2005).



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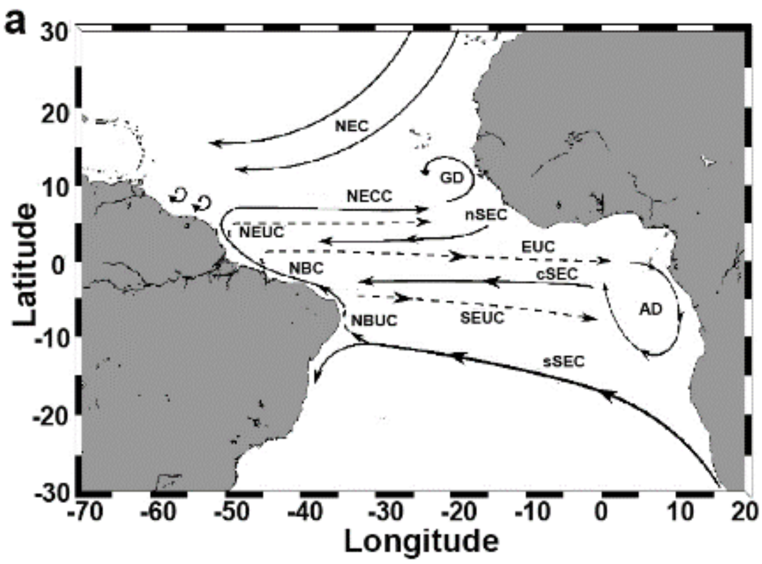


*Figure 2.2. Map of the main currents in the tropical Atlantic: North Brazil Undercurrent/North Brazil Current (NBUC/NBC), Brazil Current (BC), northern/central/southern South Equatorial Current (n/c/sSEC), North Equatorial Counter Current (NECC), North Equatorial Current (NEC). Guinea Dome (GD) and Angola Dome (AD). Source: Araujo et al. (2019).*

The north and northeast Brazilian shore is an unusually energetic coastal region subject to strong seasonally-driven focings, such as the Amazon River discharge, the North Brazil Current transport, and trade winds. The Amazonian water lenses extent up to 300/50 km offshore during the periods of maximum/minimum discharge (see Figure 2.3 for SST Chlorophyll concentration in April-June 2008). In both situations the halocline is at about 20 m depth (Silva et al., 2005). During boreal late winter and spring the Amazonian water lenses move southwestwards along the coast in northern Brazil. This pattern is less pronounced in summer and not observed in fall (Fratantoni et al., 2000).

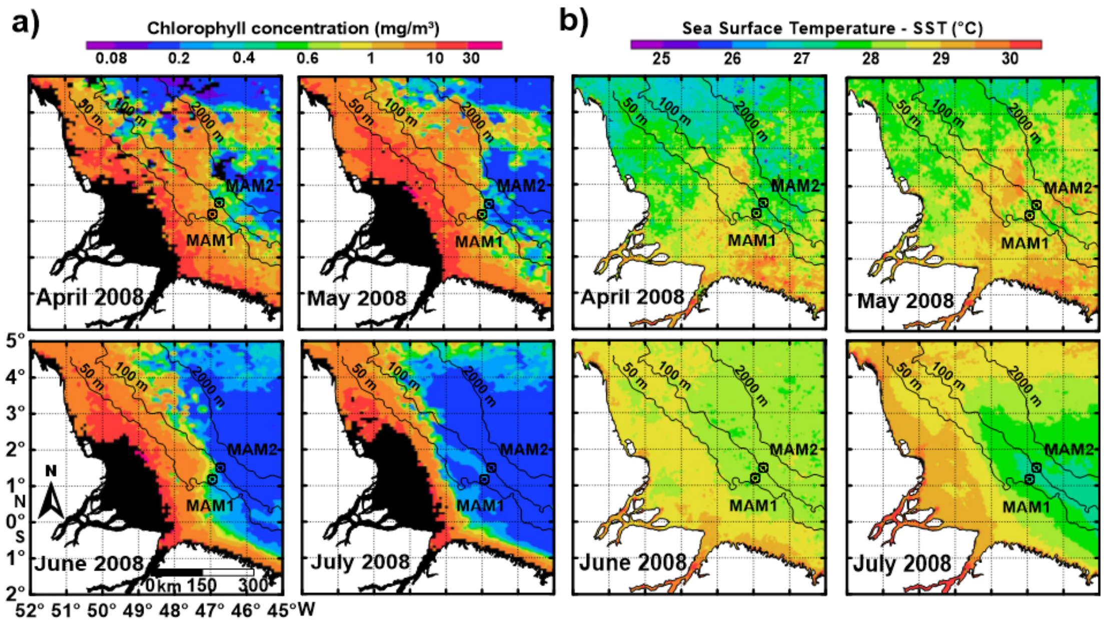


*Figure 2.3. Time series of satellite images for April, May, June, and July 2008, in northern Brazil; a) GSM-4km for chlorophyll; and b) MODIS-4km for MST. Isobath lines at 50 m, 100 m, and 2000 m are also shown, as well as the position of moorings MAM1 and MAM2 in the study area during Programme Amandes. Redrawn from: Prestes, 2016 and Prestes et al. (2018).*



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Trends in sea surface temperature (SST) anomalies from 1979 to 2017 along the northeastern coast of Brazil averaged from 2° from the coast, are presented Figure 2.4. This time-series was calculated using the daily means of the SST of the TROPFLUX dataset (Kumar et al., 2012). Until 1996, the most significant positive SST anomalies occurred in 1987-1988, reaching values slightly higher than 1°C. From 1997 on, the pattern of positive SST anomalies changes became more frequent, the highest intensity (1.2°C) occurring in the period 2008-2010. The warming is stronger in strength and intensity south of 23°S (up to 1.5°C) since 1997. Throughout this region, the years with the greatest SST positive anomaly were 1998, 2003 and 2010. Finally, drier conditions are projected along the semi-arid coast of Northeast Brazil (Jennerjahn et al., 2017).

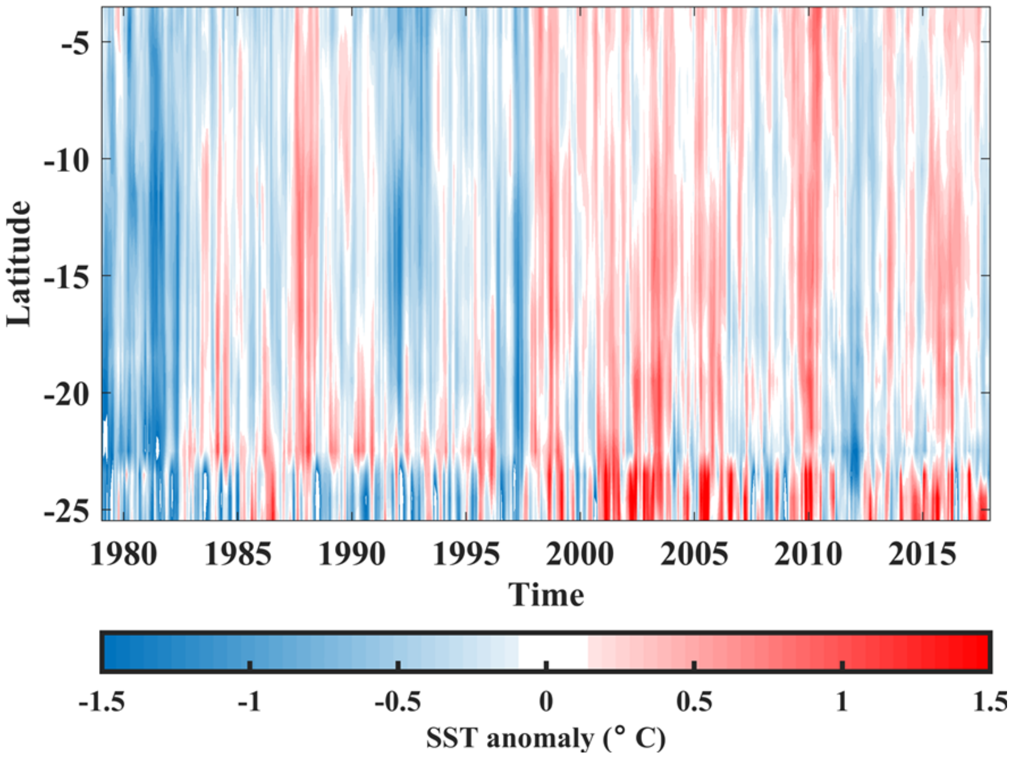


*Figure 2.4. Hovmuller of SST anomalies along the Northeastern coast of Brazil from 3.5°S to 25.5°S in the period 1979-2017.*

## 2.3. Natural and anthropogenic forcing

The Northeast is one of the most densely populated coastal regions of Brazil, with the Pernambuco State, standing out as the epicentre of this concentration. In this region, urbanization and the degradation of coastal ecosystems has resulted in multiple impacts, mainly due to domestic pollution, industrial activity and habitat degradation and loss, most severe around the main urban centre, Recife (Mérigot et al., 2017). There, the rapid growth and expansion of the urban centre over the last decades have severely affected coastal ecosystems, such as mangroves, seagrass beds and coral reefs, as well as their connectivity. Considering the multiple usages, coastal and marine resources are fundamental for the development of the country (Burke et al., 2001). However, human occupation and expansion threatened water quality and aquatic biodiversity with mangrove removal, changes in trophic structure, elimination of spawning and nursery sites, decrease in diversity, infection by pathogens, increase in parasites in commercially important species, and mercury accumulation (Viana et al., 2010, 2012).



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Brazil harbours the second largest mangrove area in the world. Based on remote-sensing data, Brazilian mangroves were estimated to have been reduced from 10,124 $km^2$ in 1983 to 9,630 $km^2$ in 2000 (Giri et al., 2011). More recently, Diniz et al. (2019) evaluated the annual Brazilian mangrove cover status as part of a continental-scale analysis from 1985 to 2018. The first period, from 1985 to 1998, presented an upward trend, which seems to be related more to the uneven distribution of Landsat-satellite data than to a regeneration of Brazilian mangroves. Then, from 1999 to 2018, a negative trend of Brazilian mangrove coverage was registered, with a loss reaching up to 2% of the mangrove forest. In terms of persistence, ~75% of the Brazilian mangroves remained unchanged (Figure 2.5) for two decades or more, including the states of North and Northeast Brazil, particularly in the State of Pará where extractive reserves (RESEX) have been implanted and run by regional cooperatives. Climate change may lead to a maximum global loss of 10% to 15% of this mangrove forest by 2100 (Alongi, 2008) but such predictions are to be considered with caution. Nevertheless, in Northeast Brazil, mangroves are expanding rapidly as result of drier conditions and saline intrusion (Jennerjahn et al., 2017). Overall, mangroves of the region are not expected to be strongly impacted by the predicted effects of climate change but by anthropic pressures (Alongi, 2015; Bertrand et al., 2018). Indeed most threats to mangroves arise from land use changes, urbanization, shrimp farms, alterations to river catchment hydrology, over-exploitation of natural resources, and coastal construction (Jennerjahn et al., 2017). Protection of coastal ecosystems and management of the use of their natural resources is hence of pivotal importance. The extractive reserves implemented in Northeast Brazil explicitly aim at sustainable resource use in locally managed consortia of stakeholders. For instance, artisanal crab-fisheries and small-scale wood-extraction for the construction of fish-traps have, according to the latest evaluations, had little, or even negligible, effects on the mangrove system of the Ajuruteua peninsula. Ongoing analyses of time series of satellite imageries of this region (V. Helfer and J. Quandt, unpublished data) aim at depicting changes in mangrove area and species composition over the last decade.

In Northeast Brazil, shrimp farms have been identified as a main threat for mangrove loss (Guimarães et al., 2010). Pelage et al. (2019) also observed a negative effect of the aquaculture in Pernambuco state, more evident in Santa Cruz Channel (Figure 2.6). However, in some estuaries of Pernambuco, an increasing trend of mangrove coverage was observed from satellite data (Diniz et al., 2019; Figure 2.5Figure 2.6), probably related to the salinization, which is a result of anthropogenic activities and climate change (Jennerjahn et al., 2017; Bertrand et al., 2018). The construction of ports, such as Suape in Pernambuco, is also another example of human-induced salinization, which altered the geomorphological and hydrodynamic conditions of the area (Koening et al., 2003), with an increase in salinity, showing a large ecological impact (Muniz et al., 2005).



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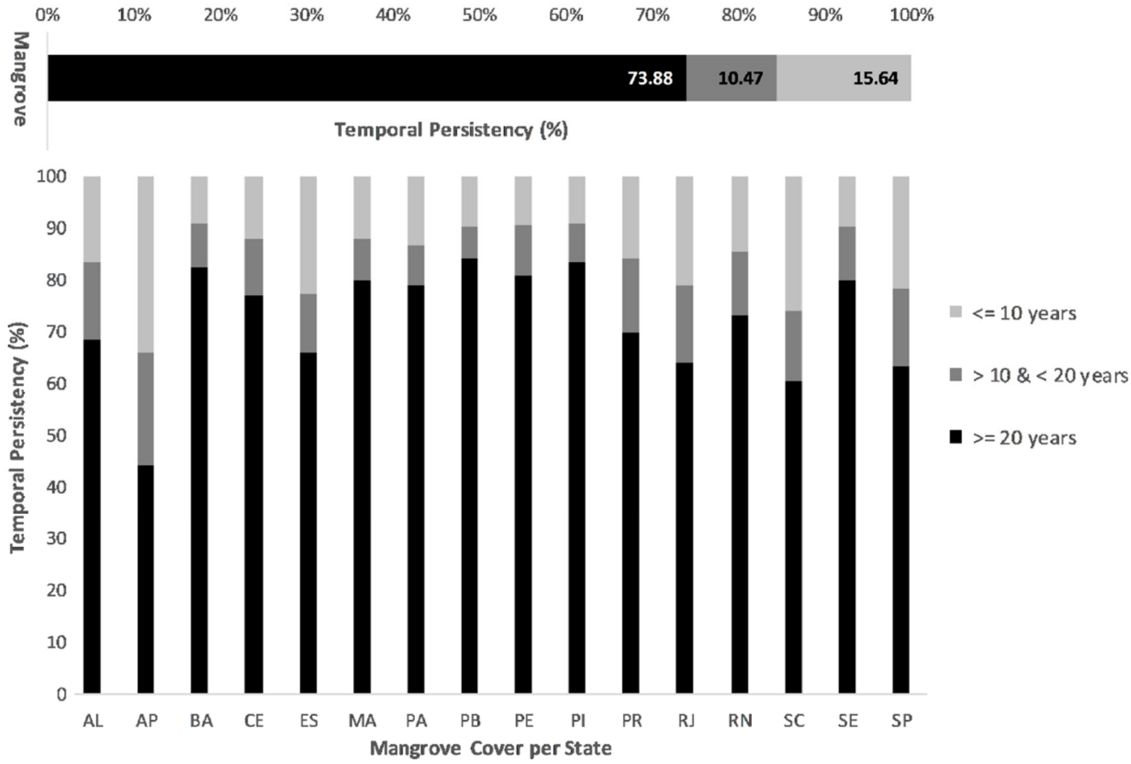


*Figure 2.5. Brazilian mangrove cover at the national and regional scale. The top bar shows the overall mangrove persistence. The bottom graph shows the mangrove persistence per state. The x-axis represents the state distributions, whereas the y-axis represents the mangrove cover temporal persistence percentages (%). Black represents 20 years or more of stability, dark grey indicates stability between 10 and 20 years and light grey represents stability for less than 10 years. The following acronyms represent the Brazilian coastal states: AL (Alagoas), AP (Amapá), BA (Bahia), CE (Ceará), ES (Espírito Santo), MA (Maranhão), PA (Pará), PB (Paraíba), PE (Pernambuco), PI (PiauíCE (Ceará), ES (Espírito Santo), MA (Maranhão), PA (Pará), PB (Paraíba), PE (Pernambuco), PI (Piauí), PR (Paraná), RJ (Rio de Janeiro), RN (Rio Grande do Norte), SC (Santa Catarina), SE (Sergipe) and SP (São Paulo). Source: Diniz et al. (2019).*



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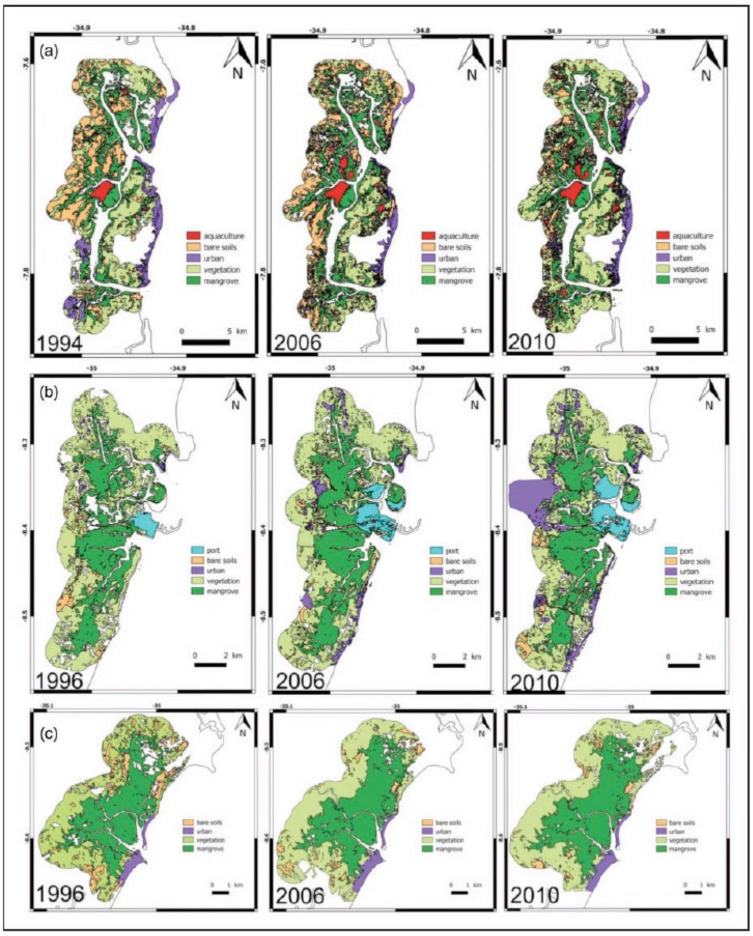


*Figure 2.6. Spatial evolution of mangrove areas and anthropic activities over the past three decades in (a) the Santa Cruz Channel, (b) Suape, and (c) Sirinhaém in Pernambuco (Brazil). Source: Pelage et al. (2019).*

Anthropogenic impacts related to mercury contamination in the sediment of the drainage basin of the north coast of Pernambuco state has been also previously documented (Meyer et al., 1998; Lima, 2008, 2009; Gondim, 2015), as a large source of contamination. Despite regulations, which contributed to reduce the use of mercury (Lacerda, 1997), the problem persists. Mercury is indeed highly stable in the environment and bioavailable through its biogeochemical cycle for several years, even if the source of contamination has ceased, as observed in others countries (Birkett et al., 2002; Fitzgerald and Lamborg, 2013; Levin, 2015). In Pernambuco state, mercury concentrations in the sediment are higher than the acceptable limit for maintenance of the biota. In addition, strong relationships were observed between Hg levels in the sediment and those in organisms, confirmed by a methylmercury biomagnification model (Flavia Lucena-Frédou, unpublished data).

Leaving the coastal zone, Oceanic islands, present in Northeast Brazil are particular environments that, given their geographic isolation, usually harbour a peculiar biodiversity, with a large number of endemic species. In Fernando de Noronha for example, the construction of jetties in the late 1980s generated a population explosion of the white urchin (*Tripneustes ventricosus)* (Soto, 2009).



