Food and Agriculture Organization of the United Nations

FIPI/C1113 (En)

FAO Fisheries and Aquaculture Circular

ISSN 2070-6065

CASE STUDIES ON CLIMATE CHANGE AND AFRICAN COASTAL FISHERIES: A VULNERABILITY ANALYSIS AND RECOMMENDATIONS FOR ADAPTATION OPTIONS

Cover photos:
Clockwise from top: Melita Samoilys, Melita Samoilys, Matt Richmond.

FAO Fisheries and Aquaculture Circular No.1113 **FIPI/C1113 (En)**

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CASE STUDIES ON CLIMATE CHANGE AND AFRICAN COASTAL FISHERIES: A VULNERABILITY ANALYSIS AND RECOMMENDATIONS FOR ADAPTATION OPTIONS

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2016

ISBN 978-92-5-109218-7

PREPARATION OF THIS DOCUMENT

This circular has been compiled as part of the New Partnership for Africa's Development (NEPAD)–FAO Fish Programme (NFFP) Component C (FMM/GLO/003/MUL) and the FAO's EAF-Nansen Project. The objective of this circular is to investigate the nature of the impacts of climate change on four case study fisheries in Africa, to gauge the vulnerability of their corresponding social-ecological systems and to identify current and potential coping mechanisms/strategies and biophysical and social characteristics/attributes that increase resilience to these impacts. The case studies were selected according to a set of criteria defined by the NFFP and the EAF-Nansen Project. The criteria included geographic location (the Gulf of Guinea, the coast of Northwest Africa and the western Indian Ocean) and the inclusion of a small island developing state. The case studies are:

- the small pelagic fisheries of the United Republic of Tanzania;
- the coral reef fishery of Seychelles;
- the small pelagic fisheries of Ghana; and
- the small pelagic fisheries of Senegal.

The coral reef fishery of Seychelles was included because of the importance and widespread nature of this kind of fishery in the western Indian Ocean; the fact that the vulnerability of fisheries in small island states is often more easily observed than for other fisheries; and as an alternative case study for comparison to the pelagic fisheries chosen for the three other case studies.

FAO. 2016.
Case studies on climate change and African coastal fisheries: a vulnerability analysis and recommendations for adaptation options, edited by Jim Anderson and Timothy Andrew. FAO Fisheries and Aquaculture Circular No. 1113. Rome, Italy.

ABSTRACT

The NEPAD–FAO Fish Programme (NFFP) and the EAF-Nansen Project are currently collating and exploring evidence for the current and potential impacts of climate change on fisheries in Africa. The overall goal of this activity is to contribute to the design and implementation of appropriate interventions, with a view to reducing these impacts, both on the ground at a local level and at the national and regional policy level.

To this end, the Western Indian Ocean Marine Science Association (WIOMSA) was contracted to coordinate four specialist authors who were asked to produce case studies on small-scale fisheries in different parts of Africa. The objective was to *investigate in detail the nature of the impacts (of climate change) on, and vulnerabilities of the selected social-ecological systems and, to identify current and potential coping mechanisms/strategies as well as biophysical and social characteristics/attributes that increase resilience to these impacts.*

The report consists of five chapters. The opening chapter introduces the general approach and methodology used to compile the case studies and a definition of terms. It also provides a brief overview of the phenomenon of ocean acidification – to which all four case study fisheries are vulnerable – and an introduction to some key observations on the ecology of small pelagic species, the focus of three of the four case studies. The remaining four chapters deal in turn with the individual case studies, providing ecological and socio-economic details on the four fisheries and collating a wide range of available knowledge on their exposure and potential sensitivity to climate change or climate variability. Each chapter includes observations on the adaptive capacity of the social-ecological system and concludes with observations on the potential role of fisheries management institutions to reduce vulnerability to climate change.

ACKNOWLEDGEMENTS

This report was researched and written by a team of specialist authors – Jim Anderson, Melita Samoilys, Nana Ama Browne Klutse, Francis K.E. Nunoo and Djiga Thiao – under the auspices of the Western Indian Ocean Marine Science Association (WIOMSA). The compilers of this report are grateful to these authors, to the NEPAD FAO Fish Programme team and the EAF-Nansen Project, in particular Florence Poulain, Kwame Koranteng, Tarub Bahri, Cassandra DeYoung and Merete Tandstad. Thanks also go to Claire Attwood and Marianne Guyonnet for their contribution to the finished publication.

CONTENTS

Chapter 5

THE SMALL PELAGIC FISHERIES OF SENEGAL

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Chapter 5: The small pelagic fisheries of Senegal

Contents .... Page

List of figures

List of tables

1. The small pelagic fisheries of Senegal

1.1. The marine environment

Senegal extends from 12° to 17° N and from 11° to 18° W. Oriented north–south, its coastline is approximately 700 km long (Figure 1). The continental shelf is about 23 092 km^2 and the EEZ approximately 158 861 km^2. The width of the continental shelf off Senegal is about 27 nautical miles (nmi) adjacent to the northern city of Saint-Louis, but it narrows to 5 nmi in the central Cape Verde Peninsular around Dakar and is at its widest (about 87 nmi) in the Casamance coastal region in the south of the country. Around the Cape Verde Peninsular, the seabed is rocky, but other areas of the Senegalese coast are characterized by either sandy or muddy seabeds.

Figure 1: The coastal zone of Senegal and Northwest Africa

The key feature of this marine environment, as it pertains to fisheries, is the presence of a winter upwelling and the basic parameters of this upwelling are presented in Table 1. During the summer period the area off Senegal (and southern Mauritania) is characterized by an active downwelling.

Table 1: Some parameters of African upwellings (source: Roy, Nd.)

Location	Period	SST (Median °C)	Wind speed (m/s^{-1})	Upwelling index ($m^3/s^{-1}/m$)	Wind mixing (m^3/s^3)
Senegal	**Dec–May**	**25.8**	**4.8**	**1.0**	**197**
Ivory Coast & Ghana	Jan–Feb June–Oct	27.8 27	3.7 3.7	1.0 1.3	95 95
Namibia	Permanent	15.9	6	1.1	432

1.2 The fishery

The Senegalese coast is rich in fisheries resources and small pelagic fish species currently constitute more than 75 percent of total landings. Small pelagic species are mainly exploited by artisanal fisheries, using purse seines and gillnets. Since 2010, just four small industrial purse seiners have targeted small pelagic fish and average total landings have amounted to 3 500 tonnes per annum. With annual total landings of around 450 000 tonnes during recent years, the artisanal fisheries are responsible for more than 80 percent of total fisheries production in Senegal.[1] An estimated 50 percent of the total national catch is landed at the major coastal fish landing sites which are presented in Figure 2.[2]

There is a substantial degree of cross-border fishing activity by Senegalese fishers who operate in Mauritanian waters, to the north. However, much of their catch is landed in Senegal, at the port of Saint-Louis. In 2012, 275 Senegalese canoes were issued with licences to fish in Mauritanian waters for a period of three months. Among the regulations imposed on licensees was a requirement to land 15 percent of the catch in Mauritania itself. The export of small pelagic species is an important regional trade opportunity for Senegal, particularly with Burkina Faso, Guinea and Mali.[3]

Figure 2: Major coastal landings sites of Senegal (source: redrawn from FAO, 2008)