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## 2.4. Fisheries distribution, abundance, seasonality, production and Aquaculture

### 2.4.1. Overall characteristics

In Brazil, small-scale fisheries (SSF) represent more than 90% of employment in the fisheries sector. In 2011, almost 600 000 fishers were engaged directly in full time fishing activities within fishing fleets composed of vessels of less than 12 m length. Most of the industrial fishing fleet is concentrated in Southern Brazil, while most SSF effort is concentrated in the north and northeast regions (Bertrand et al., 2018). Brazil has a poor record in fisheries management and several stocks in that country face over-exploitation and lack of systematic management (Gasalla et al., 2017). Marine extractive reserves represent the most significant government-supported effort to protect the common property resources upon which traditional small-scale fishers depend. They benefit 60 000 small-scale fishers along the coast, even though their efficiency is hampered by low enforcement and other anthropic and economic pressures, including tourism (Santos and Schiavetti, 2014; Bertrand et al., 2018). In addition, Brazil is a data-poor region in terms of fisheries. Weak governance, the erosion of traditional resource use systems, open-access regimes, poverty, lack of alternative employment, and easy access to stocks with low investment and operating costs have promoted overfishing and exacerbated climate-induced changes in SSF (Gasalla et al., 2017; Bertrand et al., 2018). Actually, there is a continuous worsening of the problems affecting the production of artisanal fisheries owing to the depletion of fisheries resources, environmental degradation of coastal areas, and ultimately to the ineffectiveness of governmental strategies in overcoming the obstacles that impede the sustained development of the artisanal fishing communities along the Brazilian coast. The overall lack of information about these fisheries is a subsidiary problem that gives low political visibility to the sector and thus helps perpetuate its status (Vasconcelos et al., 2011).

In Northeast Brazil, SSF account for more than 80% of the total landings (Paiva, 1997; Diegues, 2006). Fisheries are based on small- to medium-sized boats using sail or small engines, canoes using oars or sail. Based on a multi-year Brazilian research Program REVIZEE (Avaliação do Potencial Sustentável da Zona Econômica Exclusiva do Brasil) created by the Brazilian Government in compliance with the United Nations Convention of the Law of the Sea, carried out during the late 1990´s and early 2000, sailboats accounted for 58.2% of the landings, whereas motorized boats accounted for 40.8% (Lessa et al., 2009b).

There is a large diversity of species and fishing gear/methods used in coastal fisheries in the northeast (Vasconcelos et al., 2011). Lobsters (*Panulirus argus* and *P. laevicauda*), caught by traps, is an important exportation product and, although it has long been overexploited, it is the most valuable product in the region. In northeast Brazil, Penaeidae shrimp fishery is carried out mainly by artisanal motorized boats operating in shallow coastal waters with trawlers, catching (decreasing order in landing volume) the seabob shrimp *Xiphopenaeus kroyeri* (Santos et al., 2006), the white shrimp *Litopenaeus schmitti*, (which has the highest economic value), and the pink shrimps *Farfantepenaeus subtilis* and *F. brasiliensis.*

In coastal waters, gillnets, longlines, hook-and-line and traps are the most common gears in catching fish (see Table 2.1 for the main gear for the main species caught in Northeast Brazil). According to Lessa et al. (2009b), bottom lines and surface lines contribute to around 34% of the production, capturing species of great economic value, whereas gillnets are responsible for 27% of the regional production and capture species of lesser value. The line fleet operates up to 250 meters deep, with distances of up to 30 nm from the coast on trips of up to 22 days. The gillnetting fleet operates in waters shallower than 100 m on an average 3-day trips. Fish traps are more used in the Pernambuco than other Northeast States (Lessa et al., 2009b).



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Demersal species such as snappers (*Lutjanus analis, L. jocu, L. synagris, L. vivanus, L chrysurus*), and pelagic species such as dolphinfish (*Coryphaena hippurus*), flying fish (*Hirundichthys affinis*), mackerels (*Scomberomorus brasiliensis* and *S. cavalla*) represents 40.6% of total landing in weight. Added the catches of groupers (*Seriola dumerili* and *Mycteroperca bonaci*) and pompanos (*Caranx spp*), this percentage reaches 65.3% (Lessa et al., 2009b).

Fishery inside estuaries and coastal lagoons capturing anchovies, mullets, needlefish, and shrimps are also reported. Manual collection of crabs and molluscs in mangrove areas is particularly important throughout the region (Vasconcelos et al., 2011). More than 80% of the rural households in Pará State gain resources for their livelihood directly from the mangrove forest; 43% of all households fish and sell mangrove crabs (Glaser 2003; Glaser et al. 2010), being mayor key for sociopolitical stability and social sustainability in the region and for low-income classes (Glaser, 2003; Glaser and Diele, 2004, Diele et al. 2010). Professional crab fishers capture crabs in their burrow by hand and sell them alive or for processing, earning about the Brazilian minimum wage (Glaser 2003). Fishing grounds are reached from land either by walking, with a bicycle or by public bus transportation. Small canoes or motor vessels are used to access fishing grounds adjacent to the sea. Little is known about the spatial expansion of the crab fisheries (Araujo 2006).

Brazilian Fisheries Statistics have not been reported since 2007, when the existing system was gradually dismantled and not replaced. According to the results of this program, Brazilian fisheries far exceeded sustainable target levels in the main portion and, the majority of stocks were either fully (23%) or over-exploited (33%) (MMA, 2006). Particularly in the Northeast, 16% were in a development stage, 25% was considered overexploited, 16% were considered fully exploited and the remaining 44% of the resources were not assessed (MMA, 2006). The main available information is summarized Table 2.1. Snappers were mainly over or fully exploited. *Pseudupenaeus maculatus*, *Haemulon aurolineatum, Carangoides bartholomaei, Carangoides crysus* were, by this time, underexploited and, most small pelagic were considered overexploited, fully exploited or near to fully exploitation (MMA, 2006). Stocks of lobsters are being overfished and show a decreasing trend in landings since the 1990s, and landings of groupers show a decreasing trend over time with long-lived species being overfished, resulting in the targeting of smaller and shorter-lived groupers (Vasconcelos et al., 2011). In this time, there was no assessments of the status of the stock(s) of mangrove crabs. However, the decrease in landings of mangrove crabs in most northeastern states (but not all, e.g. Pará) is understood as a sign of overfishing (Vasconcelos et al., 2011). It is important to outstand that those assessment of northeast Brazilian resources were not actualised since the early 2000. **This is a serious obstacle for the development of an effective Marine Spatial Planning.**

After the Program REVIZEE, the stocks have never been re-assessed though a national initiative. However, specific programs were developed to assess the sustainability of some fishery resources. For example, the status of the stocks of penaeidae exploited in Pernambuco have been assessed. Results indicated that L. schmitti and seabob-shrimp *X. kroyeri* stocks are relatively close to the state of full exploitation (Lopes et al., 2014; Silva et al., 2018a) and the pink shrimp *F. subtilis* exploitation rate for maximum recruitment yield is lightly above the exploitation rates (0.50-0.64) (Silva et al., 2015).


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*Table 2.1. Main species of Northeast Brazilian coast, gear of main vulnerability, depth of occurrence and status of the stock. Modified from MMA (2006)*

| Species | Gear of main vulnerability | Depth of occurrence | Status of the stock |
|---|---|---|---|
| | | ***Reef species*** | |
| *Lutajnus analis* | Bottom longline | Continental shelf (20 -80m) | Overexploited |
| *Lutjanus crysurus* | Bottom longline | Continental shelf (< 100m) | Overexploited |
| *Lutjanus jocu* | Bottom longline | Continental shelf | Fully exploited |
| *Lutjanus synagris* | Bottom longline | Continental shelf | Overexploited |
| *Lutjanus vivanus* | Bottom longline | Continental shelf (> 70m) | Near to fully exploitation |
| *Lutjanus purpureus* | Bottom longline | Continental shelf (31 a 140m) and Oceanic banks | Overexploited |
| *Pseudupenaus maculatus* | Fish trap | Continental shelf (< 90m) | Bellow the maximum limit |
| *Haemulon aurolineatum* | Fish trap | Continental shelf (15 a 60m) | Underexploited |
| *Haemulon plumieri* | Fish trap and gill net | Continental shelf | Not evaluated |
| *Seriola dumerili* | Bottom longline | Continental shelf | Not evaluated |
| *Caranx latus* | Handline | Continental shelf | Not evaluated |
| *Carangoides bartholomaei* | Bottom longline and handline | Continental shelf | Underexploited |
| *Carangoides crysus* | Gill net | Continental shelf | Underexploited |
| *Myctepoperca bonaci* | Bottom longline | Continental shelf | Not evaluated |
| *Rhizoprionodon porosus* | Gill net | Continental shelf | Not evaluated |
| | | **Small pelagics** | |
| *Hirundichthys affinis* | Gill net | 0-100 | Overexploited |
| *Scomberomorus brasiliensis* | Surface gill net | Continental shelf | Fully exploited |
| *Scomberomorus cavalla* | Pelagic longline | Continental shelf | Near to fully exploitation |
| *Hemiramphus brasiliensis* | Seine | Continental shelf | Bellow the maximum limit |
| *Hyporhamphus unifaciatus* | Gill net | Continental shelf | Overexploited |
| *Ophistonema oglinum* | Gill net | Continental shelf | Near to fully exploitation |

The Brazilian program "Institutes of the Millennium", through the project entitled "Use and Ownership of Coastal Resources" ("Uso e Apropriação dos Recursos Costeiros -RECOS), was structured in the form of an inter-institutional network, aiming at generating knowledge on fishery into a broader perspective, involving the economic, technological, social, ecological and management aspects of the fishery, in order to provide recommendations to the decision makers in the states of Pará, Maranhão, Pernambuco, Espírito Santo, Rio de Janeiro, Paraná, Santa Catarina and Rio Grande do Sul. Particularly in Pernambuco, Lessa et al. (2009a) identified seventeen fishery systems covering gillnets, traps and seines targeting fish and crustaceans as well as hand-collected mussels (Table 2.2). They observed a decreasing trend in crustacean catches from 1991 to 2009 and an increasing trend for the bivalve mussels *Anomalocardia brasiliana*, *Protothaca pectorina*, *Lucina pectinata* and *Tagelus plebeius*. Following the RAPFISH method (Rapid Appraisal for Fisheries), the shrimp system is the least sustainable, given its ecological impact mainly; and the most sustainable system were attributed to the stationary uncovered pound net, followed by the line system (Lessa et al., 2009a), which mostly approximate of the reference or ideal system (Figure 2.7).



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*Table 2.2. Fishery systems identified in Pernambuco and variables employed as criteria for system classification. Source. Lessa et al. (2009a)*

| System name | Acronym | Propulsion | Gear | Target resource | Environment | Work relation | Income |
|---|---|---|---|---|---|---|---|
| Common halfbeak | CHB | Oars, sail and motor | Gillnet | Common halfbeak | Coastal | Partnership | Equal |
| Ballyhoo | BLH | Sail and motor | Seine | Ballyhoo | Coastal | Partnership | Equal |
| Stationary uncovered pound net | SUPN | Oars | Trap | Fish | Coastal | Partnership | Equal |
| Fish trap | FTP | Motor | Trap | Spotted goatfish | Coastal | Partnership | Equal |
| Trammel bottom set | TBS | Oars | Seine | Fish and crustaceans | Estuary | Partnership | Lower |
| Barrier net | BRN | Oars | Gillnet | Fish and crustaceans | Estuary | Partnership | Lower |
| Beach seine | BCS | Oars | Seine | Fish, crustaceans and mollusks | Coastal | Partnership | Lower |
| Gillnet | GLN | Motor | Gillnet | Fish | Coastal | Partnership | |
| Line | LNE | Motor | Line | Fish | Coastal | Partnership | Higher |
| Lobster | LBT | Motor | Gillnet | Lobster | Coastal | Boat owner | Higher |
| Shrimp | SRP | Motor | Seine | Shrimp | Coastal | Partnership | Higher |
| Bottom long line | BLL | Motor | Line | Sharks, albacore | Coastal | Boat owner | Equal |
| Crab | CRB | On foot | Hand collection | Crab | Estuary | Family | Lower |
| Blue land crab | BLC | On foot | Trap | Blue land crab | Estuary | Family | Lower |
| Mangrove crab | MGC | On foot | Hand collection | Mangrove crab | Estuary | Family | Lower |
| Blue crab | BUC | On foot | Hand collection | Blue crab | Estuary | Family | Lower |
| Mussel collectors | MSC | On foot | Hand collection | Mussels | Estuary | Family | Lower |

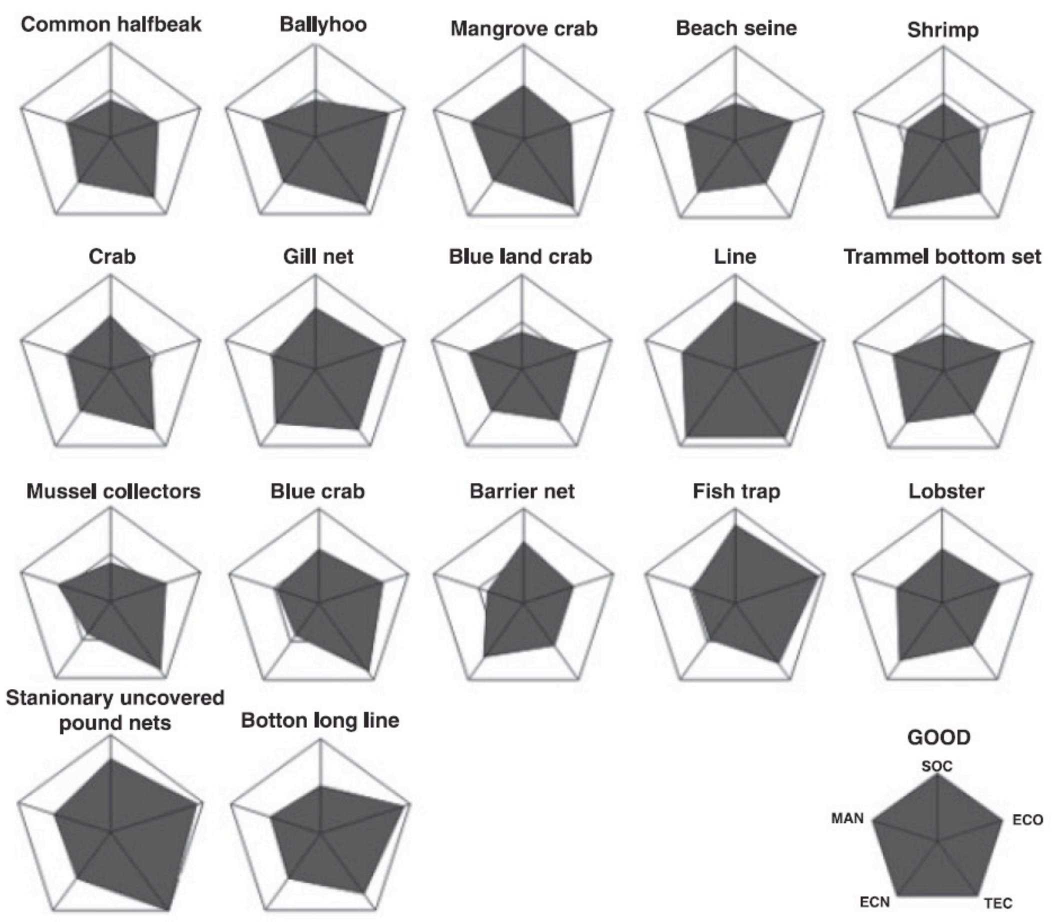


*Figure 2.7. Average percentage values of sustainability indicators of each evaluation field for fishery systems, state of Pernambuco, represented in kite diagrams. "GOOD" kite = reference or ideal system, with 100% in all evaluation fields (SOC = social, ECO = ecological, TEC = technological, ECN = economic, MAN = management). Source. Lessa et al. (2009a).*



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Brazilian aquatic resources have also been evaluated according to the IUCN Red List categories at the regional level. These categories comprise 10 levels: Extinct (EX), Regionally Extinct (RE), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). The first list of Brazilian fauna threatened to extinction was published in 1968 and included 42 species of reptiles, birds and mammals. That number doubled five years later, when 85 species were on the next list. After 16 years, in 1989, 219 species of vertebrates (except fish), in addition to some terrestrial invertebrates were evaluated (Pinheiro et al., 2015). Within the Brazilian National Biodiversity Policy instituted 2002, a review of this list was carried out, ending up in a total of 10 aquatic invertebrates and 37 threatened fish, which were considered as overexploited or under threat of overexploitation (IN 5 / 2004) (Pinheiro et al., 2015). The following year, within the National Biodiversity Targets the state of conservation of all species of plants, vertebrates and key invertebrate groups were reviewed in a process leaded by the ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade, Ministério do Meio Ambiente, Brazil), and the red list, published in 2014 (Portaria 445), enumerated 475 aquatic species as threatened (Figure 2.8Figure 2.8). Marine elasmobranchs represented 56.1% of all endangered fish in Brazil, and 82.4% of the species categorized as Critically Endangered.

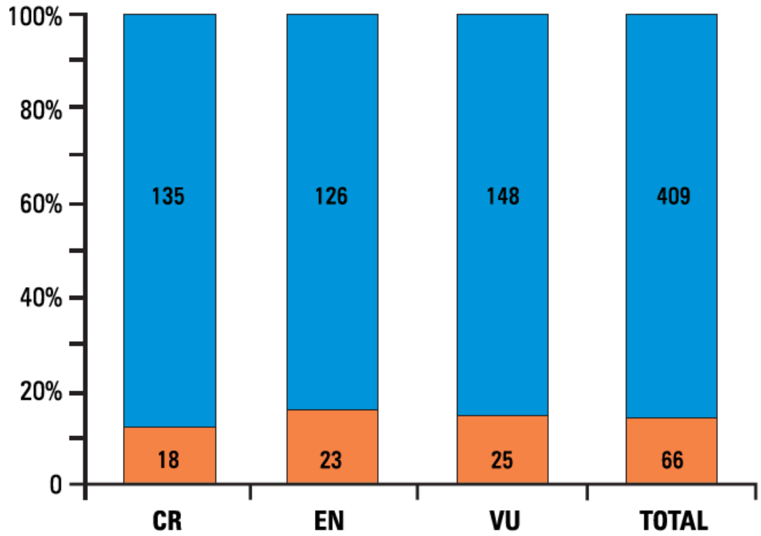


*Figure 2.8. Number of aquatic fishes and invertebrates within the three categories: CR (Critically endangered); EN (endangered); VU (vulnerable). (MMA 445/2014). Blue – aquatic fish. Orange – aquatic invertebrates. Source: Pinheiro et al. (2015).*

Some threatened species are particularly important in the northeast region. The Guaiamú (*Cardisoma guanhumi*) is an endemic crab of Brazilian estuaries, mangroves and salt flats, with slow growth, occupying restricted areas. The species is targeted by artisanal fishing and was classified as Critically Endangered, which direct impact on some traditional communities in the Brazilian Northeast, where its extraction is more frequent (Pinheiro et al., 2015). The snapper *Lutjanus purpureus*, categorized as Vulnerable, was a relevant fishing resource on the northeastern coast of Brazil in the 1960s to 1980s, until the fishing collapse in that region. Currently, the fleet explores new areas in north Brazil, where its fishing is still economically viable. The Scaridae species - *Scarus trispinosus* (EN), *Scarus zelindae* (VU), *Sparisoma frondosum* (VU) and *Sparisoma axillare* (VU) – within the current Brazilian red list, are also important resources in Northeast Brazil.

Freire and Pauly (2010) carried out an analysis of Brazilian marine fisheries catch data covering the years 1978–2000 aiming at testing for the occurrence of the 'fishing down the marine food web'



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phenomenon in the East Brazil Large Marine Ecosystem. They concluded that the marine biodiversity of Northeast Brazil is being eroded. Indeed, the decline of the average trophic level of the catches, occurring through most of Northeastern Brazil was shown to occur at a rate of 0.16 trophic level per decade, one of the highest rates of trophic level decline documented in the world. The downward trend in Marine Trophic Index (MTI) was evident when the analysis was performed by States, and "fishing down the food web" was detected in landings originating from five out of the seven northeast States for which landing data was collected by the official Brazilian statistics (ESTATPESCA program) (Figure 2.9).