1.3 Species diversity

The production of the small pelagic fisheries is essentially dominated by two sardinella species, the round sardinella (*Sardinella aurita*) and Madeiran sardinella (*Sardinella maderensis*). Other exploited small pelagic species include bonga shad (*Ethmalosa fimbriata*), false scad (*Caranx rhonchus*), chub mackerel (*Scomber japonicas*), horse mackerel (*Trachurus trachurus*) and European pilchard (*Sardina pilchardus*) (Figure 3). The Senegal (and Canary Current) ecosystem is unusual when compared to other eastern boundary upwelling systems because anchovy (*Engraulidae*) are not a significant part of the small pelagic species assemblage.[4]

Figure 3: Common small pelagic species caught in Senegal (source: Fishbase)

1. FAO, 2013.
2. FAO, 2011.
3. FAO, op cit.
4. Arístegui *et al.*, 2009.

An important feature of the small pelagic species caught off the Northwest African coast is their highly migratory nature. An approximation of the temporal and spatial migration pattern of *S. aurita* is presented in Figure 4. Note that *S. aurita* is observed off Senegal during the period of the highly productive winter upwelling. It is believed that during the latter part of the upwelling phase spawning takes place, although this is also possibly triggered by the early phase of the summer downwelling, an oceanographic phenomenon that increases larval retention rates. As the upwelling ends, the fish move north and take advantage of the strong summer upwelling located off Mauritania, and then possibly move as far as Morocco, before migrating south again, although that part of the migration is less well understood.[5]

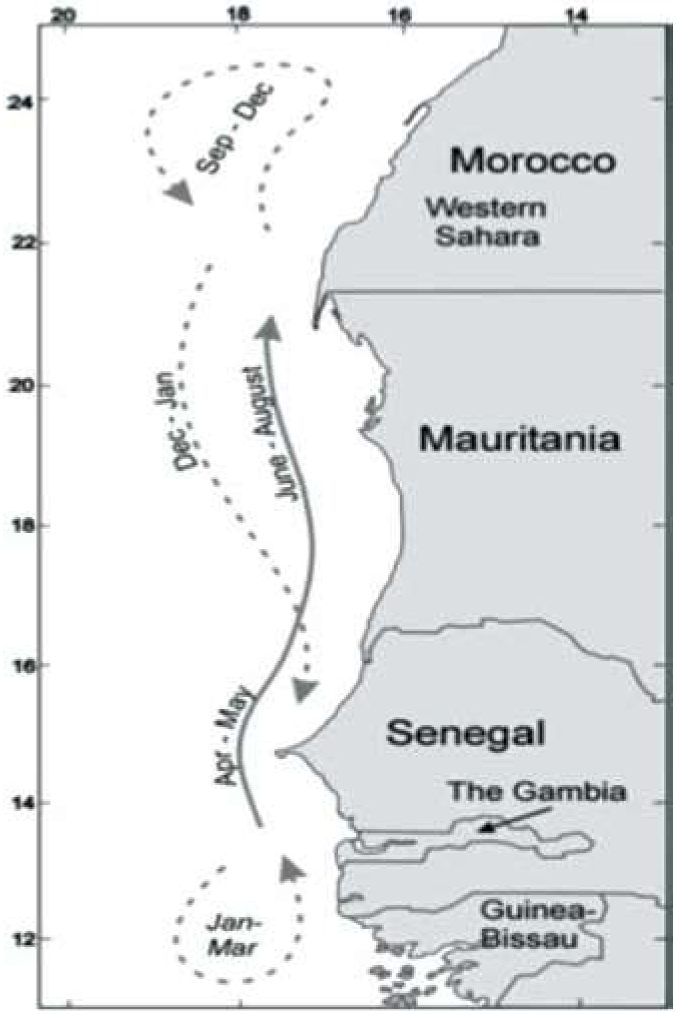

Figure 4: The migration of *S. aurita* (source: Zeeburg, 2008)

1.4 Recent trends

A time series (1990–2011) of fishing effort by the artisanal fleet is presented in Figure 5. FAO (2013) notes that although the total effort (in canoe days) has oscillated by approximately 20 percent over the period of the time series, there has been an increase in the mean size of canoes and therefore effective catching effort has increased, which is not reflected in these basic data.

In terms of total landings, *S. aurita* is the dominant species; landings for this species were characterized by a rapid increase during the 1980s, before experiencing a downward trend in the 1990s, with a lowest level of 83 000 tonnes in 1999 (Figure 6). However, since 2001 a reversal of this trend is noted, with the highest catch of *S. aurita* (263 594 tonnes) recorded in 2009.[6] This recent increase is because of a bilateral agreement between Senegal and Mauritania which annually grants about 300 fishing licenses. For *S. maderensis*, the landings recorded an upward trend that

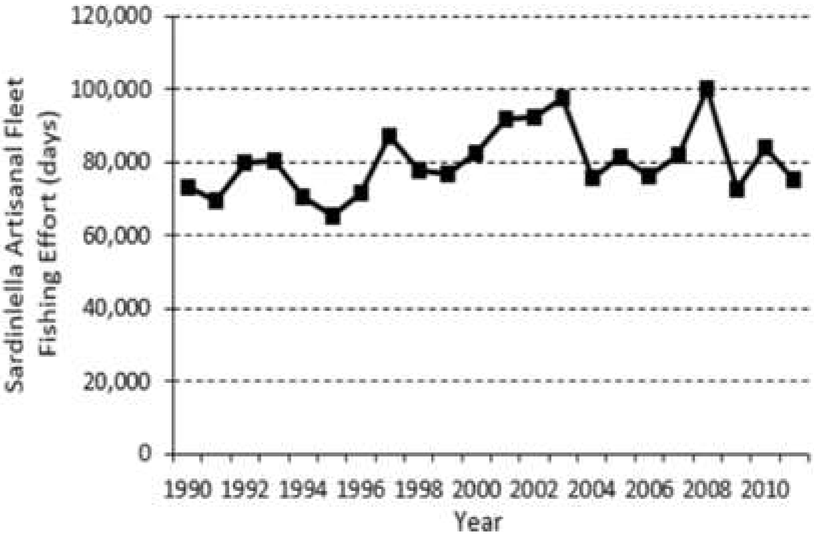

Figure 5: Fishing effort (days) by the artisanal sardinella fleet, 1990 to 2011 (source: FAO, 2013)

5. Zeeburg, 2008.

6. FAO, 2013.

reached its highest level in 2003 with 164 469 tonnes. Since then, the landings have generally decreased. The two species of *S. aurita* and *S. maderensis* constitute about 47 and 20 percent of the total artisanal fisheries production respectively. *E. fimbriata* is the third most important small pelagic species. With a maximum catch of 24 471 tonnes achieved in 2001, the production of this species has seen a significant downward trend during the last decade.