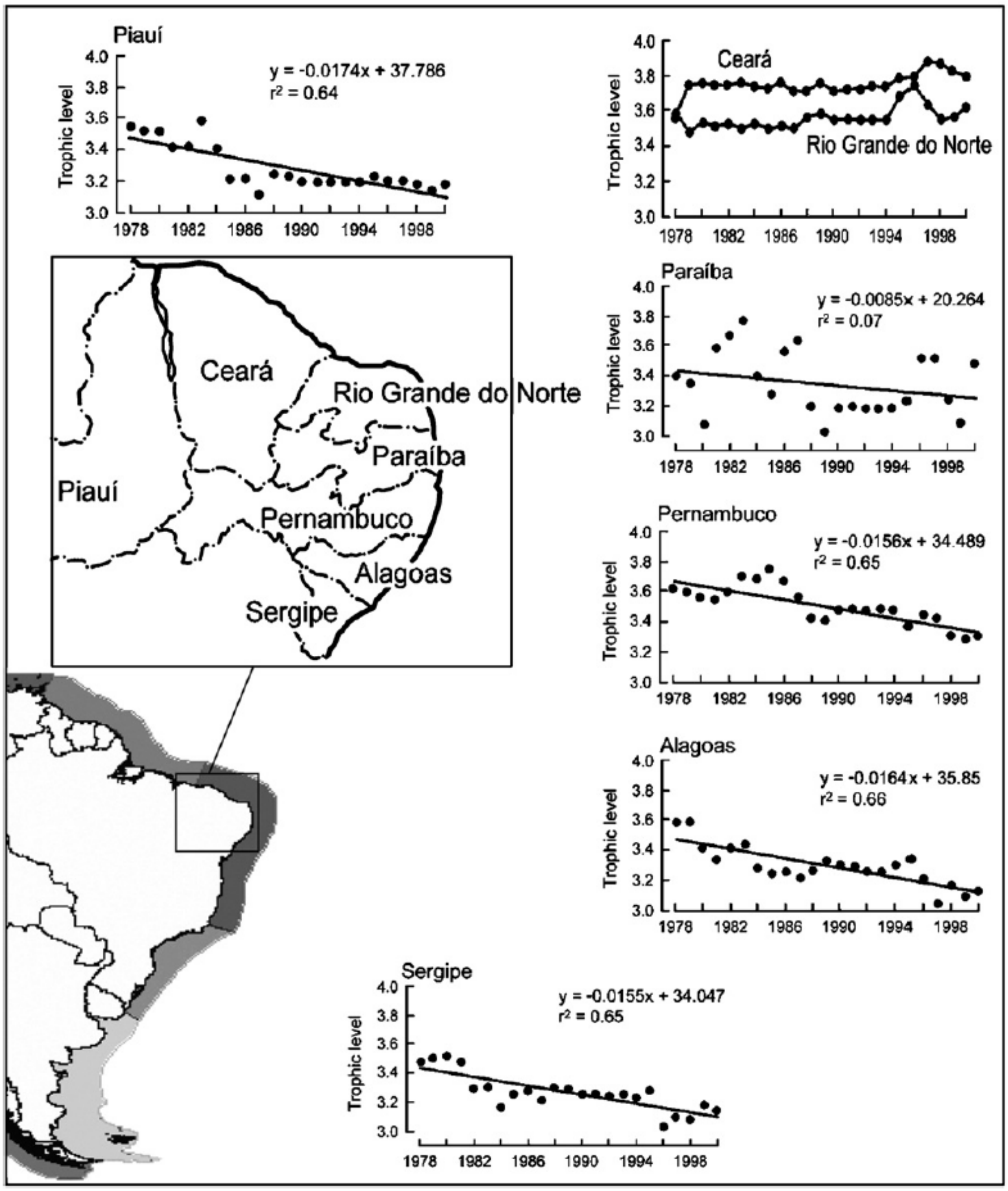


*Figure 2.9. Changes in mean trophic level for landings from Northeastern Brazil in 1978–2000. PI = Piauí, CE = Ceará, RN= Rio Grande do Norte, PB = Paraíba, PE = Pernambuco, AL = Alagoas, and SE = Sergipe. The States of Maranhão and Bahia are not shown due to the lack of a proper system of data collection. Large Marine Ecosystem 16 (East Brazil) is shown in dark gray. Source: Freire and Pauly (2010).*

### 2.4.2. Temporal trends

The last year with fisheries statistics available in Brazil was 2007, more than a decade ago. After that year on, the existing system for the collection of primary data was gradually dismantled and not



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replaced. During 1962-2007 Northeast catches increased from ~40 000 to more than 150 000 tonnes (Figure 2.10). This trend was not linear since a first maximum (~140 000 t) occurred in the early 1980s followed by a reduction in the late 1980s-early 1900s. In 2007, the total landings of marine fish from capture in the northeast region, from Bahia to Maranhão, was 155,625 t, accounting for about 30% of national landings from marine capture fisheries (540,000 t). Bahia (44,932 t) and Maranhão (41,840 t) were the largest producers, accounting for more than half (56%) of the landings in the region. The ten main finfish products were: snappers (Lutjanidae) (5,021 t), tunas and mackerels (Scombridae) (3,951 t), sardines (Clupeidae) (3,413 t), mullets (Mugilidae) (3,333 t), grunts (Haemulidae) (1,473 t), flying-fish (1,255 t) (Exocoetidae), jacks (Carangidae) (1,212 t), anchovies (Engraulidae) (1,131 t), croakers (Sciaenidae) (750 t), and catfish (Ariidae) (616 t). Among the crustaceans, the main products were the spiny lobsters (4,900 t) and shrimps, including mainly the seabob (8,607 t) and the white shrimp (3,612 t).

Catch data per municipality are available in Pernambuco state (Figure 2.11). Trends are dissimilar according to the municipality, but those accounting for the bulk of catches, located mainly in the northern part of the state (see Figure 2.12 for temporal trends in the number of active boats per municipality) presented an overall increase from 1988 to 2007. Note that these trends should be viewed with caution. Indeed, the sharp increase in catches that began in 2005 (Figure 2.11) seems unrelated to the increase in the number of active boats for this period (Figure 2.12). One of the explanatory hypotheses seems to be related to the coverage of surveys, mainly those concerning shellfish collection, which has probably increased over the years. Moreover, it is difficult to estimate the number of boats exhaustively in the absence of precise documentation and the values (catches and effort) are probably underestimated but in a lesser extend at the end of the time-series.

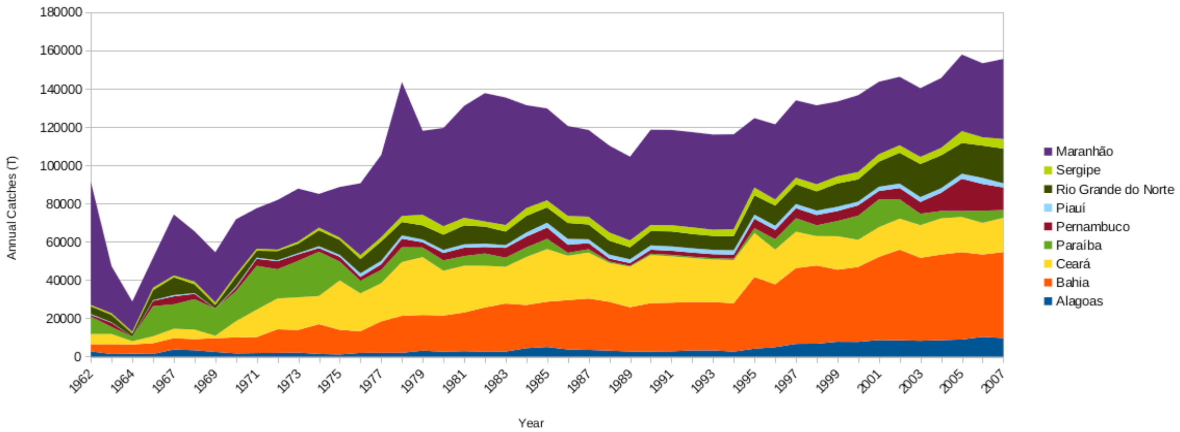


*Figure 2.10. Annual catch (in tonnes) per State in Northeast Brazil during 1962-2007.*



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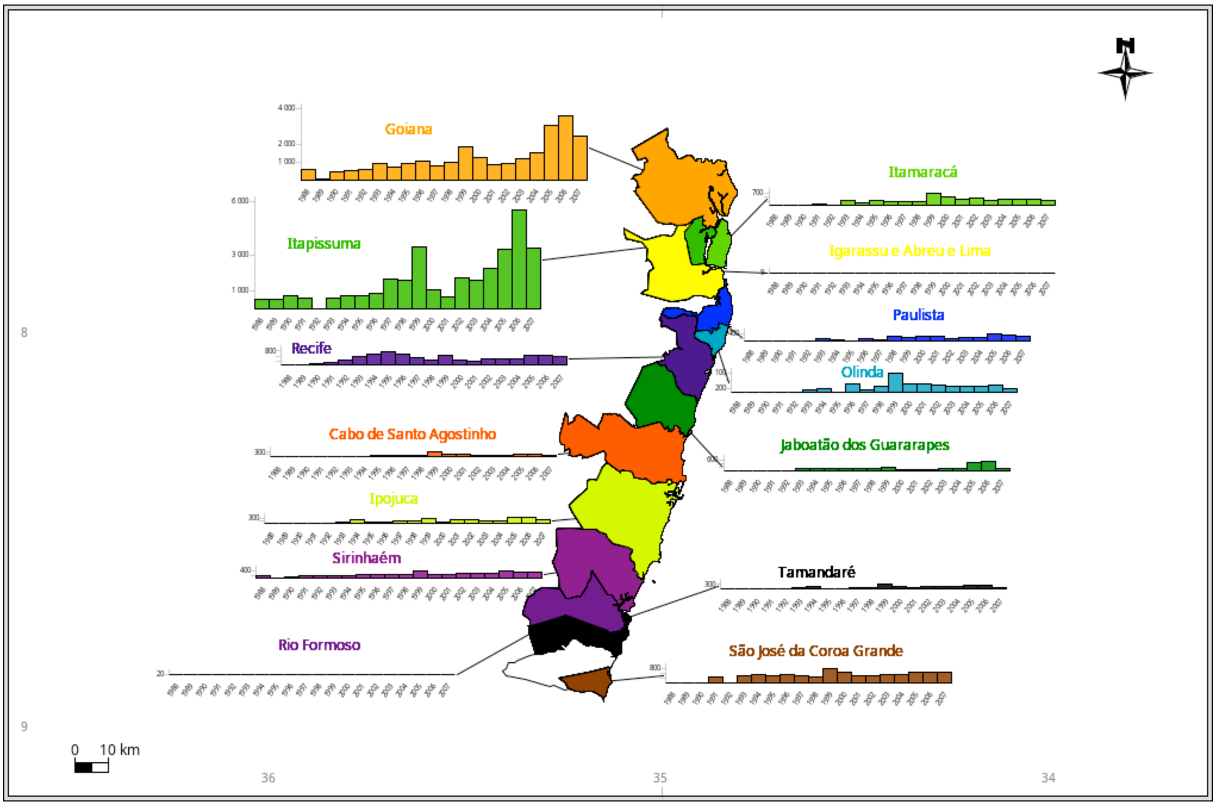


*Figure 2.11. Annual catches per Municipality in Pernambuco State from 1988 to 2007. Data source: Ibama (1995), Ibama-Cepene (2000-2007) and Freire (2003).*

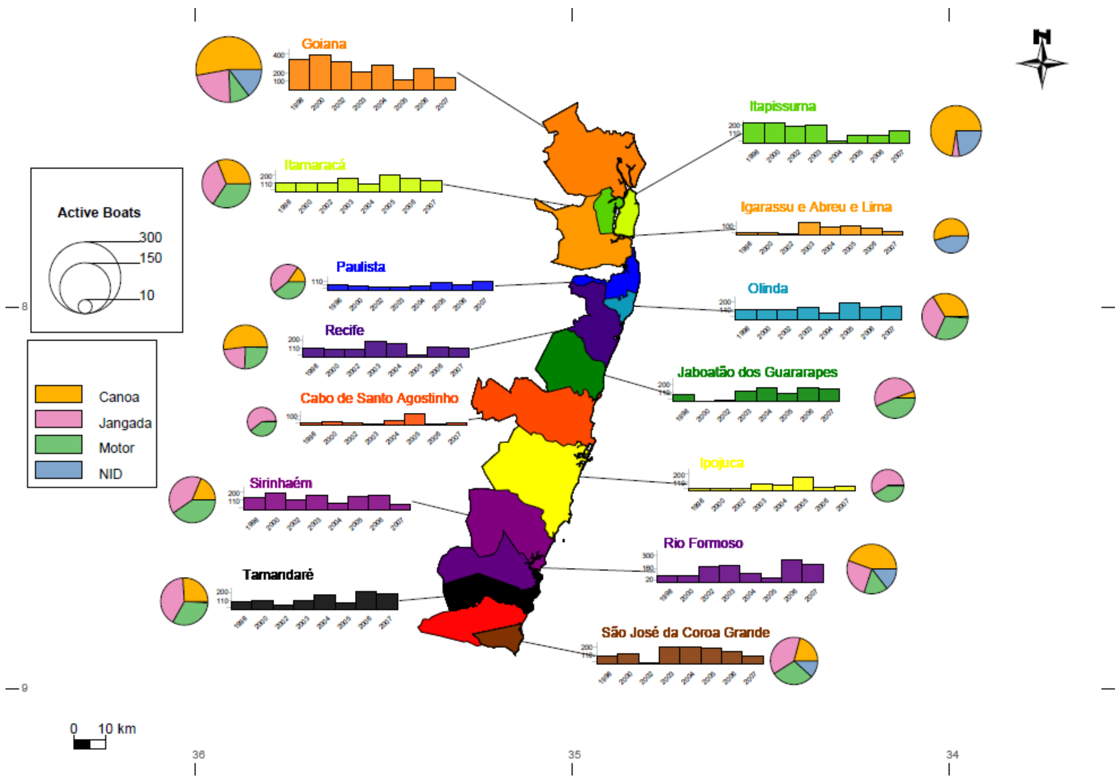


*Figure 2.12. Number of operating boat (histograms) per year and per Municipality in Pernambuco State from 1988 to 2007 and average proportion of types of boats (pies) per Municipality (NID: manual collect of shellfish). Data source: Ibama (1995), Ibama-Cepene (2000-2007) and Freire (2003).*



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**Tuna fisheries**

The fishery of oceanic pelagic species in Brazil began before the intense process of industrialization of the national fishing sector at the end of the 1960s. The first prospections for tuna on the Brazilian coast was carried out in 1956 by FAO and the Japanese oceanographic ship Toko Maru. The commercial fishing of tuna and like with longline boats on the northeastern coast of Brazil began in the same year, when Japanese boats were rented. In 1964, the activities of these leased boats, based in the Port of Recife, were suspended for political and economic reasons. Fishing activities with foreign boats were resumed at the end of 1976, and in 1983, a fishing company based in Natal (RN), started fishing with longliners using national technology and labour. From 1996 onwards, from the lease of an American boat equipped for the fishery of swordfish with monofilament, the tuna fleet of Rio Grande do Norte experienced a strong growth, reaching more than 30 boats in 2000 (Ferreira and Hazin, 1997).

During its development, the fishing of tuna and like with longlines from the port of Natal presented 6 distinct phases. In the first phase, between 1983 and mid-1986, the target species were yellowfin tuna, which accounted for most of the catches and, from that year on, given the commercial value of sharks, they became the most commonly caught species, particularly the blue shark *Prionace glauca*, characterizing the second phase. In the third phase, starting in 1988, the boats began to concentrate their fishing effort near the São Pedro and São Paulo Archipelago, during the first quarter of the year, obtaining high rates of capture of yellowfin. From June 1991, the fourth phase began, it was observed that sharks of the genus Carcharhinus were concentrated on the ocean banks located north of Rio Grande do Norte and Ceará. These sharks then became the main component of catches. In mid-1997, the fifth phase began, with a substantial increase of the capture rates of the swordfish and *Thunnus obesus*, due to the introduction of the monofilament longline fishing technique. Finally, at the end of 2001, the sixth phase began, with the introduction of rented vessels operating with Taiwanese technology, aimed at capturing the *Thunnus alalunga* and *T. obesus* (Ferreira and Hazin, 1997). Despite the 10-year lag in data, the present situation of the fisheries sector in Brazilian northeast region did not change much and, therefore, its overall composition and structure remained basically the same. The only significant change was the advent of a new fishing method, which started in 2010 and developed rapidly, reaching in 2016, about 250 boats, landing about 20,000 t of tunas every year, mainly yellowfin (67%) and bigeye (25%) tunas, with a minor participation of skipjack (7%). Most of the fish caught (more than 90%) are juvenile. This fishery started targeting the tunas gathering around the buoys of the PIRATA program ("Prediction and Research moored Array in the Tropical Atlantic", http://pirata.ccst.inpe.br), located in the equatorial Atlantic. Despite the purpose of these buoys is to collect oceanographic data, they end up acting as a Fish Aggregating Device (FAD), promoting the concentration of large schools of small tunas, mainly yellowfin and bigeye. According to Silva et al. (2018b), soon after this practice began, skippers started to realize that the boat itself could work as well as a FAD and that they could keep the schools associated to the boats and, therefore, keep fishing away from the FADs. They also realized they could transfer the school to other boats, before moving back to port to unload their catches and, therefore, keep a “captive” school out at sea. This fishery presently has landings (20,000 t) that are four times higher than the previous top group of species (snappers, with about 5,000 t). **However, fishing activity around the oceanographic buoys is prohibited and need to be better controlled since it causes serious problems to the integrity of the buoys and their material.**

The temporal trends in tuna and swordfish catches landed in Brazil and captured by Brazilian and foreign fleets between 2000-2017 is presented Figure 2.13 (Travassos, 2019). Skipjack tuna (Figure



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2.13a) is mainly captured by baitboat fishing and in a lesser extent by hand-lines. Catches have remained stable at around 24,000 to 25,000 t per year until 2010. In the period 2011-2013 catches increased, reaching about 32000 t in 2013, decreasing to values below 20000 t per year in recent years, as a result of the decrease in vessels operating in this fishery. In the last 5 years of the series, a proportion of about 15 to 20% of the catches of the species comes from the associated schooling fishery. There is no fishing quota defined for Brazil by ICCAT for this species. Yellowfin tuna (Figure 2.13b) is mainly captured by longline, baitboat and hand-line. Yellowfin tuna catches ranged from 2500 to 7000 t per year between 2000-2013. Then a significant increase was observed with catches reaching about 18000 t in 2017. This increase was also due to the catches made by the new "associated schooling" fishery. There is no fishing quota defined for Brazil by ICCAT for this species. Bigeye tuna is mainly captured by longline, baitboat and hand-line (Figure 2.13c). Bigeye tuna catches always remained below 3000 t per year until 2012. From 2013 onwards, catches have grown rapidly, reaching values close to 7000 t in the last three years. This increase occurred as a consequence of the development of a new fishery called "associated schooling", which captures fish aggregated to the hull of the vessel. There is no fishing quota defined for Brazil by ICCAT for this species. The catches of albacore tuna (Figure 2.13d) showed a significant decrease from 2003, when foreign leased vessels (Panama) stopped operating in Brazil. Since then, catches have remained well below 1000 t per year, with the exception of the 2011-2013 period, when again foreign leased vessels (Japan) operated in the country. The Brazilian quota of the species defined by ICCAT is 2,160 t. Swordfish (Figure 2.13e) is captured by longline fishing carried out by foreign leased vessels (operated until 2010) and domestic vessels. The catches reached 4500 t in 2000 and 2006, with a decreasing trend since then until reaching values close to 3000 t per year in recent years. There are swordfish fishing quotas defined by ICCAT for Brazil. From 2007-2009, the quota was 4720 t per year for the southern stock and 50 t per year for the northern stock. For 2010 and 2011 the quota for the southern stock was reduced to 3666 t and 3785 t, respectively, with no change to the northern quota. Since 2012, the quota is 3,940 t for the stock of the South Atlantic and 50 t for the stock of the North Atlantic.



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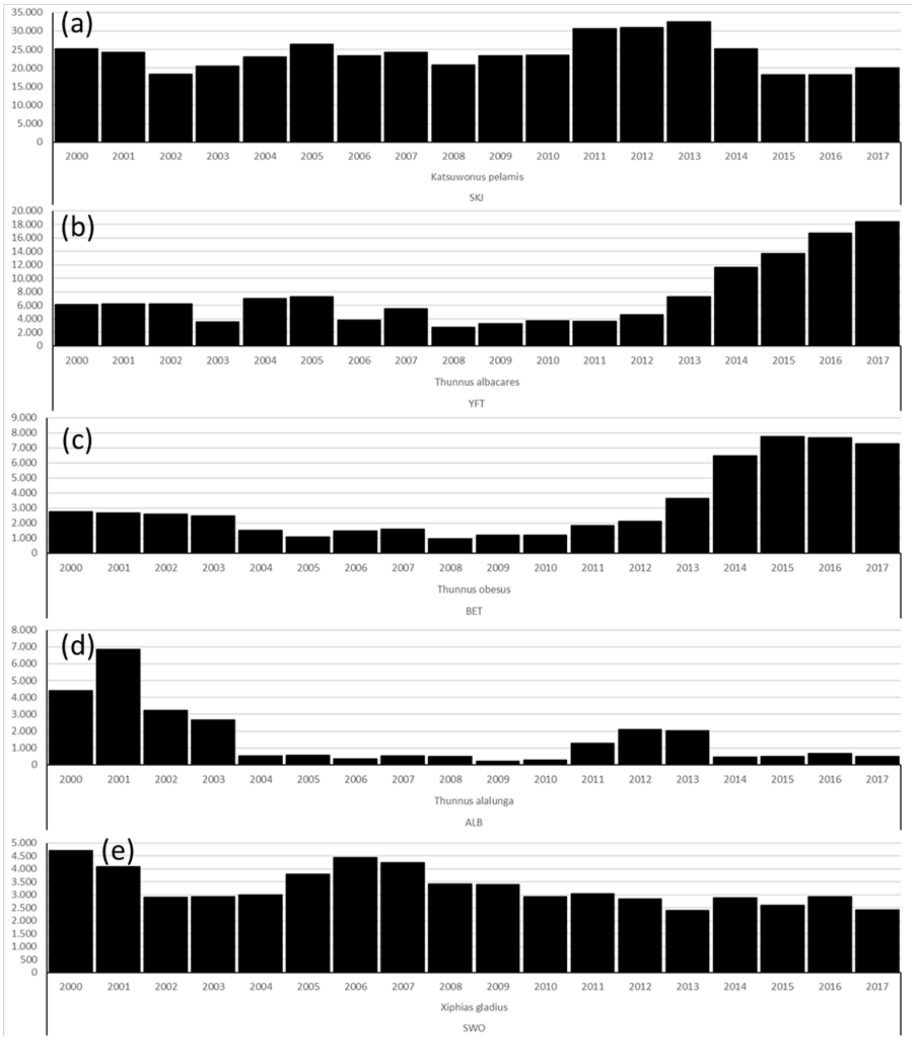


*Figure 2.13. Annual catches (in tonnes) of (a) skipjack tuna Katsuwonus pelamis, (b) yellowfin tuna Thunnus albacares, (c) bigeye tuna Thunnus obesus, (d) albacore tuna Thunnus alalunga, and (e) swordfish Xiphias gladius by the Brazilian fleet from 2000-2017. Source: Travassos (2019).*

## 2.5. Current State and existing measures for Marine Spatial Planning

Brazil possesses an EZZ of about 3.5 million km$^2$ and a continental shelf of 912 000 km$^2$, i.e., a vast ocean area named the “Blue Amazon” by the Brazilian Intergovernmental Council for Marine Affairs (www.secirm/ingles/promar.html). The recognition of the need to discuss Marine Spatial Planning in Brazil within governmental levels has raised since the Rio +20 conference. In 2014, the Ministry of Environment, with the support of UNESCO, promoted the International Seminar on Integrated Marine Planning in order to broaden the understanding on the subject, as well as to promote exchanges with international experiences. The event was opened with lectures given by the Intergovernmental Oceanographic Commission (IOC) and the Interministerial Commission for the Resources of the Sea (SECIRM) to clarify understanding and concepts of Marine Spatial Planning, and a report was generated[1]. More recently progress have been achieved with a joint action of The Blue Solutions Initiative and the Brazilian Navy who convened a training on Marine Spatial Planning (MSP). Representatives of the federal inter-ministerial working group on MSP participated in the course and

[1] http://www.mma.gov.br/gestao-territorial/gerenciamento-costeiro/colegiados/item/8956
T1 - Marine Spatial Planning Brazil (Planejamento Espacial Marinho Brasil) 2014 Report



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jointly discussed potential pathways for integrated marine and coastal policies in the country. However, so far advances at the national level have mostly been oriented towards Integrated coastal zone management (ICZM) and are mainly sectorial (DeFreitas et al., 2014; Gerhardinger et al., 2018 - who also present a review on ocean governance scenario an opportunity in Brazil).

Since 1997, the Ministry of Environment started a process of identification of "Priority Areas for Conservation, Sustainable Use and Benefit Sharing of Biodiversity". The rules for this process were formally instituted by Decree No. 5092 of May 21, 2004. The first evaluation was published in 2004 and subsequently updated in 2007 and 2018[2]. Recently, a set of initiatives, namely the Impact Reduction Plans (PRIMS), have been created, according to the Chico Mendes Institute for the Conservation of Biodiversity (ICMBio) to contribute to analyse the potential impact of the main threats to biodiversity, in order to propose alternatives for reconciliation between environmental protection and development of socioeconomic activities. Those plans aim at supporting and securing the decision-making processes and the environmental management of potential threats using systematic conservation planning tools to define spatially sensitive areas for biodiversity. From the industry point of view, this can also work as previous indication of potential conflict in the licensing process. Ideally PRIMS will be reviewed periodically to incorporate new information. In the marine regions, mining and oil and gas exploration are main considered activities so far[3].

At the legislative level, a proposal of a Marine Bill (Lei do Mar) was put forward to the Brazilian National Congress in 2013, however it is still under discussion, a process hindered by lack political momentum at the national level (Gerhardinger et al., 2018).

MSP is a process that needs to bring together multiple users of the ocean to make informed and coordinated decisions. At this date, Integrated Marine Spatial Planning has not been implemented in Brazil, however the basis for such has been growing in terms of available information. As zoning advances, mainly due to sectorial pressures, the need for an integrated approach becomes more urgent.

[2] http://areasprioritarias.mma.gov.br/2-atualizacao-das-areas-prioritarias.
[3] http://www.icmbio.gov.br/portal/images/stories/docs-prim/PRIM_Livreto.pdf.



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# 3. Canary Current system

## 3.1. Context/Situation

The Canary Current system is one of the major eastern boundary upwelling systems of the world ocean. The African part of the Canary Current system covers the EEZ of Morocco, Mauritania, and seasonally covers the area off Senegal, The Gambia, Guinea-Bissau, and can exceptionally extend into Guinean waters. Fisheries in West Africa have a crucial role both for economy and food security. Indeed, fish provide the main source of animal protein for a population exceeding 225 million people, one third of them being children (Failler et al., 2014).

The continental shelf width varies from 50 to 150 km, the largest parts being located off Western Sahara/ Southern Morocco and south of Cape Verde (Figure 3.1). Two major quasi-permanent upwelling filaments situated at Cape Ghir (~30°38'N) and Cape Blanc (~21°N), export surface water offshore. Between these two capes, other filaments are commonly found at Cape Juby (~27°56'N), Cape Boujdor (~26°12'N) or in-between (Barton et al., 1998). There are, however, many instances when there is no filament activity in this region (Aristegui et al., 1994). A seasonal upwelling filament is also present off Cape Verde (~14°30'N), when the trade winds favour upwelling in this area.

The nearest islands of the Canary archipelago (Spain) and the Cape Verde archipelago are located respectively ~100 km and ~600 km off the Moroccan and Senegalese coasts. The Canary Current flows southwards through the Canary archipelago extending 100 to 450 km from the coast (50 to 240 nautical miles), producing a large eddy field downstream of the archipelago (Barton et al., 2004), which interact with upwelling filaments and enhance the presence of neritic larvae within the oceanic-water larval community near the Canary archipelago (Rodriguez et al., 2004; Bécognée et al., 2006; Brochier et al., 2008a, 2011).

According to trade winds seasonality, the upwelling is seasonal in the northern part of the system (from north Morocco to ~28°N), permanent in its central part (~21-28°N) and seasonal again in the southern part. The latitude of southern limit between the permanent and seasonal upwelling area has been observed to change across decades, and to impact the nature and distribution of plankton communities and small pelagic fish species (Binet et al., 1988). Indeed, the small pelagic fish fisheries north of cape Blanc are usually dominated by the European sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*) while south of cape Blanc *Sardinella spp.* (*S. aurita and S. maderensis*) typically dominate the landings. Binet et al. (1988) reported a southward shift of this limit during the 1970s, and, oppositely, more recently Sarré (2018) showed a continuous northward trend of the round sardinella distribution since the mid-1990s.

The coastal environment changes significantly from the Cape Verde in Senegal to the South. Along the coast mangroves begin to spread, which reach their full development in the Guinea States, Liberia and Ivory Coast. The mangrove areas in southern Senegal form a transitional zone between the dry Sahel zone and the humid tropical rainforest. In central Senegal, the extensive Sahelian drought over the last decades resulted in the inverse nature of the Sine Saloum estuary with higher salinities inland than at the river mouth which, in turn, had severe impacts on the ecosystems along the rivers of the Sine Saloum. These different coastal structures and ecosystems influence the type of coastal fishing. While in the north industrial fishing for the small pelagic species on the outer shelf is predominant, this is changing into artisanal multi-species fishing on the coasts and in the estuaries. While there exists an exhaustive literature on the dynamics of the clupeid small pelagics in the northern upwelling area, which is especially interesting for foreign fleets, our knowledge on biology, distribution, reproduction and exploitation status of the coastal species in the southern countries (Senegal to Ivory Coast) is alarmingly low.



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The Banc d'Arguin in Mauretania and the Sine-Saloum estuary in Senegal, as examples, have been affected by climate change and direct human disturbances, and consequently have undergone significant environmental transformations (Xenopoulos et al., 2005; Mbow et al., 2008).

The mesotropic to highly eutrophic conditions of the Mauritanian shallow waters are reflected in the strong dominance of heterozoan benthos in the Golfe d'Arguin (Summerhayes et al., 1976; Michel et al., 2011a; Klicpera et al., 2013; Reymond et al., 2014). This heterotrophic-dominated biotic composition is atypical for tropical shallow-water systems and is explained by the extremely low transparency of the eutrophic waters that are loaded by eolian dust and high concentrations of as yet unstudied microbes and plankton. While high nutrient and enhanced $CO_2$ concentrations caused by upwelling together with the dust input provide an explanation for this uncommon regional ecosystem, neither the food web structure nor the transformation of the mineralogic matter in the dust into bio-available nutrients has been studied so far. Nor has the plankton community as basis of the food web been studied – with the exception of planktonic foraminifers further offshore (Mateu, 1979).

The shallow-water "bio-reactor" of the Banc d'Arguin is scientifically still largely enigmatic, because access to this extensive area is impossible for larger research vessels. During a cruise with the German RV Maria S. Merian (MSM 16-3) in 2010 and the cruise with RV Meteor (M129) in 2016, sampling on the Banc d'Arguin could be realised by means of the fast rescue boats (Westphal et al., 2014; Ekau et al., 2016) and brought some basic understanding into this unique ecosystem. Nevertheless, the sample density in this important ecosystem is still poor and biogeochemical measurements, as well as data on microbes, phytoplankton and zooplankton are entirely lacking.

The Sine Saloum in Senegal became a permanently inverted estuary in the late 1960s due to prolonged drought and an increasing lack of freshwater inflows (Pages and Citeau, 1990). Accordingly, the salinity rises upstream and the values in the whole system are generally higher than those of seawater. During the dry season (November to June) the difference between upstream and downstream could be up to 90 PSU (Diouf, 1996). Combined with indications that many arid regions are becoming drier as a result of climate change (IPCC, 2014), the changes and effects of this important environmental change (reversal of the salinity gradient) on the function of the Sine Saloum as an essential habitat and nursery area for local fish species is fairly unknown. Studies on fish assemblages from recent years show an ichthyofauna dominated by a few species belonging to three main families: Clupeidae, Mugilidae, and Cichlidae (Simier et al., 2004; Diouf, 1996). Due to the environmental conditions the fish fauna is mainly composed of species of marine origin and most of them are juvenile forms of species from the continental shelf (Simier et al., 2004). However, despite the quasi absence of sedentary fish species, the monitoring of a marine protected area in the Delta revealed important threats on fish biomass and diversity (Brochier et al., 2011; Ecoutin et al. 2014; Sadio et al., 2017). First studies on early life stages of fish have been performed by Sloterdijk et al. (2018) and showed a species composition quite different from other tropical estuaries. While it is difficult to forecast the future development for this system, the observed loss of freshwater species in favour of species of marine origin is likely to affect other West African estuaries and their larval fish species depending on the strength changes affected by global climate change. Along the same line, hydrodynamics and tidal forcing inside the spatially complex Sine Saloum estuary with its numerous tributaries (locally called *bolongs*), as well as responses to environmental changes on the level of ecosystems and their contributions to human wellbeing, are hardly known. Local societies strongly depend on natural resources that are directly or indirectly driven by the mangroves inhabiting the river banks along the estuarine stretch up to salinities of ~56 (during the dry season). The sustainability of extracting seafood, mostly through artisanal fisheries, from the estuary and the



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corresponding coastal stretch can hardly be evaluated, since neither data on landings nor on stocks of fish or shellfish exist in sufficient amount or quality.

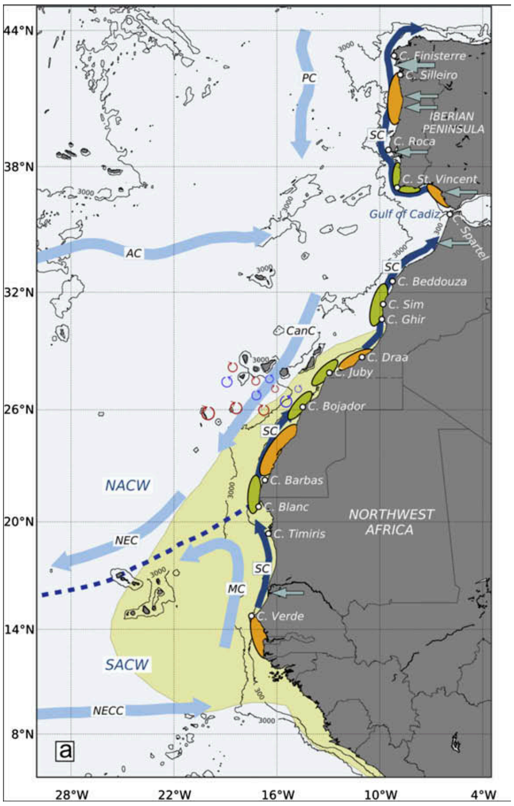


*Figure 3.1 Schematic map of the Canary Basin showing the main currents (light blue: surface currents; dark blue: slope current), major capes, freshwater (blue arrows) and dust inputs (>10 g m_2 y_1 shaded yellow), retention (orange) and dispersion (green) zones on the shelf, frontal zone between water masses (dashed blue lines) and mesoscale eddies (blue: cyclones; red: anticyclones) south of the Canary Islands. NACW: North Atlantic Central Water; SACW: South Atlantic Central Water; AC: Azores Current; CanC: Canary Current; MC: Mauritanian Current; NEC: North equatorial Current; NECC: North equatorial Countercurrent; PC: Portuguese Current; SC: Slope Current. Source: Aristegui et al. (2009).*

## 3.2. Physical dynamics

Ecosystem dynamics in this area are strongly forced by spatiotemporal variability in upwelling favourable winds along the coast. The seasonal shift of the Azores High, Saharan depression and the intertropical zone determine the balancing of the trade winds and therefore the position and intensity of the upwelling along the West African coast. In summer, the Azores High exerts its influence all along the Moroccan and Saharan coasts (Figure 3.2). More at the south, the intertropical convergence front rises up and the monsoon exerts its influence to southern Mauritania. Surface circulation over the Senegalese and Mauritanian continental shelf is directed northward, and there is an accumulation of water close to the coast with locally significant desalination. In winter, the system is shifted south. The North of the Moroccan Atlantic coast is reached by the depressions from the



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boreal front, which bring rain from Gibraltar to the Canary archipelago. There is no upwelling north of Cape Juby (28°N). But, south of this cape, the surface circulation directed towards the south, accompanied by resurgences, is felt to the Bijagos front (12°N; Figure 3.2, right).

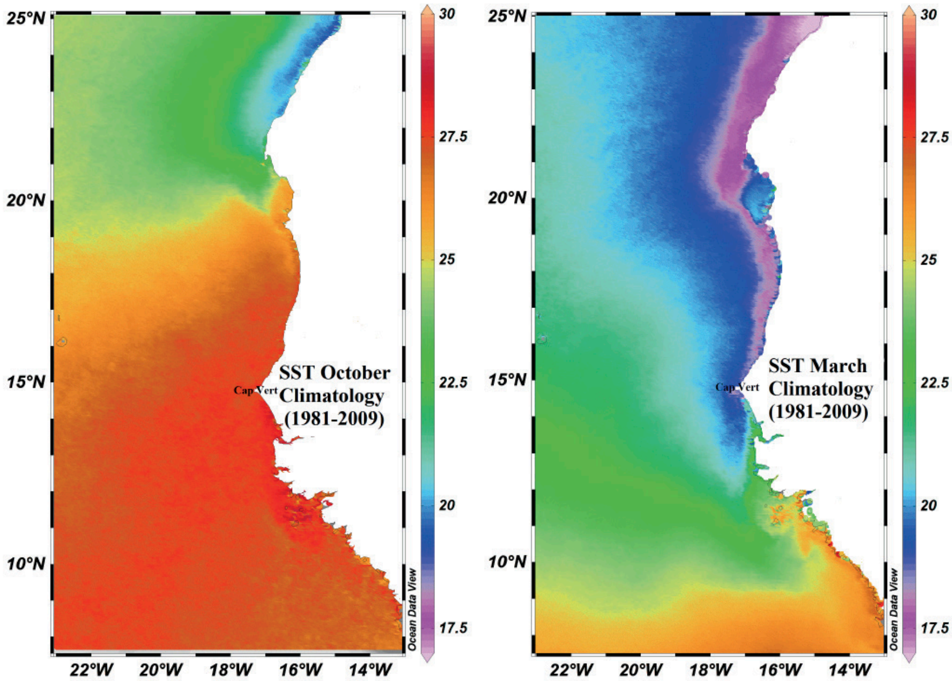


*Figure 3.2. SST distribution in March (left) and October (right) in the southern Canary Current system. Redrawn from Diankha et al. (2015)*

As described by Auger et al. (2015), wind-driven upwelling takes place all along the NW African coast at the eastern boundary of the North Atlantic subtropical gyre following the meridional migration of the atmospheric pressure systems. It occurs mainly in summer in northern Morocco, all year round (though more intense in summer) in southern Morocco, and in winter and spring south of Cape Blanc in the Senegal-Mauritanian region (Figure 3.3; Mittelstaedt, 1991; Wooster et al., 1976). Upwelling-induced vertical motions generally occur within the 0–100 km coastal band as estimated from the Rossby radius of deformation in the NW African region (Chelton et al., 1998), so the coastal jet is confined nearshore. Offshore, the background circulation is mainly driven by the eastern branch of the North Atlantic subtropical gyre. The Canary Current, seen as a natural extension of the zonal Azores Current (Mason et al., 2012; Sala et al., 2013; Stramma, 1984), flows southward along the NW African coast before feeding the North Equatorial Current. North of Cape Blanc (21°N), the Canary Current System (CCS) is thus composed of the Canary Current (CanC) and the Canary Upwelling Current (CanUC) (Mason et al., 2011). South of Cape Blanc, a cyclonic recirculation drives a poleward circulation opposed to the coastal upwelling jet (Mittelstaedt, 1991). The convergence of the water masses transported by the subtropical gyre and the recirculation gyre finally takes place in the Cape Verde Frontal Zone (Zenk et al., 1991) off Cape Blanc as attested by in situ and satellite observations (e.g. Lathuilière et al., 2008; Van Camp et al., 1991).