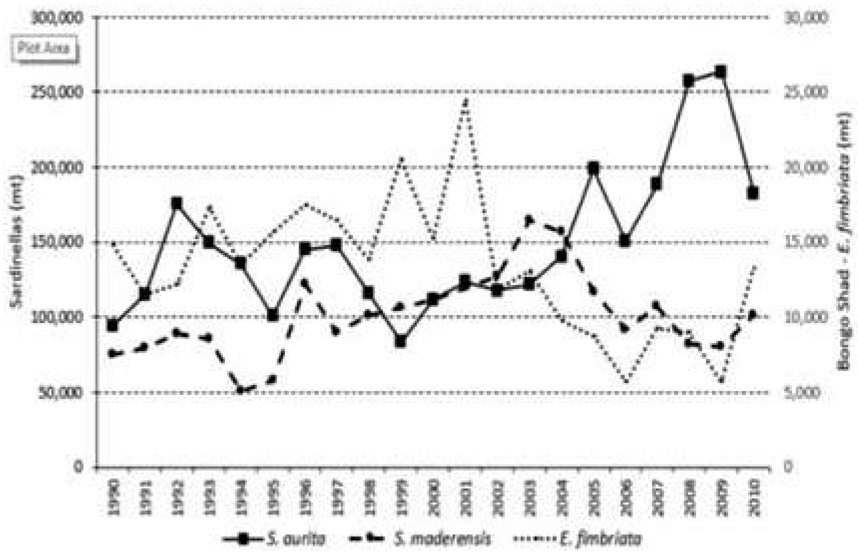

Figure 6: Total catch of small pelagic species, 1990 to 2011 (source: FAO, 2013)

2. Senegal's marine environment and its exposure to climate change

2.1 Atmosphere and climate

Windstress

There are two principal wind patterns in Senegal and each is associated with the relative position of the ITCZ. During the winter months, the wind is predominantly from the northeast and drives upwelling; during the summer months the wind is predominantly from the southwest and drives downwelling processes. The timing and extent of the migration of the ITCZ is (generally) determined by cross-equatorial SST gradients and atmospheric heat gradients and therefore should be sensitive to the effects of increased GHG emissions on these parameters. However, there is some evidence[7] that the position of the ITCZ may in fact be relatively insensitive, or at least the sensitivity may be highly variable regionally.

Cropper *et al.* (2014) presented evidence that supports the realization of the so-called Bakun upwelling intensification hypothesis off Northwest Africa. This hypothesis suggests that global warming associated with increased GHG emissions will cause reduced night time cooling and increased daytime heating of continental landmasses, therefore increasing the gradient between land and oceans and generating a subsequent increase in windstress and associated upwelling/downwelling. However, the windstress indices for the Mauritania-Senegalese zone actually showed a decreasing trend (although it was significant for only one of the indices) during the winter upwelling period, but with an increase in downwelling-favourable winds south of 19 °N during the summer. The IPCC (2014, chapter 30) highlights the challenges of determining any sort of trend given the often contradictory nature of available data and analyses. For example, the IPCC cites Gómez-Gesteira *et al.* (2008) who found a 20 percent (winter) and 45 percent (summer) decrease in the strength of upwelling for the Canary Current as a whole over the period 1967 to 2006, as a result of decreasing wind speed. On the other hand, the IPCC reports the work of Barton *et al.* (2013) which did not indicate any clear trend in wind strength over the past 60 years.

There are also variable but non-GHG emission related background atmospheric processes that can drive windstress variability. For example, the NAO, which is an atmospheric phenomenon driven by pressure differences between the Icelandic polar low pressure zone and the Azores subtropical high pressure zone.

7. McGee *et al.*, 2014.

The NAO index explained as much as 53 percent of the variability of windstress delivered by northeasterly trade winds, at least off Mauritania.[8]

Rainfall

In the tropical and subtropical areas rainfall plays a significant role in the balance of the seasonal and long-term ecological condition of coastal waters. Therefore, its trend is a key indicator of the exposure of the Senegalese coastal environment to climate change.

Data available from three major coastal stations (Ziguinchor, Dakar and Saint-Louis) indicate a very high interannual variability but a general decreasing trend of rainfall in Senegal since 1950,[9] although at a single station the interannual variation could be hundreds of millimeters. At Ziguinchor station, for example, the difference in rainfall between 1977 and 1978 was 815 mm. There was a partial recovery in the 1990s. Then, between 2000 and 2009, the recovery slowed down and the 2000 to 2009 mean remained about 15 percent lower than the 1920 to 1969 mean.

On a wider time–space scale, many studies are in agreement about high rainfall variability and a general decrease in precipitation in Senegal and the whole Sahel region.[10] At the same time, the rainfall contours shifted progressively from north to south. In the whole Sahelian zone, the rainfall was also characterized by high variability on interannual and interdecadal timescales, which make long-term trends difficult to identify, and to determine the current and potential effects of anthropogenic climate change forcing. For the WAM itself, the IPCC WGI AR5 (2013) stated that "There is low confidence in projections of a small delay in the West African rainy season, with an intensification of

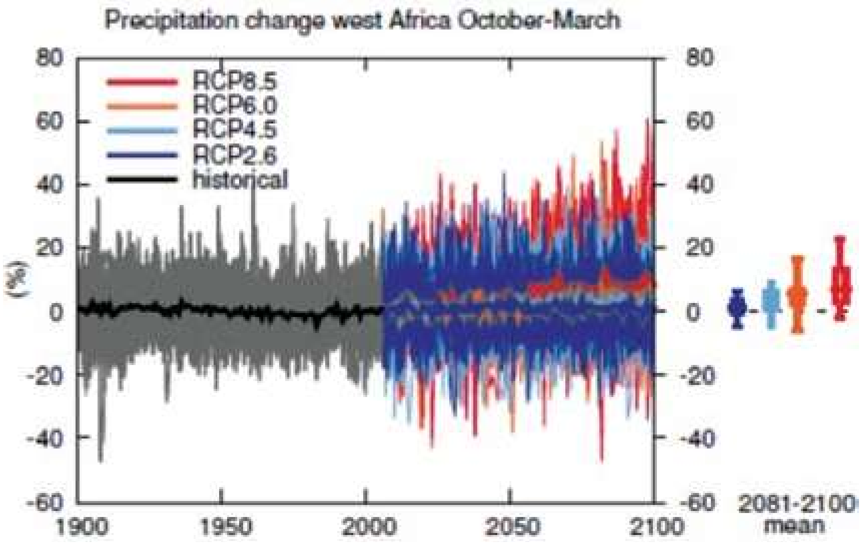

Figure 7: Modelled changes in precipitation for West Africa, October to March (source: IPCC, 2013a)

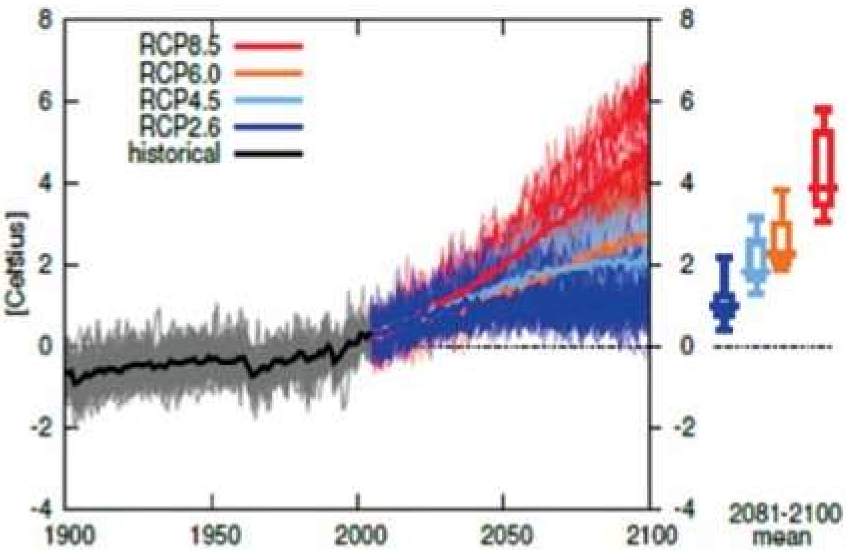

Figure 8: Modelled temperature change in West Africa June to August (source: IPCC, 2013a)

8. Meiners *et al*., 2010.

9. Thiao, 2009.

10. e.g. Malou *et al*,. 1999; Niang-Diop *et al*., 2002.

late-season rains. The limited skills of model simulations for the region suggest low confidence in the projections". Figure 7 presents IPCC model outputs for potential change in precipitation in West Africa.

As far as atmospheric temperatures are concerned, the projections are for an increase across West Africa, with the actual degree being dependent on the particular climate model chosen, and a worst case scenario of a mean increase of temperature approaching 5 °C during the summer (which is also the period of the major upwelling) by 2100 (Figure 8) and a similar forecast for the winter period.[11]

2.2 Ocean currents and thermal dynamics

The major currents off the coast of Northwest Africa are presented in Figure 9. Among these coastal currents, the Canary Current is the main driver in the so-called Canary Current Large Marine Ecosystem (CCLME) region.

Figure 9: Major ocean currents off West Africa (source: redrawn from Arístegui *et al*., 2009)

Sea surface temperature

The IPCC,[12] reporting the work of various authors, states that the Canary Current in its entirety has shown a warming trend since the 1980s (0.09 °C decade^{-1}, p-value<0.05). The IPCC goes on to provide a mechanism that could drive such warming, i.e. a mean decrease in wind speed (windstress) in the region. However, the evidence of an apparent decrease in wind speed is acknowledged in the same IPCC report as being contradicted by other, apparently equally plausible, analyses.

There are also important subregional variations. For example, Arístegui *et al*. (2009) cited the work of Ould-Dedah *et al*. (1999) who analysed International Comprehensive Ocean-Atmosphere Data Set (ICOADS) SST data for the period 1946 to 1988 and reported that nearshore waters between 20 °N and 26 °N were cooling. This is consistent with the analysis of Cropper *et al*. (2014) and the upwelling intensification hypothesis. But Ould-Dedah *et al*. also observed an overall warming south of 20 °N, i.e., in the northern sector of the Mauritanian–Senegalese subregion, possibly consistent with increased downwelling in that area. A closer look at specific analyses completed by Arístegui and his colleagues – research that was cited by the IPCC as evidence for a general warming trend in the Canary Current – reveals distinct regional differences in SST trend, particularly at the southern extreme of the current system where cooling was observed, albeit using a relatively short time series of AVHRR data from 1998 to 2007. These data are presented in Figure 10. Such variations, not unsurprising given the evident transition zone in climate and oceanography south of approximately 20 °N, highlight the importance of research at appropriate geographical scales and that the reporting of this research adequately captures those subregional variations.

11. IPCC, 2013a.

12. IPCC, 2014 (chapter 30).

Upwelling

The climatology of the coastal region of Northwest Africa results in three zones of upwelling, each with their own particular characteristics. To the north (from latitudes 26–35 °N) a permanent upwelling exists, but it is seasonal with increased intensity in summer months; a permanent, year-round upwelling is observed in latitudes 21–26 °N; and finally to the south there is a winter upwelling from 12–19 °N, the Mauritania–Senegalese upwelling zone.[13] In contrast to the zones to the north, the Senegalese zone is characterized by downwelling during the summer months (e.g. Jun–Jul–Aug) (Figure 11). The cool and nutrient-rich upwelled waters along the coastal shelf edge are a consequence of longshore wind forcing (Ekman transport). The strength and position of the wind depends on the latitudinal migration of the ITCZ and the associated Azores high pressure area, both oscillating between their northernmost and southernmost positions in summer/winter respectively.

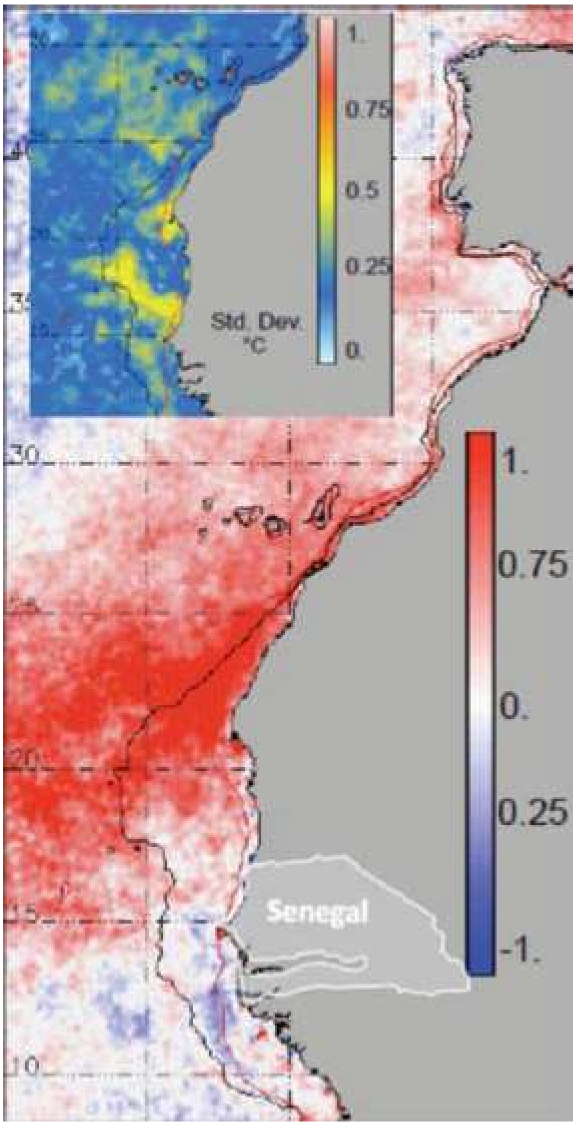

Figure 10: Decadal trends in SST from the period 1998 to 2007 (with SD of trends) (source: Arístegui *et al*., 2009)

Observations in Section 2.1 relating to windstress and the upwelling intensification hypothesis, indicated that some evidence exists that the upwelling off Mauritania/Senegal may be affected by increased windstress resulting from increased land-ocean thermal gradients driven by anthropogenic GHG emissions.

And, mention has already been made of the apparent effect of the NAO on windstress in Section 2.1. A positive NAO has been shown to explain 53 percent of windstress variability (off Mauritania) and therefore is also likely to explain a high percentage of upwelling variability given the cause–effect relationship between the two phenomena. During NAO+ phases (e.g. 1990 to 2000) upwelling is more intense and more widely extended along the coast of Northwest Africa. There is evidence that the NAO index has been increasing in recent decades (i.e. representing an increased atmospheric pressure differential) and that interdecadal variability has also increased, suggesting more intense NAO+ as well as more intense NAO- events.