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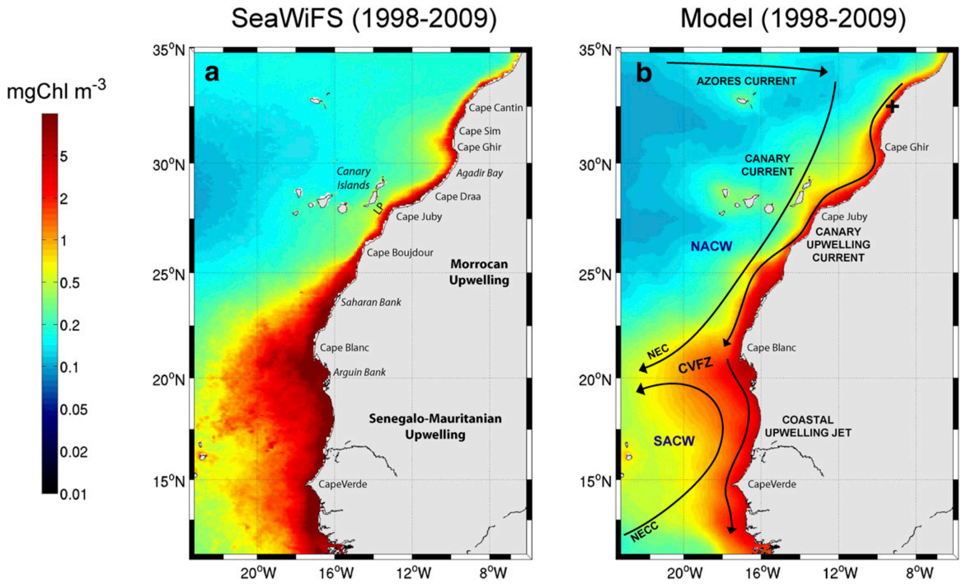


*Figure 3.3 Map of surface chlorophyll concentrations from (a) SeaWiFS and (b) ROMS-PISCES model averaged over the period 1998–2009. Major capes, main surface currents and deep water-masses are indicated. LP: Lanzarote Passage; NEC: North Equatorial Current; NECC: North Equatorial Counter-current; CVFZ: Cape Verde Frontal Zone; NACW: North Atlantic Central Water; SACW: South Atlantic Central Water. The black cross indicates the location of the anthropogenic Cd loads. Redrawn from Auger et al. (2015).*

## 3.3. Natural and anthropogenic forcing

The North-West (NW) African coast, being one of the four major eastern boundary upwelling systems (EBUS), is characterized by high biological productivity owing to its upwelled nutrients, which help to sustain large fish populations (Fréon et al., 2009). Fishing is of major importance for the economy and the food security of north-west African coastal countries which benefit from the productive Canary Current upwelling system (from Morocco to Guinea). To date, the majority of long-lived species livestock are depleted, and Small Pelagic Fish (SPF) became the main exploited species, both for global food industry (Fish meal, Tacon, 2004) and for human consumption in West Africa (Failler, 2014). Because of the Sahelian food crisis the demographic pressure on the coastal fringe increased the effort of artisanal fishing (Binet et al., 2012; Failler, 2014), which adds up to the industrial fishing. Yet, SPF overfishing threatens the marine ecosystem capacity to sustain fisheries (Laurans et al., 2004; Pala, 2013; Pauly et al., 1998; Thiao et al., 2012), which amplifies the risk of collapse (McOwen et al., 2015; Essington et al., 2015).

Morocco is the second largest phosphate producer in the world. 27 million tonnes of phosphate ores are extracted and processed annually (Annual Report, Office Chérifien des Phosphates, Morocco, 2012) to produce phosphoric acid and phosphorus-based fertilizers. The Moroccan phosphate industry releases large amounts of heavy metals, particularly cadmium (Cd), in the North-West (NW) African upwelling around Safi and Jorf-Lasfar (33°N) with locally significant contamination of mollusc communities (Auger et al., 2015 and references herein). As a consequence, mussels for instance are considered unsuitable for human consumption in this region (Moustaid et al., 2005). Phosphate industry is also present, though less developed, in Mauritania and Senegal (Auger et al., 2012).

The fishing effort in North-West (NW) African is composed of a number of foreign fleets fishing both legally and illegally, and the Senegalese artisanal fishing fleet, which is one of the most developed artisanal fleet of Africa. The latter operates within and outside the Senegalese Exclusive Economic Zone (EEZ). Belhabib et al. (2014) showed that artisanal fisheries are increasingly competing with the industrial sub-sector operating in Senegal including fleets from the EU, Asia and Eastern Europe.



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Agnew et al. (2009) estimated that total catches in West Africa being 40% higher than reported catches.

Senegalese waters host high fish productivity and stocks are exploited since more than fifty years. Indeed, in contrast to the other countries of north-west Africa, Senegal has a long time fishing tradition, and the artisanal fishing fleet was both modernised and increased in number during the second part of the 20th century. The coastal upwelling constitutes the major factor determining productivity. Exploitation intensively increased over the last four decades, inducing ecological changes in the composition of marine populations. Actually, some demersal stocks are collapsed to the advantage of other species, mainly the short-lived species (sardinella and octopus). Over the 1980-2010 period, landings of the Senegal EEZ have been increasing, from 153 000 to 432 000 tonnes. The biomass of the main demersal resources fell by 70% in 50 years; stocks of *Epinephelius aeneus*, *Pagellus bellottii*, and *Galeoides decadactylus* are strongly overexploited, with reduced catches, compared to the biological potential, and with a large risk of collapse for some stocks.

In contrast, in the last three decades, new species started to be exploited intensively (especially *Sardinella aurita* and *S. maderensis*, Clupeidae), mackerel (*Scomber scombrus*, Scombridae), horse mackerel (*Trachurus trachurus*, Carangidae), deep-sea species and some crustaceans and molluscs). In Northwest African upwelling system, interannual fluctuations of *S. aurita* abundance are respectively driven by the precocity and the duration of the upwelling season that is attributed to distinct migration patterns. *Sardinella* species also respond with a delay of around 4 years to the winter NAO index and the autumn CUI, and the AMO index respectively, either related to migration patterns (Thiaw et al., 2017). The wide variations in *Sardinella* biomass are caused by variations in environmental conditions, which should be considered in the implementation of an ecosystem-based approach in *Sardinella* stocks management.

## 2.4 Fisheries distribution, abundance, seasonality, production and Aquaculture

Historically, fisheries have always been most intense in Morocco, with about 150 thousand tonnes in 1950 (beginning of the FAO dataset), with an increasing trend up to 1.3 million tonnes in 2016 (Figure 3.4). The second main landings were in Senegal, with an increasing trend from ~10 thousand tonnes landed in 1950 to ~400 thousand tonnes during in 1997, and oscillating between 300 and 400 thousand tonnes since then (up to 2016). By contrast, landings in Mauritania were relatively small from 1950 to 1995 (under 40 thousand tonnes) but sharply increased since then, reaching 550 tonnes in 2016, thus now the second main landings in the region, after Morocco.



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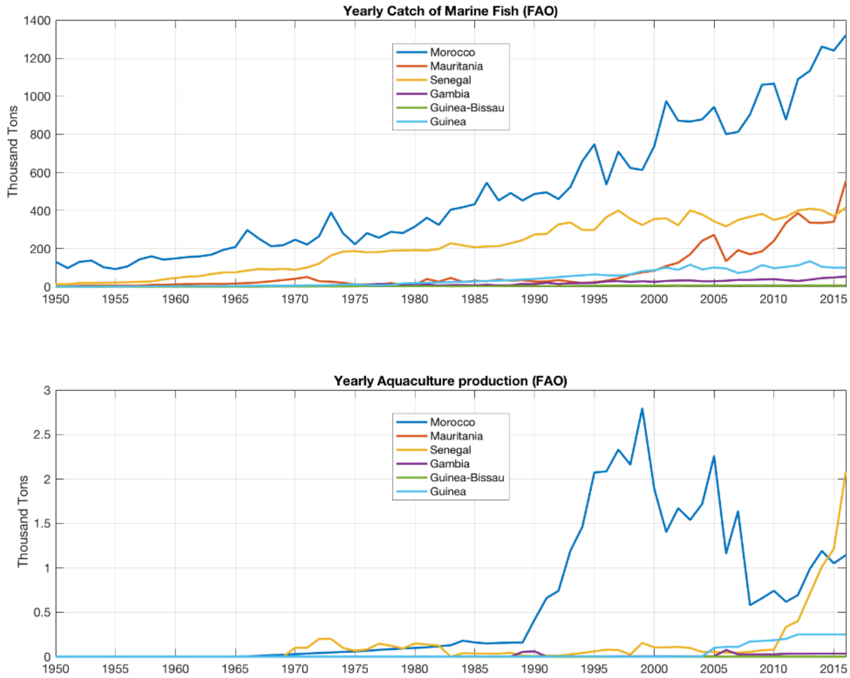


*Figure 3.4. Trends in annual catch of marine fish (top) and aquaculture production (bottom) in northwest Africa (FAO, 2019).*

Sardinella (*Sardinella aurita* and *Sardinella maderensis*) play an important role in NWA fisheries and marine ecosystems (Fréon et al., 2009). In the period from 1990 to 2009, catches of sardinella in the NWA area accounted for 26% (450,000 tonnes per year) of the total catch of small pelagic, with 28% of *S. maderensis* and 72% of *S. aurita*, commonly called round sardinella (FAO, 2011). This latter percentage increased during the last 4 years and now stands at 80% (FAO, 2013). Until the late 1990s, distant, large-vessel fleets working under various access regimes in Mauritania accounted for most of the catches. Most vessels did not land their catches in Mauritanian harbours. The artisanal fishery using canoes equipped with purse seines has become established in Mauritania during the last two decades with an increase in landings from 15,000 tonnes in 1994 to over 114,000 tonnes in 2009 (IMROP, 2010). Meanwhile, a European fleet of modern trawlers began fishing in the Mauritanian Exclusive Economic Zone (EEZ) in 1996, first under private agreements and under a EU fisheries agreement since 2002 (Braham et al., 2014).

Sardinella fisheries is emblematic of the problems faced in the case of the management of shared stocks. Indeed, these species is thought to perform transnational migrations, at least across Gambia, Senegal and Mauritania (Boely et al., 1982; Figure 3.5). Recently, habitat modelling coupled with individual based models suggested that the migrations may be derived by a change in habitat distribution that seasonally shifts from the southern to the northern part of the system (Figure 3.6). The same study suggests that the majority of the round sardinella biomass originated from Mauritanian reproduction areas (mainly the Arguin Bank), and this biomass seasonally extends southward or northward, following and ideal free distribution within the habitat (Brochier et al., 2018a).



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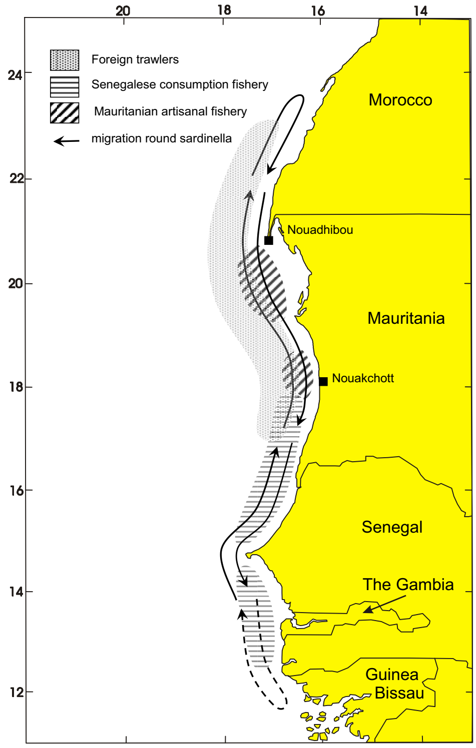


*Figure 3.5. Presumed migration path of round sardinella, based on Boely et al. (1982); and the fishing area of different fleets exploiting the species. The Mauritanian artisanal fisheries are conducted mainly by Senegalese canoes that operate from Mauritanian ports. Their catches are predominantly used for fishmeal. The southern limit of the presumed regional stock is not clearly defined, as is indicated by the hatched arrows. Redrawn from Corten et al. (2017).*

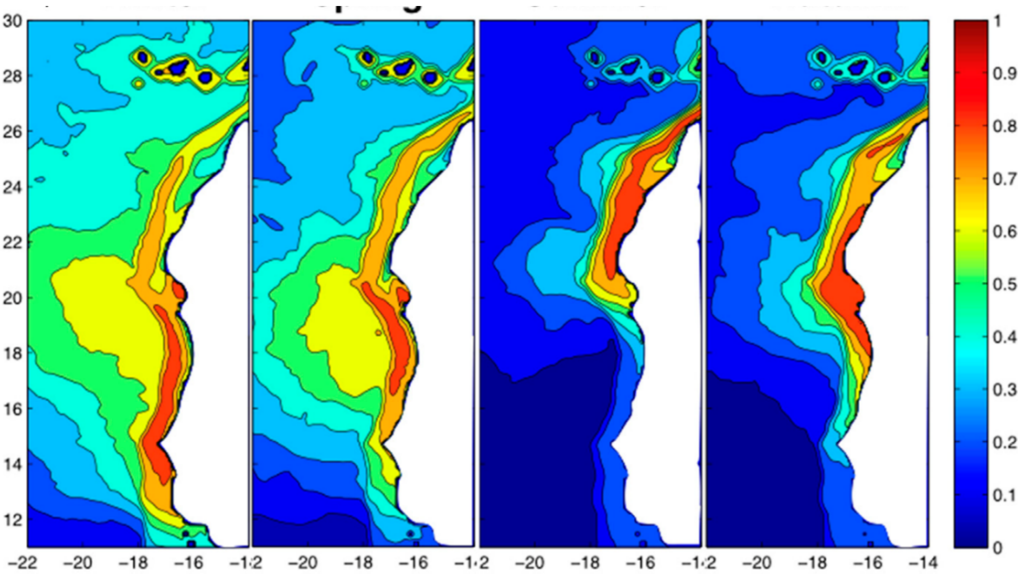

*Figure 3.6. Mean seasonal distribution of typical round sardinella habitat (Temp=21 °C, continental shelf). Source: Brochier et al. (2018).*

Thus, north/south fish stock connectivity in North West Africa might be enhanced by the strong seasonal variability and the movement of Cape Verde Frontal zone related to the seasonal ITCZ movement. The matter of fish stock connectivity is of particular importance in the context of increasing national fishing fleet capacity, and bilateral fishing agreement with distant fishing fleet nations, because optimal fishing management need a collaborative approach (Brochier et al., 2018b). In recent years (since 2012), an increasing share of the small pelagic fish catch has been used in local



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fish meal factory, first in Mauritania (Corten et al., 2017) with a growing investment in fish meal factory and now in Senegal. Given the number of "players", such tendency of competitive fisheries exploiting a shared stock may drive the whole fishing system toward a less productive, over-exploited state (see Brochier et al., 2018 and references here in).

The mean trophic level index decreased in the four decades reflecting an overall catch decrease of demersal fish stocks as well as the overall biomass decrease of these resources in the ecosystem. Over the period 1980-2010, the landings/biomass ratio shows a general increasing trend, reflecting the overall increase in catches of small and short-lived species (sardinella and octopus) and the biomass decrease of demersal fish stocks (Figure 3.7).

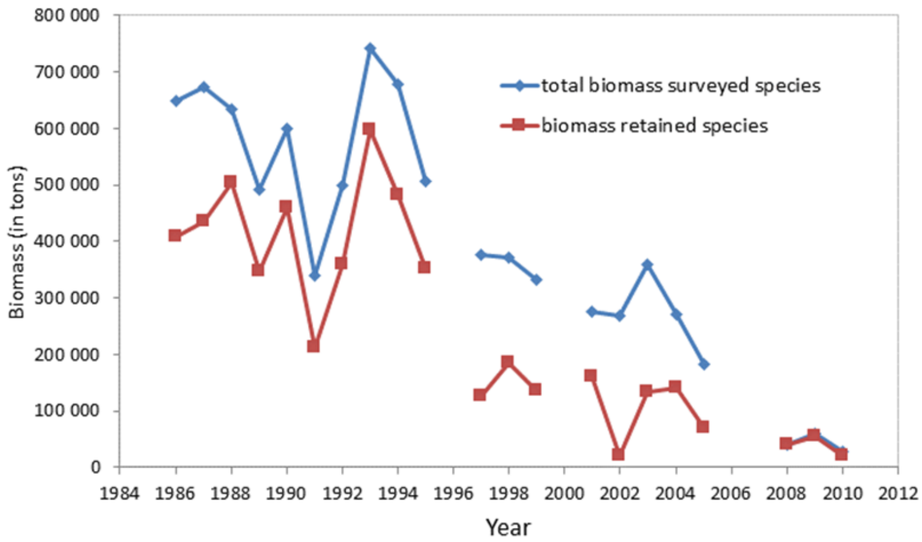


*Figure 3.7. Biomass trends of surveyed and retained species in Senegalese Shelf over the period 1986-2010. Source: Thiaw et al. (2013).*

### 3.3.1. Current State and existing measures for Marine Spatial Planning

Senegal has a low human development index (HDI) with a relatively small size and poor ecological status. Despite the economic and social importance of the fisheries sector in Senegal, it has faced considerable challenges for several years, mainly due to the lack of effective management and governance approach (Thiao and Laloe, 2012). Historically, the public policies to improve the management and governance of the fisheries sector and to rebuild major fish stocks are ineffective because of many socioeconomic and managerial constraints that undermine any attempt to reduce the fishing pressure, restore and conserve the coastal ecosystem and regulate economic incentives (Thiao and Laloe, 2012). A marine spatial planning exists (Bonnin et al., 2013) but seems poorly respected (Belhabib et al., 2014).

Since the 2000s, a number of marine spatial planning initiatives has been developed in Senegal, resulting in Marine Protected Areas (http://www.rampao.org/-Senegal-.html). It is interesting to notice the diversity of the initiatives, either occurring at the national or communal level, mostly driven by the fishermen themselves (Mbaye et al., 2018) and by NGOs (*Figure 3.8*). However, depending on the cases there is a questionable effect of co-management on fishing effort, as surveillance is not always funded on the long term, and artificial reef deployment may disturb social and ecological equilibriums (e.g. Brochier et al., 2015).



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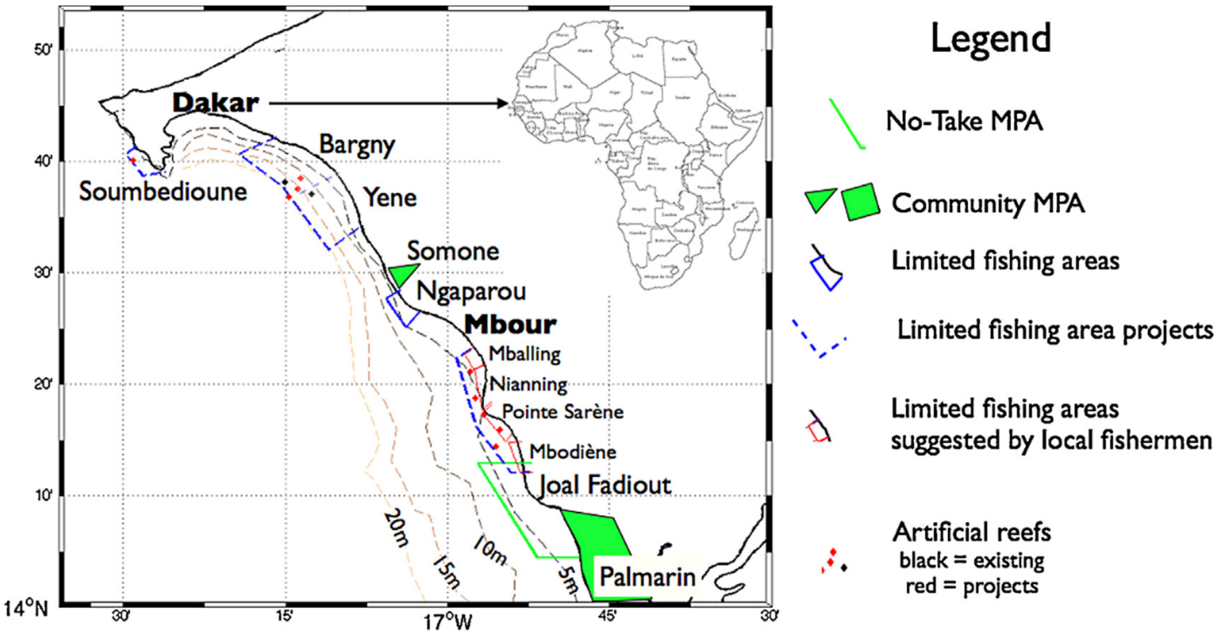


*Figure 3.8: Synthesis of existing and planned marine protected areas (MPAs) and artificial reefs along a part of the south coast of Senegal. No-take MPAs, created by Presidential decree, and community MPAs are managed by the DAMCP (Direction des Aires Marine Communautaires Protégées/Senegalese ministry of the environment), while 'limited fishing areas' (called ZPP) are managed by the DPM (Direction des Pêches Maritimes/Senegalese ministry of fisheries and marine economy) and artificial reefs were deployed by international NGOs and local fishermen. Source: Brochier et al. (2015).*



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# 4. Cape Verde

## 4.1. Context/Situation

Cape Verde, consists of ten volcanic islands , one of them –Santa Luzia- uninhabited, and several islets that lie 385 miles (620 km) off the west coast of Africa, located between 14°30′ and 17°30′ N and between 22°30′ and 25°30′ W. The archipelago with 4 033 km$^2$ total area is divided into:

- the Barlavento (Windward) group, which include Santo Antão, São Vicente, Santa Luzia, São Nicolau, Sal, and Boa Vista islands, together with the islets of Raso and Branco
- the Sotavento (Leeward) group to the south, which include Maio, Santiago, Fogo, and Brava islands and the three islets called the Rombos - Grande, Luís Carneiro, and Cima (Figure 4.1).

The Cape Verde archipelago is grouped together with the Azores, Madeira, the Selvagens, and the Canary Islands in the Macaronesian region, which is situated in the North Atlantic Ocean, close to the West African coast and the West Mediterranean region. The archipelago is spread over 58,000 km$^2$ of ocean and has about 1050 km of coastline.

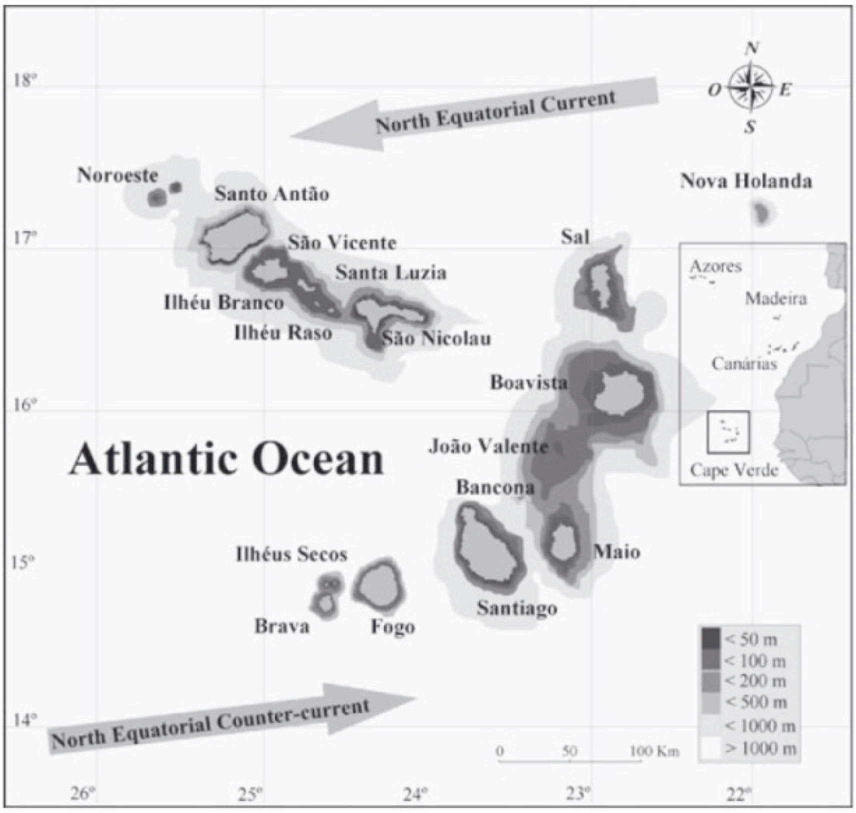


*Figure 4.1. Map of Cape Verde archipelago. Source: Medina et al. (2007).*

The physical environment of these islands creates a multiplicity of habitats with a great wealth of fauna and flora. Nevertheless, this biodiversity is naturally restricted to the narrow geographical limits of the islands and is extremely vulnerable to disturbances caused by human activities (Duarte and Romeiras, 2008). Santiago is the largest island and is home to more than half of Cape Verde's total population (484 437 inhabitants as of the 2010 census).



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## 4.2. Physical dynamics

In Cape Verde a warm seasons occurs from May to November and a cold one from December to April. The warm season is divided into a dry period between May and July, under the influence of Harmattan wind and dust from the Sahara, and a wet period from August to September, which is influenced by north-easterly Trade Winds from the Azores anti-cyclone and by south-westerly Trade Winds from the Santa Helena anticyclone. SST follows the average air temperature, varying from 18°C to 27°C during the year (Medina et al., 2007).

The Cape Verde Frontal Zone (CVFZ) stretches approximately from the Cape Verde Islands to Cape Blanc. North of the CVFZ there is a dominance of North Atlantic Central Water (NACW), of northern subtropical origin; south of the CVFZ the waters have a much more distant origin, originally coming from the subtropical South Atlantic but becoming largely modified after a long journey in the tropical regions (Peña-Izquierdo et al., 2012; Figure 4.2). The NACW flows southwards as the Canary Current (CC) until it reaches the CVFZ, where it departs offshore as the North Equatorial Current (NEC). South of the CVFZ the upper thermocline is meteorologically driven by seasonal changes in the Intertropical Convergence Zone (ITCZ). The cyclonic winds cause positive Ekman pumping, which drives offshore upwelling, the outcome being the Guinea Dome (GD), SW to the archipelago and the associated cyclonic circulation (Siedler et al. 1992; Peña-Izquierdo et al., 2012).

Canary Current (CC) influences mostly the northern part of the archipelago and carries cold water to the inner part of the archipelago. Its average speed is 15 cm $s^{-1}$ and stretches along the W African coast down to 800-1000m. CC reaches Cabo Verde with SW direction and turns W and NW joining the North Equatorial Current (NEC). The Southern part of the archipelago is influenced by the North Equatorial Current (NEC) and by the North Equatorial Undercurrent (NEUC) that near the W African coast originates the warm Mauritania Current (MC) that moves north in warm season and south in the cold season. Dominant surface circulation signal in the study area has a seasonal pattern, accompanying the seasonal wind field variability known for the region and is particularly evident in the southernmost region of the archipelago area. The interannual signal, although typically weaker than the seasonal one, is not negligible in some years, being strongest at lower latitudes, where maximum values of the seasonal cycle are also found (Lazaro et al., 2005).

In summer the ITZC moves north and the wind regime follows it. Two transatlantic eastward zonal jets, the North Equatorial Undercurrent (NEUC) at about 4°N and the North Equatorial Counter Current (NECC) approximately along 8°N, intensify and feed the southern portion of a relatively large summer GD (Siedler et al., 1992; Stramma et al. 2005; Peña-Izquierdo et al., 2012). In winter the ITZC moves south and the NECC weakens (Stramma and Schott 1999; Peña-Izquierdo et al., 2012). South of the CVFZ, the cyclonic winds remain intense but move southeast, their centre being located near-shore. Since the GD is forced by the wind field it follows the seasonal ITCZ displacements, hence moving southeast from summer to winter (Peña-Izquierdo et al., 2012).

The area between 10° and 20°N, where the Cape Verde Archipelago is located, can be regarded as a region of interactions between the main current systems described. Since these transport different water masses and meet in the surroundings of the archipelago, a large-scale frontal system is formed, and a potentially productive zone can be expected near the islands. Favourable conditions for the aggregation of large pelagic migratory fish species can arise, sustaining the fisheries activity of the country (Lazaro et al., 2005)



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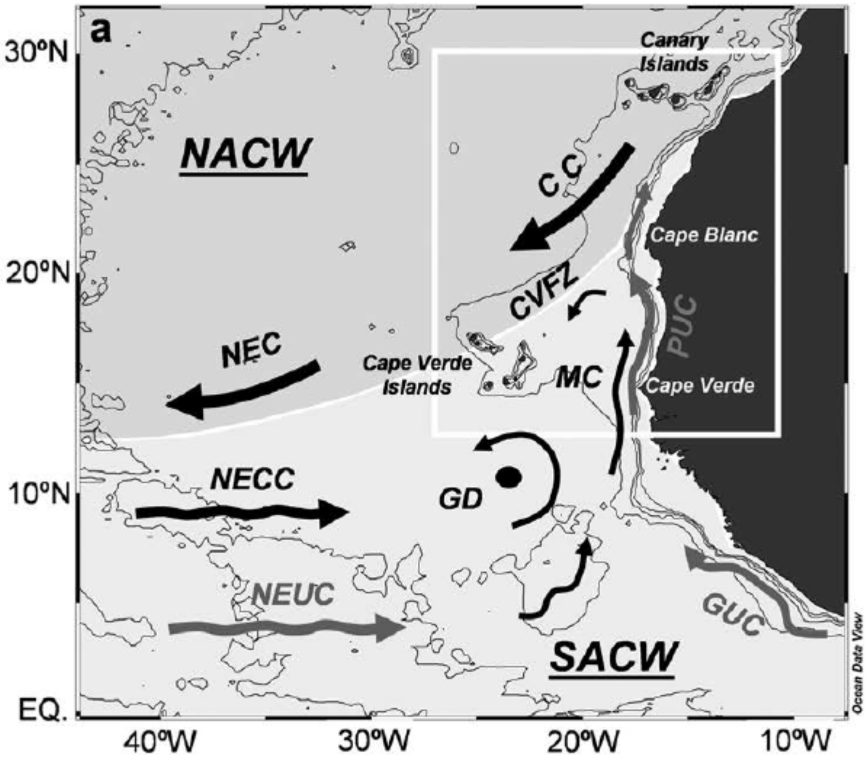


*Figure 4.2. Schematic pattern of the circulation showing the main currents and dynamic features: Canary Current (CC), North Equatorial Current (NEC), North Equatorial Counter Current (NECC), North Equatorial Under Current (NEUC), Poleward Undercurrent (PUC), Mauritania Current (MC), Guinea Undercurrent (GUC), Guinea Dome (GD) and Cape Verde Frontal Zone (CVFZ). Contours of 500, 1000, 2000 and 4000 m isobaths are grey coloured. Source: Peña-Izquierdo et al. (2012).*

## 4.3. Natural and anthropogenic forcing

### 4.3.1. Biodiversity

In spite of many scientific expeditions having passed by the Cape Verde archipelago there remain some knowledge gaps regarding on its marine communities (Morri et al., 2000; Reimer et al, 2010).

Morri et al. (2000) gave a preliminary description of the marine zoogeography of the Cape Verde Islands, stating its mixed character of temperate and tropical species. The marine fauna and flora of the Cape Verde Islands show a strong amphi-atlantic component where western Atlantic elements appear to be particularly common in the (warm) sublittoral and less pronounced in the (more temperate) midlittoral and circalittoral. In biogeographic terms the Cape Verde islands have been considered part of the Tropical Eastern Atlantic (TEA) Province (Briggs & Bowen, 2012) but with a certain transitional character (West African Transition *sensu* Spalding et al., 2007) between this province and the Atlantic-Mediterranean. However, recent studies (e.g. Brito et al., 2007; Freitas, 2014; Gonzalez, 2018), have been evidencing the singularity of the Cape Verde marine fauna, with the acknowledgment of a certain level of endemicity. Besides, it also displays some macaronesian elements (Gonzalez, 2018), or characteristic species of the Eastern Atlantic insular arc that extends from the Azores to Cape Verde. Moreover, the relevance of amphi-Atlantic taxa of warm affinity found in the Cape Verdean carcinofauna suggest a bio-connexion between the Cape Verde ecoregion and the North Brazil Shelf biogeographic province (Spalding et al. 2007).



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The high species richness and high endemicity of certain groups, e.g. molluscs (Abad et al., 2016; Peters et al., 2016) and crustacean (Gonzalez, 2018), led the archipelago to be considered as a tropical marine biodiversity hot-spot (Roberts et al., 2002). In spite Cape Verde is located in a high productivity area, this does not translate into high local population densities. Factors such as the limited continental shelf, irregular coasts, small intertidal extent, seasonal bio-oceanographic conditions and weak precipitation are suggested to explain this paradox (MAAP, 2004).

The eastern tropical Atlantic, is considered one of the poorest areas in terms of macroalgae (DGA, 2004). The sponge fauna of Cape Verde share many affinities with the West African fauna, and these faunas are relatively similar to the eastern Mediterranean fauna. 257 species of sponge were reported during the CANCAP expeditions. Léon et al. (2005) reported 32 species of medusae in Cape Verde. This region is considered a marine hotspot of coral since it is a centre of endemism and therefore one of the global priority places for conservation, also due to some level of threat to these systems (Roberts et al., 2002). Despite the absence of major reef structures and their relatively low richness, corals are an important element of the cnidarian fauna in Cape Verde. Considering the tropical location of Cape Verde it would be expected to find more exuberant coral reefs. However, scleratinian corals development is hampered by the cold Canary Current, the small continental shelf and the strong hydrodynamics around the islands (Almeida et al., 2014). Wirtz et al. (2013) made a catalogue of Cape Verde's coastal fish including 315 species. Pelagic fish include large migrators such as yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*), Bigeye tuna (*Thunnus obesus*), Little Tunny (*Euthynnus alleteratus*), frigate tuna (*Auxis thazard*), Wahoo (*Acanthocybium solandri*), as well as swordfish (*Xiphias gladius*), marlins and pelagic sharks. Being oceanic migratory species, with seasonal passages through the waters of Cape Verde, the estimate of their potential can only be made at the level of the entire Atlantic Ocean.

The occurrence of cetacean in the archipelago of Cape Verde was summarized by Hazevoet & Wenzel (2000), who listed 18 species. During the past decade, a stranding scheme has been coordinated initially by Vanda Monteiro and afterword's by Sandra Correia at the Instituto Nacional de Desenvolvimento das Pescas (INDP) in Mindelo, São Vicente. In addition, combined efforts of ONGs across the Islands have resulted in a considerable increase in data, comparing to pre- 2000 years. The most commonly stranded species are the short-finned pilot whale (*Globicephala macrorhynchus*) and Melon-headed Whale (*Peponocephala electra*) (Hazevoet et al., 2010).
Nevertheless, the most sighted species in the archipelago are:

- The Humpback Whale (*Megaptera novaeangliae*)
- The Common Minke Whale (*Balaenoptera acutorostrata*)
- The Bryde's Whale (*Balaenoptera brydei*)
- The blue whale (*Balaenoptera musculus*)
- The Fin Whale (*Balaenoptera physalus*)
- The Short-beaked Common Dolphin (*Delphinus delphis*)
- The Short-finned Pilot Whale (*Globicephala macrorhynchus*)
- The Grey Dolphin (*Grampus griseus*)
- The Melon-headed Whale (*Peponocephala electra*)
- The Pantropical Spotted Dolphin (*Stenella attenuata*)
- The Striped Dolphin (*Stenella coeruleoalba*)
- The Atlantic Spotted Dolphin (*Stenella frontalis*)
- The Spinner Dolphin (*Stenella longirostris*)
- The Common Bottlenose Dolphin (*Tursiops truncatus*)
- The Sperm Whale (*Physeter microcephalus*)


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Cape Verde Islands are habitat for five species of sea turtle:

- The loggerhead turtle *Caretta caretta* is the most common turtle species, and the nesting population of Cape Verde is considered the second largest population of this species in the Atlantic and the third worldwide (López Jurado et al. 2007). Every year, thousands of female loggerheads migrate from their feeding grounds to Cape Verde to nest. At the beginning of their marine life, they quickly leave the coast, undertake long oceanic migrations and, after reaching sexual maturity, return to Cape Verde several years later to nest on the beaches (Marco et al., 2011). Around 85-90% of nesting is concentrated on the easternmost island of Boavista, where the population is currently estimated at more than 10,000 nests per year (López Jurado et al. 2007, Marco et al. 2008, 2010) but the whole Cape Verdean archipelago can be considered a single management and conservation unit.
- The hawksbill turtle *Eretmochelys imbricata*, does not nest in the Cape Verde Islands but is also very common and can remain feeding in shallow and protected bays for several years, migrating far away when they approach sexual maturity. International Status: Critically Endangered (IUCN classification). Status in Cape Verde: Endangered
- The green turtle *Chelonia mydas*, does not nest in the Cape Verde Islands but are very common and can remain feeding in shallow and protected bays for several years, migrating far away when they approach sexual maturity. Over 30% of the Cape Verde feeding grounds are populated by green turtles that hatched on the American continent and undertake transatlantic migrations (Monzón Argüello et al. 2010a). Other juvenile green turtles come from the coasts of West Africa, Brazil and Ascension Island in the South Atlantic (Monzón Argüello et al. 2010a). International Status: Endangered (IUCN classification). Status in Cape Verde: Endangered
- The olive Ridley turtle *Lepidochelys olivacea* is observed in Cape Verde as passing populations, registered in the islands of São Nicolau, Sal and Boa Vista. International Status: Vulnerable (IUCN classification). Status in Cape Verde: Endangered.
- The leatherback turtle *Dermochelys coriacea* migrates through the waters of the archipelago is difficult to observe. Hawksbill and green turtle juveniles are often found feeding in neritic waters of Cape Verde. These four species do not nest in the archipelago (Marco et al., 2011). International Status: Vulnerable (IUCN classification). Status in Cape Verde: Endangered

Until recently, knowledge on seabird distribution and abundance was heavily based on the data collected and compiled by Hazevoet (1995). Based on diurnal prospections of seabird colonies and nocturnal hearings of their vocalizations (to identify presence and relative abundance) on several islands of Cape Verde during 2018 and 2019, numbers of seabird species are now considered higher on Islets, especially on Raso and Rombo Islets, than on larger Islet (unpublished data). Sal Island is home to one of the largest populations of *Phaeton aethereus* of West Africa, and *Hydrobates jabejabe* is the most widespread and abundant species across main Islands, closely followed by *Puffinus boydii*. *Calonectris edwardsii* occurred on the highest number of Islands and Islets of the archipelago (9 locations; Table 4.1). GPS-tracking of several seabird species at Raso Islets revealed that during the breeding period (incubation and chick-provisioning phases) their at-sea distribution occurs mostly within the Cape Verde Economic Exclusive Zone (EEZ). Nevertheless, some species also exploited areas outside the Cape Verde EEZ, namely *Hydrobates jabejabe* and *Puffinus boydii* foraging up to 400 km off Raso Islet and *Bulweria bulwerii* and *Calonectris edwardsii* up to 600 km, off West Africa close to the coast of Senegal.