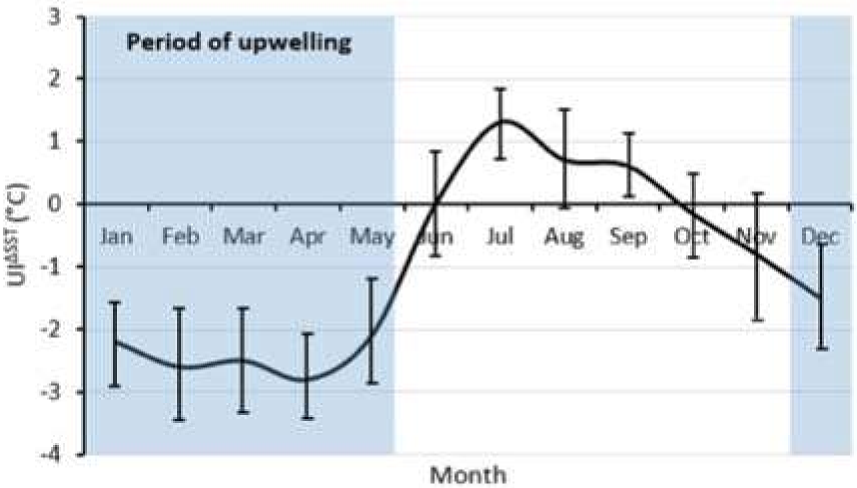

Figure 11: The monthly climatology (1981 to 2010) for the Mauritania–Senegalese upwelling zone (source: redrawn from Cropper *et al*., 2014)

13. Benazzouz *et al*., 2014; Cropper *et al*., 2014.

The possible explanation for this includes natural forcing (e.g. volcanic aerosols; changes in solar activity), but also anthropogenic forcing, i.e. GHG emissions.[14]

Salinity

Sea water salinity influences the seasonal and long-term distribution and abundance of many species. This is particularly the case for most of the small pelagic species that are generally stenohaline, meaning that they tolerate very little variation in salinity. The exception to this is *E. fimbriata* whose biological cycle is more dependent on estuarine environments. Therefore, significant modification of variability of salinity constitutes a determinant exposure factor that could result from climate change. From the data collected locally in four coastal sites by the Oceanographic Research Center of Dakar-Thiaroye (CRODT), until 1997 it was clear that the salinity had been increasing since the 1970s. For instance, an average increase of 0.03 g/l had been recorded per year in Mbour which is one of the major small pelagic landing sites in Senegal. However, unlike the period from 1970 to 1987, during which the increasing trend was considerable, a relatively moderate increase was noted during the 1990s. This situation is probably linked to the partial recovery of rainfall patterns over the same period.

2.3 Primary productivity

The Canary Current is considered as a Class 1 ecosystem corresponding to the highest level of productivity. Its total primary production is more than >300 gC^{m-2y-1}.[15] The primary production, which corresponds to plankton, is the first element of the aquatic food chain. Phytoplankton is the basic component of plankton and is generally measured as the concentration of chlorophyll. The second component that feeds off phytoplankton is zooplankton and constitutes the food of most of the exploited small pelagic species in Senegal. Therefore, the level and evolution of primary production, which is also very sensitive to environmental conditions (e.g. mineral salts concentration, sunlight, turbidity, etc.), is a key factor for the abundance of the small pelagic species. The seasonal variation in chlorophyll-*a* concentration is presented in Figure 12 and 13. In the Mauritania/Senegalese zone, chlorophyll-*a* concentrations during the winter upwelling are clearly higher.

Upwelling productivity is augmented by major river systems.[16] There are several major river systems along the Senegalese coast: the Casamance, the Senegal and the Gambia rivers, which are important sources of nutrients that further enhance ocean productivity.

An important feature of the Canary Current system is that the upwelling takes place relatively far from the coast owing to the width of continental shelf. The result of this is that there is relatively little movement of water masses perpendicular to the coast (cross-shore) compared to other eastern boundary upwelling systems.

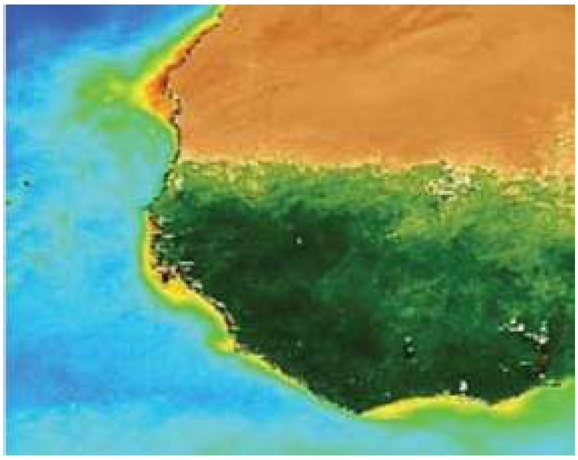

Figure 12: SEAWIFS image of chlorophyll-*a* during boreal summer

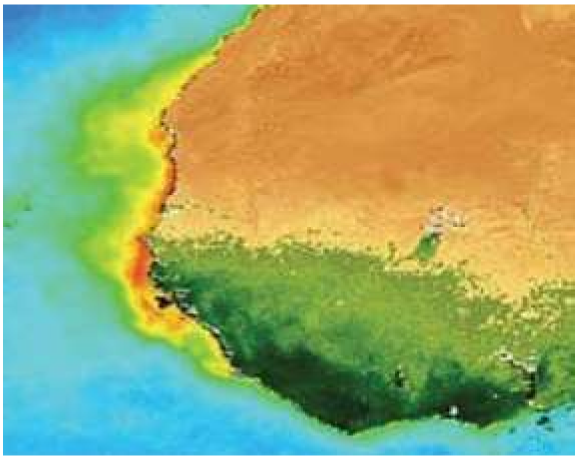

Figure 13: SEAWIFS image of chlorophyll-*a* during boreal winter

14. Gillet *et al.*, 2003.

15. Sherman & Hempel, 2009.

16. Sambe, 2012.

The significance of this for ecosystem production is that the system has relatively high rates of nutrient retention in the coastal area (e.g. iron delivered to the ocean by the substantial rivers in the region) because nutrients are not advected offshore by the upwelling cell. The relatively shallow continental shelf also means that nutrients are not lost from the system by sinking into the abyss.[17]

The IPCC[18] reports that there is "medium evidence and medium agreement that primary production in the Canary Current has decreased over the past two decades", but the picture is complicated and hugely variable locally. For example, Sherman and Hempel (2009), reporting on data from the period 1998 to 2006, indicated chlorophyll-*a* concentrations were declining at an average of 0.0139 mg/m^3 per year along the Canary Current as a whole. However, a much more nuanced regional analysis by Arístegui *et al.* (2009) suggested important regional variations, with significant increases off coastal Mauritania, but significant decreases off coastal Senegal (Figure 14). The apparent reduction in concentrations of chlorophyll-*a* off Senegal may be at least partially consistent with the increase in the strength of the summer downwelling in that region observed by Cropper *et al.* (2014).

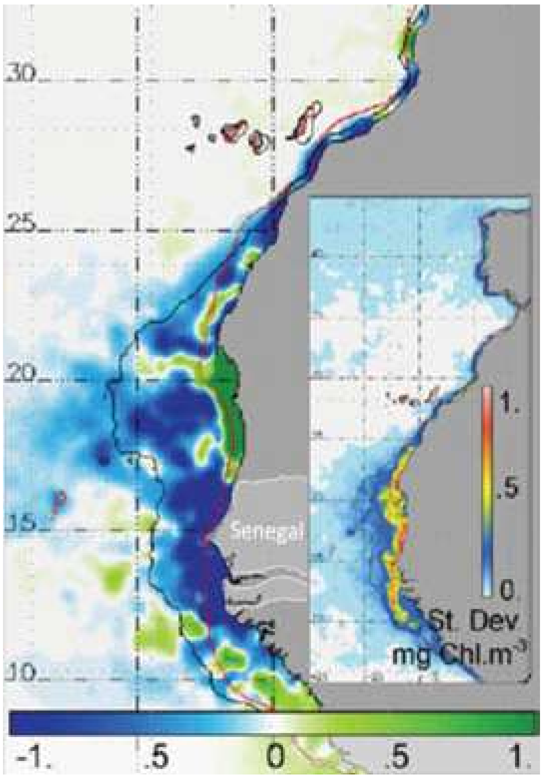

Figure 14: Decadal trends in surface chlorophyll-*a*, 1998 to 2007 (with SD of trends) (source: Arístegui *et al*., 2009)

An aspect of climate change that is attracting increased attention is the acidification of the oceans, with particular concern pertaining to the saturation rates of $CaCO_3$ (both aragonite and calcite forms) which is essential, for example, to coccolithophore and formaminerfera groups of calcereous plankton.[19] The crucial metric in this case is the $CaCO_3$ saturation rate, with pre-industrial rates typically being very low (a few percent by volume). A general description of the phenomenon is included in the introduction to this document, but more specifically for Northwest Africa, and citing the work of Barton *et al.* (2012), the IPCC notes that the waters of eastern boundary upwelling systems, such as found off Northwest Africa, are typically low in pH and have relatively high concentrations of CO_2, thereby increasing their vulnerability to ocean acidification.

However, modelling by Lachkar and Gruber (2012) suggests that the Canary Current may be less sensitive to acidification than appears to be the case for the California upwelling system, for example. They find that continued emissions of atmospheric CO_2 will increase the volume of undersaturated water in the Canary system from current levels of about 5 percent to approximately 25 percent by 2050 as atmospheric CO_2 levels increase to about 540 ppm. This will "lead to substantial habitat compression for CO_2-sensitive species in both systems, particularly organisms that use $CaCO_3$ to build mineral structures".[20] This is compared to 75 percent volume of undersaturated waters in the California system, as a result of different fractions under current atmospheric CO_2 levels (5 percent for the Canary system versus 25 percent for California). On the other hand, when upwelling-favourable winds are increased in the Canary system model, the volume of undersaturated nearshore water actually declines. In the California system model, similar scenarios result in an increase in volume up to approximately 40 percent. The authors put this down to the particular characteristics of topography and the width of the continental shelf in Northwest Africa (the same features briefly described previously that appear to play such an important role in nutrient retention).

17. Lachkar & Gruber, 2012.
18. IPCC, 2013a.
19. E.g. Doney *et al*., 2009.
20. Lachkar & Gruber, 2012. p.8.

3. The sensitivity of the small pelagic ecosystem

The IPCC Glossary of Terms defines sensitivity as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli".[21] There are a number of atmospheric, climate, oceanic and productivity parameters that have been observed to influence small pelagic fish populations and these have been identified in broad terms elsewhere in this document. To recap, these processes were neatly encapsulated by Bakun[22] in what has been subsequently termed "Bakun's Triad"[23] and are as follows:

(1) Enrichment processes (upwelling, mixing, etc.);

(2) Concentration processes (convergence, frontal formation, water column stability); and,

(3) Processes favouring retention within (or drift toward) appropriate habitat.

To this suite of processes can be added a number of other factors including, *inter alia*, SST (excluding the specific influence of upwelling), prey availability, and rates of mortality and predation. The observations in this section will be limited to the potential effects on small pelagic species of the potential or forecast changes of these factors, and to Bakun's Triad, off the coast of Senegal, with additional observations made from neighbouring Mauritania as and when they pertain to Senegal's small pelagic fishery.

Small pelagics species are generally stenoecious, meaning that they are capable of surviving only in specialized niches or habitats with specific environmental conditions. Being unable to tolerate high temperature and salinity variations, small pelagic fish, and more specifically *S. aurita*, are stenothermic and stenohaline species.[24] This affinity is already demonstrated by Cury and Roy (1989) through the optimal environmental window theory. Therefore, changes in the oceanography off the Senegalese coast are likely to affect, for example, the spawning areas and seasons, food availability, migration trajectory, abundance, etc. of small pelagic species.

A reduction in phytoplankton and zooplankton abundance, which together form the basis of the diet of small pelagic species, will likely have some impact on the abundance of the species. Pelagic fish are highly represented in the suite of species that have shifted their distributions in the past and might be especially likely to experience range shifts with global climate change.[25] Apart from *E. fimbriata*, whose distribution is more tightly determined by the environmental conditions of major West African estuaries, most of the small pelagic species are very mobile, depending on oceanographic factors and primary production. Trends in primary productivity across the Canary Current region, reported in Section 2.3, suggest an overall decline, while subregional analysis (albeit of relatively limited data sets) points to important local variations in that trend, including declines off Senegal but increases in coastal productivity off Mauritania. Although these changes may be specifically linked to climate change effects (continental heating) on windstress and subsequent upwelling/downwelling, they may also be (at least partly) driven by background atmospheric processes such as the NAO. It has been noted elsewhere that there may be a northwards shift in the distribution of *S. aurita*, which may reflect the local increase in primary productivity, perhaps lengthening residence times during migration. The implications of this for Senegalese fishers would not be positive.

However, Demarcq (2009) observed non-significant relationships between trends in SST and trends in biomass within upwelling systems. And Arístegui *et al.* (2009) argue that recent changes (overall declines) in productivity in the Canary Current ecosystem, whether or not caused by climate change, are not necessarily feeding through into fisheries production. They argue that the distribution of sardinella species is primarily determined by thermal, rather than productivity, gradients. The two may be indirectly linked, of course.

21. IPCC, 2001.

22. Bakun, 1996; Bakun, 1998.

23. e.g. Checkley *et al*., 2013.

24. Binet, 1982; Fréon & Misund, 2013.

25. Harley *et al*., 2009.

Thermal gradients are driven by the extent of upwelling, a phenomenon driven by atmospheric processes including the NAO, which is also mediated by the particular geomorphology (e.g. the width of the continental shelf) off Northwest Africa. Evidence presented in Section 2.2 suggests that an increase in NAO index is at least partly driven by anthropogenic GHG emissions, but that the positive direction of change in the NAO may result in increased upwelling. In turn, there is evidence that the abundance of sardinella (and sardines further north), as measured by catch rate data, is at least partly dependent on the NAO index. ICES (2012) presented analyses that suggest *S. aurita* has quite a wide tolerance of NAO-influenced environments, with an environmental window between -1 to 0 and at >2. The NAO explained 32 percent of the abundance of *S. aurita*. The situation was a little different for *S. maderensis*, with optimal NAO values from 0–1.7, and a declining abundance as the NAO index increased beyond that. The NAO index explained 42 percent of the abundance of *S. maderensis*.

Population adaptation/recovery potential

Biomass estimates generated from acoustic surveys conducted by the R/V *Dr Fridtjof Nansen* off Northwest Africa are presented in Figure 15. It is clear that there is a large amount of interannual natural variability of production, a feature characteristic of small pelagic species. Some of the adaptive ecology of these species has already been described in the introduction to this document.