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*Table 4.1. Current distribution of seabird colonies in the main Islands and Islets of the Cape Verde archipelago. Sa: Santiago, Fo: Fogo, Br: Brava, Ro: Rombo, SA: Santo Antão, SV: São Vicente, SL: Santa Luzia, Ba: Branco, Ra: Raso, SN: São Nicolau, Sl: Sal, BV: Boa Vista, Ma: Maio.*

| Species/Island | Sa | Fo | Br | Ro | SA | SV | SL | Ba | Ra | SN | Sl | BV | Ma |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Bulweria bulweria* | | | | X | | | | X | X | | X | | |
| *Calonectris edwardsii* | X | X | X | | X | X | | X | X | | X | X | |
| *Fragata magnificens* | | | | | | | | | | | | | |
| *Hydrobates jabejabe* | | | | X | X | | X | | | X | X | X | X |
| *Pelagodroma marina* | | | | X | | | | X | | | | X | X |
| *Phaethon aethereus* | X | X | X | X | X | | | | X | | X | X | |
| *Pterodroma feae* | X | X | | | X | | | | | X | | | |
| *Puffinus boydii* | X | X | X | X | X | | | X | X | | X | | |
| *Sula leucogaster* | X | | X | | | | | | | | | X | |

## 4.3.2. Coastal and Marine Protected Areas

Cape Verde Decree-Law No. 3/2003, of 24 February, establishes the legal regime to manage coastal and marine protected areas, according to their importance in terms of biodiversity, natural resources, ecological function, socio-economic and touristic interest. It consists of 8 chapters and 1 annex specifying the principles to be adopted in order to define and manage protected area and national parks according to the Cape Verdean National Protected Areas' Programme. The Annex lists a classification of the mentioned protected areas by island. Decree-Law No. 44/2006, of 28 August, amending Decree-Law No. 3/2003 on Protected areas management (Table 4.2).

*Table 4.2. Cape Verde Coastal and Marine Protected Areas*

| Island | Protected Area Category | Name PA/MPA | Terrestrial surface (Ha) | Marine area (Ha) | Total area (Ha) |
|---|---|---|---|---|---|
| **Sal** | Natural Reserve | Costa da Fragata | 346.0 | 2347.0 | 2693.0 |
| | Natural Reserve | Ponta do Sino | 96.0 | 5651.0 | 5747.0 |
| | Natural Reserve | Serra Negra | 331.0 | 2296.0 | 2627.0 |
| | Marine Natural Reserve | Baía da Murdeira | 182.0 | 5925.0 | 6107.0 |
| | Natural Reserve | Rabo de Junco | 154.0 | 0.0 | 154.0 |
| | Protected Natural Heritage | Monte Grande | 1309.0 | 0.0 | 1309.0 |
| | Protected Natural Heritage | Salinas Pedra Lume e Cagarral | 802.0 | 0.0 | 802.0 |
| | Protected Natural Heritage | Buracona-Ragona | 545.0 | 0.0 | 545.0 |
| **Boa Vista** | Integral Natural Reserve | Ilhéu de Baluarte | 7.7 | 87.0 | 94.7 |
| | Integral Natural Reserve | Ilhéu dos Pássaros | 0.8 | 38.0 | 38.8 |
| | Integral Natural Reserve | Ilhéu de Curral Velho | 0.8 | 41.0 | 41.8 |
| | Natural Reserve | Ponta do Sol | 465.0 | 283.0 | 748.0 |
| | Natural Reserve | Boa Esperança | 3631.0 | 379.0 | 4010.0 |
| | Natural Reserve | Morro de Areia | 2131.0 | 436.0 | 2567.0 |
| | Natural Reserve | Tartaruga | 1439.0 | 13436.0 | 14875.0 |
| | Natural Park | PN do Norte | 8910.0 | 13137.0 | 22047.0 |
| | Natural Monument | Ilhéu de Sal-Rei | 89.0 | 0.0 | 89.0 |
| **Maio** | Natural Reserve | Casas Velhas | 130.9 | 6495.2 | 6626.1 |
| | Natural Reserve | Lagoa Cimidor | 51.1 | 406.3 | 457.4 |
| | Natural Reserve | Praia do Morro | 101.7 | 565.0 | 666.8 |
| | Protected Natural Heritage | Salinas de Porto Inglês | 400.6 | 134.1 | 534.7 |
| | Protected Natural Heritage | Barreiro e Figueira | 1080.8 | 0.0 | 1080.8 |
| | Natural Park | Norte da Ilha de Maio | 4715.9 | 20886.6 | 25602.5 |
| **Santa Lúzia** | Marine Natural Reserve | Santa Lúzia | 3427.0 | 27318.0 | 30745.0 |
| **Santo Antão** | Marine Natural Park | Cruzinha | 4433.5 | 8054.4 | 12487.9 |
| | Protected Natural Heritage | Pombas | 311.9 | 0.0 | 311.9 |
| **São Nicolau** | Natural Reserve | Monte do Alto das Cabaças | 1325.0 | 0.0 | 1325.0 |



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### 4.3.3. Anthropogenic forcing

Being an archipelago, Cape Verde strongly depends on marine traffic to transport goods and services among the islands, and in and out of the country. All nine inhabited islands have at least one small port, and there are two Port Authorities: one for the islands of the Barlavento group, and the other for the islands of Sotavento group. The State Concession of the Harbours was given to ENAPOR (DL 31/2015, 18th of May) (http://www.enapor.cv/page/homepage), a public enterprise. The ENAPOR concession is supervised by the IMP (Instituto Marítimo-Portuário/Maritime-Port Institute - www.imp.cv), former AMP (Agência Marítimo-Portuária/Maritime-Port Agency), a public entity.

In January 2018, the president of APESC (Associação de Armadores de Pesca de Cape Verde/Cape Verde Fishermen Association) stated that although bunkering and shipyard activity have potential to grow in the island of S. Vicente, these are activities that bring environmental and public health risks, combined with an internal fragility because of the lack, for instance, of emergency/disaster preparedness or contingency plans. He also stated that since the Cape Verde fishing-fleet is rather small (around 74 vessels up to 14 m) they can only move within the 50 miles off the coast, leaving the remaining EEZ to foreign vessels (over 200 mainly from Japan, China and the EU).

In short, although fishing is considered a major activity, both for food security and as a revenue source of the Cape-Verdeans (Monteiro and Ramos, 2014), future investments on local harbours seem more focused on developing the tourist activity.

Due to the absence in the Ports of infrastructures to collect waste and residual waters from the vessels that use them, the ship crews of those vessels may choose to launch their wastes and contaminated waters in the sea, increasing the level of contamination in the Cape Verdean national waters (PANA II, 2004a).

In Cape Verde, the semi-industrial or industrial dredging on coastal areas is mainly related to the construction or enlargement of ports (Monteiro and Ramos, 2014). Apart from that, other few dredging areas that exist in the sea bed are all located next to the coast line; for instance there has been some sand extraction on the coasts of the islands of Maio and Fogo, but this activity was interrupted given the menace it represents for the marine biodiversity (Correia, 2012), a fact already pointed out by the European Commission (2010), based on studies conducted in the United Kingdom on the impacts of dredging on marine benthos. Given the presence of large sand banks on many of the islands, the country dredging areas are mostly located in beaches and freshwater beds.

The World Bank considers tourism as one of the most important investments for the future of Cape Verde. But if the country wants to turn tourism into a major contributor of the GDP (Gross Domestic Product), it will have to tackle first issues like sanitation, waste management and illegal inert extraction. Still, the tourism sector has been greatly responsible for the income of foreign currency and the creation of new jobs (Fortes, 2016). In the year 2000 the tourism sector represented 6.4% of the GDP, in 2010 reached 16.1%, and in 2018 it was 22.3% (BCV, 2019), showing a general growing tendency. This increase in tourism exerted pressure on the coastal and marine habitats, expressed on the built of new tourist infrastructures, an increase need for sand extraction and seafood products, and the practice of harmful recreational activities in sensitive habitats (e.g. off-road on the dunes). To face this reality, PANA II (2004b) contains a series of planned programs and studies, that aim the valuing and conservation of the country's biodiversity, using it to build a sustainable tourism strategy (e.g. Reina, 2015), and vice-versa (e.g. Luz, 2013).



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## 4.4. Fisheries distribution, abundance, seasonality, production and Aquaculture

Cape Verde is a country of high fish diversity but relatively low abundance (Moniz, 2009). Even though fisheries contribute only around 5% to the GNP, the sector is important to the economy. It employs around 11,000 people. Fish is the main source of animal protein in the diet of the people and exports of fisheries products are of considerable importance to the economy (Benvindo, 2000).

Tuna fishery is the most valuable fishery in Cape Verde. As an example, until 1991 it contributed around 80% to the industrial catches (Table 4.3). The increase of purse seine fisheries, along with a decline in tuna catches, has brought the tuna landings down to about 40% of the total (INDP, 1998).

*Table 4.3. Tuna catches in the artisanal and industrial fisheries in Cape Verde 1986-1999 (INDP 1999). Review made by Benvindo (2000).*

| Year | Artisanal catch | % of Artisanal catch | Industrial catch | % of Industrial catch | Total |
|---|---|---|---|---|---|
| 1986 | 2,930 | 62 | 2,215 | 86 | **5,145** |
| 1987 | 2,444 | 61 | 3,007 | 91 | **5,450** |
| 1988 | 2,627 | 64 | 1,840 | 80 | **4,467** |
| 1989 | 2,812 | 44 | 1,860 | 84 | **4,672** |
| 1990 | 2,182 | 44 | 1,351 | 82 | **3,533** |
| 1991 | 1,796 | 41 | 2,105 | 84 | **3,901** |
| 1992 | 1,863 | 43 | 967 | 43 | **2,830** |
| 1993 | 2,032 | 42 | 832 | 38 | **2,864** |
| 1994 | 2,242 | 42 | 940 | 32 | **3,182** |
| 1995 | 1,919 | 42 | 1,737 | 44 | **3,656** |
| 1996 | 2,042 | 42 | 1,640 | 39 | **3,682** |
| 1997 | 1,967 | 40 | 1,233 | 26 | **3,200** |
| 1998 | 1,681 | 32 | 1,152 | 32 | **2,833** |

In 2014, exports of fish and fish products reached a record of 84.3% of national total exports (INE 2014). Tuna is the most-exported fish (43% of the total amount), followed by processed forms of mackerel (40%). The fisheries sector is often divided by destination of catches and type of vessels, leading to two distinct categories:

- **Artisanal fisheries:** responsible for decentralized fish supply to local communities and islands;
- **Industrial fisheries**: responsible for the export, supply of the canning market, and supply of the main urban centres of fish consumption at the country level.

### 4.4.1. Artisanal/Demersal Fisheries

The artisanal sector is characterised by the use of 4-8 m long wooden boats with 8-25 HP outboard engines. It employs around 5000 fishermen and the fleet is about 1500 boats with 2-3 men on board (INDP 1998). They fish close to the coast and the main fishing gear are handlines for demersal fish and tuna, and purse seine 130x15 fathom and beach seines 50x3 fathom for small pelagics. This sector accounts for more than 50% of the total catches, which supply the local market. The artisanal sector has been relatively stable for several years with catches ranging from 3281 to 6976 tonnes during 1986-2018 (Table 4.4 and Table 4.5).


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*Table 4.4. Summary of catches (tonnes) and effort in the artisanal sector, 1986-2018 (Source: Official statistics from INDP, 2019).*

| Year | Artisanal Fishing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total capture | Small pelagics | Tuna | Demersal | Coastal Lobster | Divers | Total effort (nº of travels) |
| 1986 | 4 764 | 1 024 | 2 930 | 619 | 0 | 191 | 119 851 |
| 1987 | 4 005 | 721 | 2 443 | 641 | 0 | 200 | 135 478 |
| 1988 | 4 092 | 540 | 2 627 | 741 | 0 | 184 | 116 663 |
| 1989 | 6 391 | 2 045 | 2 812 | 1 087 | 0 | 447 | 154 368 |
| 1990 | 4 935 | 1 270 | 2 170 | 765 | 0 | 730 | 137 998 |
| 1991 | 4 884 | 1 540 | 1 797 | 778 | 2 | 767 | 138 534 |
| 1992 | 4 308 | 1 567 | 1 863 | 641 | 0 | 237 | 112 737 |
| 1993 | 4 829 | 1 817 | 2 032 | 629 | 0 | 351 | 123 016 |
| 1994 | 5 347 | 2 040 | 2 242 | 801 | 0 | 264 | 134 699 |
| 1995 | 4 547 | 1 413 | 1 919 | 882 | 0 | 333 | 128 732 |
| 1996 | 4 912 | 1 527 | 2 042 | 1 013 | 9 | 321 | 134 667 |
| 1997 | 4 920 | 1 184 | 1 967 | 1 313 | 11 | 445 | 140 404 |
| 1998 | 5 242 | 2 165 | 1 681 | 994 | 6 | 396 | 148 158 |
| 1999 | 5 968 | 2 460 | 2 089 | 915 | 0 | 504 | 155 009 |
| 2000 | 6 976 | 2 931 | 2 193 | 1 224 | 0 | 628 | 173 856 |
| 2001 | 5 649 | 1 849 | 2 335 | 1 091 | 21 | 353 | 154 408 |
| 2002 | 5 383 | 1 708 | 2 339 | 925 | 0 | 411 | 156 714 |
| 2003 | 5 206 | 1 981 | 1 812 | 1 038 | 0 | 375 | 155 034 |
| 2004 | 5 259 | 2 164 | 1 648 | 1 065 | 0 | 382 | 141 718 |
| 2005 | 4 822 | 2 151 | 1 339 | 909 | 0 | 423 | 118 854 |
| 2006 | 4 530 | 1 383 | 1 674 | 935 | 0 | 538 | 124 740 |
| 2007 | 4 323 | 1 370 | 1 624 | 875 | 2 | 452 | 123 686 |
| 2008 | 3 780 | 1 233 | 1 125 | 957 | 3 | 462 | 117 369 |
| 2009 | 4 348 | 1 266 | 1 564 | 943 | 5 | 570 | 136 001 |
| 2010 | 4 618 | 1 462 | 1 358 | 1 102 | 5 | 691 | 144 752 |
| 2011 | 4 050 | 1 010 | 1 471 | 1 054 | 3 | 512 | 145 282 |
| 2012 | 4 310 | 914 | 1 610 | 1 045 | 4 | 737 | 146 373 |
| 2013 | 4 575 | 1 050 | 1 588 | 1 252 | 4 | 681 | 59 055 |
| 2014 | 4 553 | 764 | 2 027 | 1 202 | 3 | 557 | 140 269 |
| 2015 | 4 285 | 1 202 | 1 456 | 1 093 | 4 | 530 | 158 542 |
| 2016 | 4 122 | 869 | 1 436 | 1 198 | 0 | 619 | 137 704 |
| 2017 | 3 281 | 645 | 998 | 1 112 | 6 | 520 | 113 212 |
| 2018 | 4 027 | 894 | 1 225 | 1 300 | 0 | 608 | 137 704 |

*Table 4.5. Description of the 13 most important types of artisanal fishing activities during 2006-2010 (UNIDO, 2016).*

| Type of fleet | Fisheries description | Geography | Seasonality (majority of landings) |
|---|---|---|---|
| Artisanal | Handline - Albacora (*Thunnus albacores*) | All islands | April/August |
| | Handline - Serra (*Acanthocybium solandri*) | All islands | November /April |
| | Handline - Chicharro (*Selar crumenophthalmus*) | All islands | All year with variations |
| | Handline - Demersals | All islands | March/August |
| | Handline - Garoupa (*Cephalopholis taeniops*) | All islands | All year with variations |
| | Handline - Moreias (Muraena spp) | All islands | October / May |
| | Handline - Salmonete (Pseudupeneus prayensis) | All islands | January/June |
| | Purse-seine nets - Cavala preta (*Decapterus macarellus*) | Mainly in Santo Antão, Sao Vicente and Sal | Mainly in the 2nd and last quarter of the year |
| | Purse- seine nets - multiple species | Mainly in Santo Antão, Sao Vicente and Sal | All year with variations |
| | Gillnets - Dobrada (*Spicara melanurus*) | Mainly in Santiago and Santo Antão | Between 1st and last quarter of the year |
| | Beach seine - juveniles of Chicharro (Selar crumenophthalmus) | All islands | September/January |
| | Plongée diving - Buzio (*Strombus latus*) | Mainly in Sao Vicente, Santiago and Santo | October /February |
| | Plongée diving – multiple species | All islands | October /February |



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In 2000, Martins et al. (2002) reported that although the catches were increasing slowly, stocks were intensively exploited in certain areas. Demersal stocks are made up of very small populations, with limited genetic diversity and slow individual growth. They are very sensitive to fishing effort. Generally, it is difficult to increase the catches of rocky bottom demersal species (Monteiro 1998). The sandy bottom demersal species are under-exploited and their potential is estimated at 700-2,800 tonnes/year (Thorsteinsson et al. 1995). The species living below 200 m are slightly exploited but recent studies show that they are not abundant and therefore they will not support high fishing effort (Menezes et al. 2001). INDP has recommend preserving the demersal species for the national fleet and banning the use of gillnets and trawls on the rocky bottom and sea mountains (Martins et al., 2002).

### 4.4.2. Industrial Fishing

In Cape Verde, the industrial fishing fleet consists of 70-80 vessels varying in size from 8 to 25 m with 40-510 HP engines. The production is mainly for export and processing plants. The main species caught are tunas, small pelagics, demersals and lobsters. Most of the industrial fleet targets tuna species using pole and line and longlines with live bait. Some vessels catch small pelagics with purse seines; lobsters with traps and demersals with handlines. Annual catches have fluctuated considerably in the 1990s (Table 4.6) with an average around 3000 tonne and reached its maximum in 2014 with 10746 tonnes. Tuna represented more than 50% of the total catches of the industrial fleet until 1991 followed by small pelagics and demersals. Since 1992, catches of small pelagics have increased after foreign vessels were permitted to buy mackerel from national vessels. Catches of pink lobster varied from year to year with a maximum in 1992 due to an experimental fishing cruise that took place at that time. Their number have largely decreased afterwards (Table 4.6).

*Table 4.6. Summary of catches per and effort (days at sea) in the industrial sector 1986 - 2018 (Source: Official statistics from INDP, 2019).*

| Year | Industrial Fishing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total capture | Small pelagics | Tuna | Demersal | Pink Lobster | Divers | Fishing effort (days at sea) |
| 1986 | 2 578 | 327 | 2 215 | ND | 36 | ND | 2 272 |
| 1987 | 3 307 | 216 | 3 007 | 33 | 51 | ND | 2 218 |
| 1988 | 2 295 | 221 | 1 840 | 209 | 25 | ND | 1 668 |
| 1989 | 2 223 | 210 | 1 860 | 121 | 30 | 2 | 2 301 |
| 1990 | 1 644 | 244 | 1 351 | 16 | 30 | 3 | 2 021 |
| 1991 | 2 404 | 309 | 2 015 | 2 | 70 | 8 | 2 253 |
| 1992 | 2 265 | 1 179 | 967 | 2 | 106 | 11 | 1 304 |
| 1993 | 2 171 | 1 193 | 832 | 20 | 76 | 50 | 3 860 |
| 1994 | 2 909 | 1 823 | 940 | 58 | 68 | 20 | 2 829 |
| 1995 | 3 948 | 1 990 | 1 737 | 126 | 60 | 35 | 3 106 |
| 1996 | 4 243 | 2 230 | 1 640 | 240 | 29 | 104 | 3 426 |
| 1997 | 4 707 | 3 230 | 1 233 | 137 | 25 | 82 | 5 057 |
| 1998 | 4 218 | 2 734 | 1 188 | 156 | 27 | 113 | 5 877 |
| 1999 | 4 403 | 2 003 | 2 065 | 164 | 35 | 136 | 5 949 |
| 2000 | 3 844 | 1 892 | 1 742 | 90 | 29 | 91 | 4 822 |
| 2001 | 3 241 | 1 734 | 1 284 | 74 | 26 | 123 | 3 450 |
| 2002 | 3 669 | 2 471 | 1 103 | 40 | 23 | 32 | 5 366 |
| 2003 | 3 213 | 2 088 | 987 | 22 | 17 | 99 | 5 123 |
| 2004 | 3 441 | 2 027 | 1 294 | 61 | 26 | 33 | 2 682 |
| 2005 | 3 168 | 2 358 | 675 | 83 | 0 | 52 | 1 068 |
| 2006 | 5 657 | 4 045 | 1 366 | 159 | 1 | 86 | 1 738 |
| 2007 | 4 434 | 3 518 | 801 | 64 | 2 | 49 | 1 916 |
| 2008 | 4 102 | 3 158 | 835 | 62 | 0 | 47 | 4 971 |
| 2009 | 4 317 | 2 762 | 1 438 | 79 | 0 | 38 | 6 184 |
| 2010 | 4 833 | 3 378 | 1 316 | 97 | 0 | 42 | 7 197 |
| 2011 | 4 619 | 2 978 | 1 429 | 105 | 2 | 105 | 6 818 |
| 2012 | 5 954 | 3 947 | 1 709 | 124 | 3 | 171 | 6 264 |
| 2013 | 8 265 | 5 783 | 1 422 | 837 | 0 | 223 | 3 860 |
| 2014 | 10 746 | 2 575 | 6 952 | 1 026 | 27 | 166 | 4 946 |
| 2015 | 9 693 | 1 597 | 6 509 | 1 437 | 7 | 143 | 5 267 |
| 2016 | 5 338 | 1 079 | 3 985 | 238 | 0 | 36 | 3 860 |
| 2017 | 6 087 | 1 850 | 3 818 | 381 | 2 | 35 | 3 860 |
| 2018 | 9 973 | 3 410 | 6 292 | 262 | 1 | 9 | 3 860 |



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In general, the main fish stock reserves of Cape Verde can be grouped into four main categories: small pelagics, large oceanic pelagics, demersals, and lobsters.