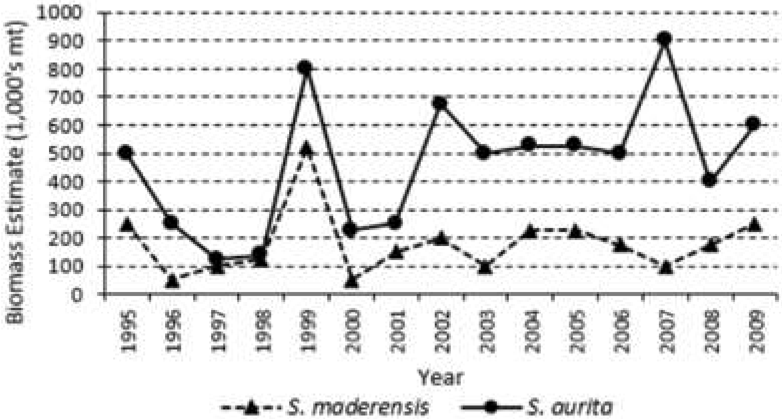

Figure 15: Biomass estimates for sardinella

More specifically, for the Morocco-Senegal subregion a stock assessment has been carried out for *S. aurita* under the auspices of the FAO CECAF working group and its most recent output is presented in Table 2.

Table 2: Results of FAO working group on small pelagic fish (source: FAO, 2013)

Stock / indicator of biomass	$B_{cur}/B_{0.1}$	B_{cur}/B_{MSY}	F_{cur}/F_{MSYyr}	F_{cur}/F_{MSY}	$F_{cur}/F_{0.1}$
S. aurita / CPUE EU fleet	53 %	58 %	228 %	323 %	359 %

Current biomass is just 58 percent of the estimated biomass that can yield a maximum sustainable yield (MSY). Current fishing mortality is estimated to be more than three times the optimal limit for MSY. The assessment also indicated that the strong year classes of 2002 and 2007 were largely fished out within two years, such is the level of fishing effort and fishing mortality. The clear implication is that weak year classes will not be able to sustain the fishery.

3.1 Social dimension of small pelagic fisheries in Senegal

Fish consumption in Senegal

Fisheries resources are an important component of Senegal's economy and food security, with fish protein contributing 80 percent of total animal protein consumed by the coastal population.[26] Senegal has the highest level of fish consumption in West Africa, with an estimated 330 000 tonnes of small pelagic fish consumed annually (this represents an approximate mean figure over the last five years). The mean annual per capita consumption is about 25.9 kg/person/year.[27] Only about 15 percent, or 45 000 tonnes, of the landings of small pelagic species are exported.

26. Failler & Lecrivain, 2003.

27. Lam *et al*., 2012.

In the interior of the country small pelagic fish are almost the only type of fish available and are marketed fresh (transported by refrigerated trucks) as well as in dried and smoked form. The available data do not separately indicate the contribution of the different species to overall fish consumption. The majority of the fish consumed domestically is provided by the artisanal fisheries, with a negligible contribution by industrial fisheries. Although there are other species available, including demersal species and cephalopods, these are typically more expensive and export-oriented, with close to 100 percent of the latter being exported.[28] The main destination for exports are Mali, Burkina Faso and Guinea.

Availability and accessibility of small pelagic fish

Economic realities also play a role in a country where poverty levels are high. Low purchasing power encourages people to buy small pelagic fish because they are the cheapest and most accessible sources of protein available to the population. Therefore, Senegal is very sensitive to changes in the abundance of these species, whether climate change driven, because of continued overfishing, or as a result of natural variability. The decline of fish availability on the national markets, with the associated rise in prices, is currently a major concern that increases this sensitivity.

According to CRODT, which permanently monitors ex-vessel prices at the major Senegalese coastal landing sites, prices of the two sardinella species (*S. aurita* and *S. maderensis*) that constitute the majority of the small pelagic catch, have almost doubled from around 30 CFA Francs per kilogram in the early 1990s, compared to a decade later. More recently, ex-vessel prices have increased in a spectacular way for these two species: 90 CFA Francs for *S. maderensis* and 120 CFA Francs for *S. aurita*. It is important to mention that the ex-vessel prices considered here are lower than the market prices, for which data are not available. This emphasizes that despite their low purchasing power, Senegalese households have to spend more and more on fish for consumption. Increasing demand for fish in a context of insufficient local supply is a very worrying trend that is likely to be exacerbated by the potential negative impacts of climate change on small pelagic fisheries.

Role of small pelagic fisheries in employment

Small pelagic fisheries in Senegal are extremely important in terms of employment. According to the most recent artisanal fisheries census, the highest average crew (16.1 permanent fishers/vessel) is noted aboard artisanal purse seiners that specifically target small pelagic fish.[29] It has been estimated that 60 000 artisanal fishers operate in Senegal, with 20 percent (about 12 000) being engaged exclusively in small pelagic fisheries. Because the crew of small pelagic vessels often require physical ability more than technical skills, this occupation is also suitable for those who did not grow up in the fisheries sector and lack any fisheries experience. Thus, small-scale fisheries provide significant employment opportunities for the poorest, and least well educated, people of Senegal, including farmers for whom agriculture may no longer profitable (a sector also threatened by climate change). In addition to direct employment, pelagic fisheries provide an estimated 40 000 jobs in the post-harvest industry. There are believed to be about 7 000 women working in fish processing and trading and their income typically plays a crucial role in household budgets. Despite this, women only constitute about 5 percent of the membership of fisheries-related management institutions nationally.

3.2 Adaptive capacity of small pelagic fisheries in Senegal

Level of education of fisher communities

Adaptive capacity comprises elements such as levels of social and human capital, as well as the appropriateness and effectiveness of governance structures.[30] The assumption is that countries with high levels of economic and human development have the resources and institutions necessary to undertake planned adaptation. Therefore, aspects related to, for example education, life expectancy, size of economy and governance should be taken into account when assessing adaptive capacity.

28. Thiao & Laloë, 2012; Thiao *et al.*, 2012.

29. Thiao *et al.*, 2006.

30. Allison *et al.*, 2009.

The level of education is generally very low in Senegalese fishing communities. This is particularly evident in the artisanal fisheries subsector where small pelagic fisheries constitute a principal component. The 2006 artisanal fisheries frame survey reported that only 34 percent of fishers had experienced formal education.[31] Among those who attended school, less than 13 percent pursued their studies beyond primary school level. Moreover, only 5.5 percent of fishers had attended professional training to develop specific skills, which were mostly linked to the Fisheries Code and management. A lack of infrastructure is not necessarily the main reason for the fishers' low education levels. In fact, in most of the fishing localities along the Senegalese coast there are sufficient schools and the major small pelagic landing sites are located in urban areas (e.g. Saint-Louis, Dakar, Mbour and Joal) where a range of educational opportunities are available. The reality is that fishers' children are generally involved from a very early age in fisheries-related activities, following in their parents' footsteps to become fishers. Given the fact that fishing requires apprenticeship that starts from an early age, children are occupied in learning about the sea, vessel handling and fishing techniques instead of investing too much time in formal education, which has traditionally not been much valued by fishing communities. By putting children to work at an early age so that they can contribute to household income, parents are depriving their children of education. This reduces the children's chance to develop knowledge and skills so that they might diversify their opportunities inside or outside the fishing sector. Consequently, the low education level of fishers in general, and more specifically for those who are engaged in small pelagic fisheries, implies low sector mobility and will significantly reduce their capacity to cope with any additional impacts that climate change may have on fishery productivity or profitability.