**Small pelagics**

The small pelagic stocks are characterized by their volatile abundance, interrelated with fluctuations of environmental and recruitment parameters. The most abundant and important species of the small pelagic are horse mackerel (*Decapterus macarellus*), scad mackerel (*Decapterus punctatus*) and chicharro-bigeye scad (*Selar crumenophthalmus*). These species are found in Cape Verdean waters all year round and usually feed on zooplankton (Benvindo, 2000). Because of their abundance and low price in the local market, small pelagic are the most important food fish for the population (Medina 2000). Also, small pelagic are used as bait for the tuna fisheries, which are most important for export. Horse mackerel catches increased until 1997 because of the demands for frozen bait for the Canary based long lining tuna fleet and decreased again after this period. The scad mackerel constituted almost 40% of total catches at the peak of the fishery in 1997 and 1998. This proportion decreased to about 20% in recent years, corresponding to 2104 tonnes in 2004. The artisanal scad mackerel seine fishery is rather small, comprising about 24 boats (≈10 m) with outboard engines, but is characterised by high CPUE when compared to other gears. These boats catch around 250 kg per trip in recent years, while the overall artisanal mean is 37 kg per trip. Most of the fishing activity takes place in the northern islands, where scad mackerel is more abundant. Nonetheless, results indicated that island or regional effects could be ignored, as the differences could be attributed to gear effects mainly. It is important to point out that artisanal fisheries in Cape Verde are multispecies and multigear fisheries, creating problems in determining directed effort to specific target species.

**Large pelagics**

The archipelago of Cape Verde is located in a productive zone for tropical tuna and tuna like species. Among the large oceanic pelagics is tuna and related species, including the yellowfin tuna (albacora, *Thunnus albacares*), skipjack (gaiado, *Katsuwonus pelamis*), bigeye (patudo, Thunnus obesus), the little tunny (merma, *Euthynnus alleteratus*), frigate tuna (judeu ou cachorrinha, *Auxis thazard*) and wahoo (serra ou ilhéu, *Acanthocybium solandri*). The estimated TAC for coastal and deep-sea waters is 25,000 tonnes (Hallier 1996) and they are considered moderately exploited (INDP 1996). Tuna and tuna like species are exploited by national and foreign fleets, with different fishing gears. The total catches of both fleets are below the estimated potential yield (Martin, 2000). The catches of the foreign fleet appear to be underestimated but they have never exceeded 3,000 tonnes. The low exploitation level in Cape Verde has been attributed to lack of bait. Although this is partly true it's not the main reason. There are external factors, such as low and decreasing prices for skipjack tuna in the international market, which hinder its traditional fishing (Hallier 1996). Tuna species are mainly caught by hand line or with pole and line. To catch skipjack live bait is essential and therefore all pole and line vessels are equipped with purse seines. Yellowfin and bigeye can be caught with long line using dead bait, frozen or fresh. A pole and line vessel catches annually around 250-450 tonnes, the average specific catch composition from August to November is: 70% skipjack, 25% yellowfin and 5% bigeye. From April to August and from October to December it changes to 70% yellowfin, 10% bigeye and 20% skipjack.

The International Commission for the Conservation of Atlantic Tunas (ICCAT) is responsible for the conservation of tunas and tuna-like species in the Atlantic Ocean and adjacent seas. ICCAT is the only fisheries organization that can undertake the work required for the study and management of tunas and tuna-like fishes in the Atlantic. Such studies include research on biometry, ecology, and oceanography, with a principal focus on the effects of fishing on stock abundance. The Commission's work requires the collection and analysis of statistical information relative to current conditions and



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trends of the fishery resources in the Convention area (Figure 4.3). The Commission also undertakes work in the compilation of data for other fish species that are caught during tuna fishing ("bycatch", principally sharks) in the Convention area, and which are not investigated by another international fishery organization. Landing data concerning Cape Verde Region is available in the ICCAT website: http://old.iccat.int/en/accesingdb.htm.

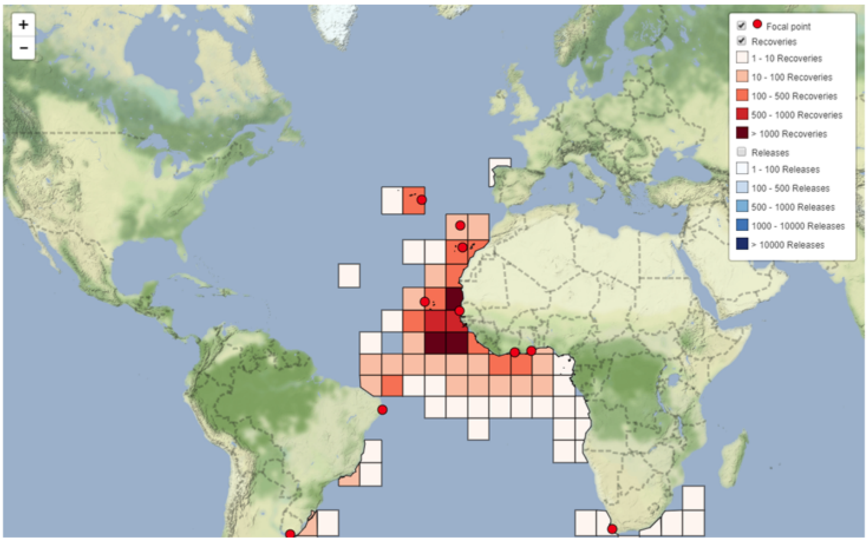


*Figure 4.3. ICCAT Atlantic Ocean Tropical tuna Tagging Programme (AOTTP): Data on recovered species. ICCAT Project: Evidence Based Approach for sustainable management of tuna resources in the Atlantic. Data actualised in May 2018.*

**Demersal**

Demersal fish stocks include a diverse group of species living on the seabed. Characterized by relatively slow populational growth, these species are highly vulnerable to situations of over-exploitation. Two of the most exploited species are the grouper and mullet. The grouper *Cephalopholis taeniops* (Valenciennes, 1828), is an abundant serranidae species living on rocky bottoms. It is among one of the fish with greatest commercial interest in artisanal fishing and is landed throughout the year. Its distribution is limited to the eastern part of the Atlantic Ocean, between Western Sahara and Angola, including the islands of Cape Verde and those of São Tomé and Príncipe, with a habitat corresponding to rocky or sandy bottoms, between 20 and 200 meters deep. In Cape Verde, the species is caught, mainly with hand line, either by artisanal fishing or by industrial fishing. The fishing effort data are expressed in number of boat trips for artisanal fishing, and in days of sea fishing for industrial fishing. These effort data are those of all species caught by the hand line. Indeed, it is a multispecies fishery, which does not specifically target a species (Medina, 2002). There are no studies on the identification of grouper stocks. However, since it is a coastal species and given the great depth that separates the different groups of islands, it is assumed that there must be different stocks in Cape Verde. Tariche et al. (2002), sampled at Salamansa (São Vicente Island) and concluded that this species is considered close to full exploitation. However, the evaluation needs improvement by using other methods for size frequency decomposition, as well as more complete series of data (Tariche et al. 2002). The striped red mullet *Mullus surmuletus* is another important demersal species. It lives in sandy bottoms and is caught by the artisanal fishery through different gear, such as line, gill net, purse seine or beach seine. This species is also captured by bottom trawling in areas of the continental shelf at Boavista Island (Medina, 2002). Catches per unit effort (CPUE) for these two species present an increasing trend although fishing effort is also increasing. This situation has also been verified for other species caught by artisanal fishing (Medina, 2002).



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**Lobster fishery**

All lobster species have commercial interest. Annual catch potential until 1992 was thought to be around 1,000 tonnes for the mains species. Demersal surveys from 1995 to 1999 showed a decreasing CPUE trend, with the conclusion that all were overexploited (Martins 2002). Management measure have been implemented and coastal lobster's fisheries are closed from the 1st of May until the 31st of September. The minimum size of coastal lobsters is 9 cm of carapace length.

Three species of coastal lobsters are caught down to depths of 55 m, either by divers (using a gaff to extract lobsters from their dens) or with traps (among the reefs and around islands with a narrow shelf):

- *Panulirus echinatus* (brown spiny lobster) has been assessed as Least Concern by the IUCN. This abundant widespread species is harvested in most parts of its range there are no fisheries data available to indicate whether this is having significant impact on the global population. There have been declines, however the ecological characteristics of spiny lobsters make them relatively resistant to extinction as they do not need to aggregate to spawn and are highly fecund with well-connected populations via long-lived larvae.
- *Panulirus regius* (Royal spiny lobster) has been assessed as Data Deficient by IUCN. It has a wide distribution but is fished throughout its range. There is little quantitative information on population trends or catch levels, but landings statistics and anecdotal reports suggest it has been intensively fished for decades along much of the West African coast with little or no regulation. The result is that stocks are likely overexploited in some regions, particularly in the north and south of its range (e.g., Mauritania, Cape Verde Islands, Angola). In Cape Verde, *P. regius* is referred to as 'lagosta verde', and it is heavily fished at most of the islands. In 2007, it accounted for 71% of the catch of shallow-water lobster species in the north-west islands. *P. regius* spawns year-round, with a spawning peak from June to September at Cape Verde (Dias 1993). In 2007, Freitas et al. proposed the introduction of a maximum landing size, in addition to the pre-existing minimum landing size (MLS), to protect larger females who dominate egg production. They also recommended increasing the MLS to 25 cm TL, equivalent to increasing the minimum landing weight from 500 g to 600 g, to protect more effectively reproductive females (Freitas et al. 2007).
- *Scyllarides latus* (Mediterranean locust lobster) has been assessed as Data Deficient by the IUCN. This species has been subject to intense harvesting pressure throughout its range. This species is the subject of intensive harvesting and as a result it has become rare along the European coast of the west Mediterranean and in its Atlantic Ocean range of distribution. In some areas, such as Italy and the Azores, the attempts to recover its stocks may be too late. A global management strategy needs to be implemented that focuses on protecting key habitat areas.

There is also one endemic species of deep water lobster *Palinurus charlestoni* (Cape Verde spiny lobster or pink lobster) that has been assessed as Near Threatened by IUCN. This species has an estimated extent of occurrence of 15,000 km² and is subject to an ongoing decline in the number of mature individuals because of harvesting pressure (Cockcroft, 2018). *P. charlestoni,* live on rocky, uneven bottoms at depth ranging from 50 to 400 m, but is (relatively) abundant between 100 and 250 meters (Carvalho and Latrouite 1992). The results of the experimental fishery conducted by Muncreca 1991/92 showed that the abundance is unequally distributed between Cape Verdean islands and varies according to exposure to Sotavento or Barlavento (Carvalho and Latrouite, 1992). Overall, the favourable area to this specie is very limited. This lobster only targeted by industrial fishing using the trap technique and is caught for nine months in the year (fishing ban from the 1$^{st}$ of



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July to the 30th of November). Gradually, fishers replaced French and Portuguese traps with Cape Verdean traps. The latter are more efficient and more adapted to the characteristics of the fishery (Medina et al., 2003). Lobster fishery statistics cover the last twenty years (Figure 4.4) and show a clear period of increase in catches, with a very sharp peak between 1991 and 1992 (85 tonnes), followed by a sharp decline. It is noted that the fishing effort data do not cover the entire period (Medina et al., 2003), and it should be noted that fishermen are constantly looking to increase their yields.

The deep lobster stock is considered "moderately overexploited", but this global diagnosis could mask contrasting situations between different sub-stocks that are subservient to the different Cape Verdean island regions; the stock is thus qualified as uncertain (Gascuel et al., 2002).

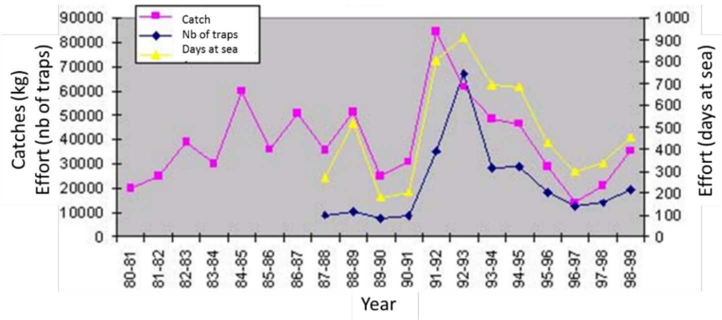


*Figure 4.4. Annual evolution of pink lobster catches (kg) and fishing effort (number of traps and days at sea) (Medina et al., 2003).*

### 4.4.3. Aquaculture

In 2010, the government of Cape Verde, with the support from FAO, developed a Strategic Framework for Aquaculture Development (2010). This strategic agreement planned a project to develop capacity building, training administrative professionals, as well as the development of pilot-experiments (UNIDO, 2016). Under cooperation with China, a similar project was developed with the aim of fattening tuna in cages (mariculture in inshore waters). Preliminary results were encouraging, including the possibility of extending the experiment to other species. Tuna is of high commercial value, and thus, the success of this initiative was expected to provide great economic revenues. However, the experiment ended abruptly due to vandalism and theft.

With a growing tourist sector in Cape Verde and a worldwide trend to fulfil protein demand with seafood, shrimp farming has been considered a good market opportunity in the region. A Brazilian company has joined with companies in Cape Verde and in 2009 a joint venture to implement a shrimp farm on Sao Vicente was created. The Shrimp and Tilapia Farm is located 17 km from the City of Mindelo, in Calhau, and entered in operation in January 2018 (Cabral T., 2017). The shrimp farm consists in open ponds and is expected to replace shrimp import in short term and to export the surplus production. In the future, the farm aims to incorporate its own nursery facility and to grow *Litopenaeus vannamei* to the size of 12 g. Overall, the objective is to produce up to 200 tonnes of shrimp per year, covering the internal market demand and exporting to the European market. The project was strongly endorsed by the Cape Verde Government and was support by the Dutch Government under a Private Sector Partnership Program (Cabral, 2017). Lack of live bait has also been a historical bottleneck for tuna fisheries using the traditional pole and line technique. Therefore, this aquaculture project also aims to farm tilapia juveniles to be used as live bait in the pole and line fisheries. The facility will produce all-male tilapia juveniles to the size of 8 to 10 cm to be used in the pole and line tuna fisheries. The aquaculture facility planned to be the first to use 100% renewable energies in a combination of wave and solar power.



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## 4.5. Current State and existing measures for Marine Spatial Planning

Cape Verde does not have a fully implemented Marine Spatial Planning (MSP) legal framework. However, there are currently several instruments that can support and facilitate MSP good practices. In general, space, activities and conflict management is currently done through a sectorial approach, where each area (Fisheries, Tourism, etc.) is regulated by its respective ministry and policies.

### 4.5.1. National Legal Frameworks that can enhance MSP

The Law on Urban and Spatial Planning (Legislative Decree No. 1/2006, of 13 February as amended by Legislative Decree No. 6/2010, of 21 June) provides a classification of land use comprised under the national territory and defines the basic principles undergoing spatial planning and management. It includes Instruments of a special nature, namely, the instruments for spatial planning of coastal and protected areas. The Decree-Law No. 43/2010, of 27 September, approves the National Regulation for Land and Urban Planning. It defines the instruments to regulate territorial: management development, planning, sectorial policy and regarding special nature, such as land planning of: protected areas, touristic areas, coastal zone management and hydrographic basins.

The Instruments of special nature concern the protection and safeguarding of natural and biological resources, including the instruments for spatial planning of coastal and protected areas. Cape Verde Decree-Law No. 3/2003, of 24 February (amended by Decree-Law No. 44/2006, of 28 August), establishes the legal regime to manage coastal and marine protected areas, according to the importance of their biodiversity, natural resources, ecological function, socio-economic and touristic interest. Cape Verde has several protected marine areas, relevant for the conservation of biodiversity (Table 4.2**Erreur ! Source du renvoi introuvable.**).

The resolution No. 35/2016, of 17 March, approving the Cape Verde National Protected Areas Strategy for all National Network of Protected Areas, can also be relevant for MSP purposes, since it aims for the establishment of a long-term expansion plan, including control strategies and/or mitigating the impacts of climate change.

Currently, the Cape Verdean environmental agency (DNA) is also working with the United Nations to improve protected areas management plans, by looking for new management strategies to achieve protected areas sustainability (such as self-funding strategies, etc.), and by updating PAs list, including new areas that have just recently been identified as in need for protection. Therefore, it is expected that the spatial distribution of protected areas might change in the near future.



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# 5. Conclusion

The tropical Atlantic is of global importance as part of the worldwide network of ocean currents and as matrix for the migration of marine species – many of them of high economic relevance on regional and global scales. Rich seafood stocks provide subsistence food security and income to millions of inhabitants of the coastal areas and are exploited by bordering countries – and beyond, including Europe. Sustainable management of these resources of and their use and extraction is pivotal on a global scale for ensuring food security (both locally and globally) and human wellbeing and livelihood, and thus preventing poverty- or disaster-driven migration. For this, not only fisheries but also competing activities and uses, as well as additional contributions of the seas and coasts to human wellbeing have to be taken into account. Marine Spatial Planning (MSP) aims at organizing and harmonizing partly competing human activities in the marine environment. Beyond focusing on these human activities and economic and societal aspects, future development and management of coastal areas will also have to consider the natural environment and the ecosystems that provide the services so urgently needed by coastal human populations. In order to avoid –or at least minimize– conflicts between human use and exploitation of natural resources and environmental protection, MSP prioritization goes one step further and brings together the requirements of local/regional societies and the need for protecting coastal and marine ecosystems from abuse and over-exploitation. The outcome will be a spatially explicit compromise of land- and seascape-use that optimizes human benefit and minimizes environmental harm at the same time.

Such an approach requires sound knowledge and understanding of coastal systems, including and bringing together ecology, environmental sciences, socio-ecological systems-analysis, socio-economics, sociology, law-studies, and governance and policy. The case studies of selected regions on the Western (Brazil) and Eastern (Cape Verde and Senegal) boundaries of the Atlantic presented herein indicate our limited knowledge on many aspects relevant for MSP and prioritization other than fisheries. Assuming that the same applies to the many coastal regions along the Tropical Atlantic that are not covered by this report, we stress the need for more and detailed studies on tropical coastal and marine ecosystems, their processes and services, their use and exploitation –including improving efficiencies and reducing impacts– and how resource-use affects these ecosystems.



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