Health conditions within the fisheries sector

Health data specific to the fisheries sector are not available. However, many organizations, such as the ILO and the United Nations International Children's Emergency Fund (UNICEF) consider that the early involvement of children in fisheries activities is harmful to their healthy growth and psychological development. While the fishers do not differentiate between "acceptable work" and "harmful work", the issue of child labour is a real concern in Senegalese fisheries. According to Senegalese marine law,[32] children below 15 years of age cannot be employed aboard fishing vessels. However a study conducted by the CRODT for the ILO[33] showed that children under this legal minimum age comprize approximately one third of the labour force in capture fisheries, boat building and repair services, outboard repairworkshops, fish processing and fish trade. The ILO study reported that the average age of children entering the fishing sector was 10.6 years.

Examining the worst forms of child labour in Senegalese marine fisheries, the results from this study indicated that the level of participation of children was particularly high aboard small pelagic fishing vessels (about one third of gillnet crews and 15 percent of purse seine crews). Children's working conditions are also particularly rigorous on the vessels. For instance, they are engaged in night fishing and also in bailing the vessels. Moreover, the lack of hygiene that generally characterizes the living and working conditions of fishers is not conducive to good health. It is common practice for fishers to retire very early, at between 40 to 50 years of age because they become unable to meet the physical demands of the job. Such a situation seriously reduces their ability to cope with any change in economic circumstances, especially with the added negative impacts on small pelagic fisheries brought about by climate change.

Availability of funds for climate change adaptation

The availability of funds is generally dependent on short- and medium-term projects through international donors or bilateral partners. For example, USD1.4 million was granted to Senegal through the Global Facility for Disaster Reduction and Recovery (GFDRR) partnership to implement a disaster risk management and climate change adaptation project (2012–2015). The objectives include strengthening the capacity of the Directorate for Civil Protection for supporting the disaster risk reduction platform and coordinating

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31. Thiao *et al.*, 2006.

32. *République du Sénégal*, 2002.

33. Thiao *et al.*, 2002.

early warning, preparedness and response. In the specific case of the Senegalese coastal area, existing funds are usually allocated to fight or mitigate catastrophic coastal erosion impacts. Therefore, instead of investing in strengthening the adaptation capacity of fisheries, the priority is to protect coastal settlements and infrastructure (houses, hotels, industries, harbours, etc.). Moreover, most of those funds are generally allocated to the Ministry of Environment while the budget of the Ministry of Fisheries remains very low despite the considerable importance of the fisheries sector to the national economy. At a microeconomic level, populations depending on small pelagic fisheries are generally very poor. In a context of fish scarcity and a rising cost of living, their overriding priority is to satisfy the basic needs of their households and consequently they are unable to significantly invest in adaptation strategies and opportunities. Given these macro- and micro-economic considerations, the adaptive capacity of the Senegalese small pelagic fisheries is very weak.

Governance framework of the fisheries sector

Effective governance is essential to support effective climate change adaptation.[34] Governance includes political stability, institutional frameworks, legislation and enforcement, regulations and adaptation strategies. With a democratic regime that is relatively successful, Senegal is one of the most politically stable countries in Africa. Fisheries management is mainly the responsibility of the Ministry of Fisheries and Marine Affairs. It acts through four major technical departments: the Directorate of Marine Fisheries, the Directorate of Inland Fisheries, the Directorate for Protection and Surveillance of Fisheries, and the Directorate of Fish Processing Industries. The Ministry is supported scientifically by the CRODT. However, all these public institutions are facing operational constraints including a lack of finance, technical staff and equipment. Other non-public stakeholders are also involved in fisheries governance, including fisheries organizations that act at national and local levels. Unfortunately, these organizations do not always have a clear vision regarding the challenges facing the fisheries sector, including those associated with climate change. Many of these organizations are also motivated by political agendas, reducing their effectiveness. To address this gap the government has been putting in place local fisheries councils for several years. Several non-governmental and international organizations and donors are particularly active in the fisheries sector and, in collaboration with the government and professional organizations, have started incorporating issues related to climate change into their project plans. These interventions have, however, not been well coordinated and have had limited success.

The legal framework that currently regulates Senegalese fisheries is the 1998 Fisheries Code.[35] It clearly states that the management of fish resources is the prerogative of the State, with a principal objective of conserving these resources, and to ensure their sustainable use. The current Fisheries Code is, however, outdated and has not succeeded in achieving this objective. For instance, the overexploitation of most of the fish stocks has occurred as a result of overcapacity in the fisheries. The fisheries resources, especially small pelagic stocks, are still characterized by an open access regime for the artisanal subsector. Regulations related to seasonal and spatial closures and minimum size at first capture are not adequately defined in the Code. The issue of climate change impacts on fisheries is not mentioned in this law. The 2001 Environment Code took into account climate change but did not stress the specific case of fisheries vulnerability. Consequently, to update the fisheries legal framework, a new Fisheries Code is currently under development. Unfortunately, this process has been slow and remains incomplete after five years.

In terms of strategic planning for climate change, Senegal produced a National Adaptation Programme of Action (NAPA) in 2006, which details the country's priority adaptation responses. However, this Programme is very generic, focusing on reforestation, restoration of mangroves, stabilization of sand dunes, physical protection against beach erosion and saline intrusion, irrigation projects, restoration of soil fertility, water conservation methods, use of alternative crops and education.

34. Glantz, 1992; Allison *et al.*, 2009; Fluharty, 2011.

35. *République du Sénégal*, 1998.

4. Socio-ecological vulnerability

4.1 *Ecological vulnerability*

Ecosystem degradation as a constraint for ecological resilience

Climate change is affecting small pelagic species against the backdrop of the generalized degradation of the Senegalese coastal ecosystems. Several combined natural and anthropogenic stresses are responsible for increasing the ecological vulnerability of Senegalese small pelagic fisheries. For instance, over the past four decades, wetland areas and mangroves have been degraded and lost as a result natural factors, including droughts that have reduced precipitation and increased the variability of river flow. This degradation has been exacerbated by human activities such as unsustainable agricultural practices, urbanization, industrialization and the exploitation of natural resources (e.g. wood, salt, aquatic resources, etc.). Pollution is also a major concern in many coastal areas, especially in coastal towns with high population densities and economic activities. This situation is particularly worrying in the cities of Saint-Louis, Mbour and Joal where small pelagic fisheries are also important. Eutrophication and the decay of organic matter create anoxia and subsequently fish mortalities in areas around major cities, bays and ports. Moreover, owing to a lack of suitable disposal and management policies, industrial and domestic solid wastes lead to increased turbidity in the major rivers and coastal waters. The degradation of coastal ecosystems potentially reduces the capacity of small pelagic species to cope with climate change impacts. It is negatively affecting primary production, spawning areas, nurseries and suitable ecological habitats in general. Multiple sources of coastal ecosystem degradation are therefore a major constraint for ecological resilience.

Recovery potential in a context of generalized overfishing

Overfishing is a key negative factor that could seriously undermine the capacity of small pelagic species to recover from climate change impacts. Although small pelagic species generate the most important fisheries production in Senegal, they are fully exploited and even overexploited (FAO, 2011). Subregional stock assessments of small pelagic fish from Senegal to Morocco indicate that *S. aurita* is overexploited. For *S. maderensis*, despite a lack of data for modelling, current catches are considered to be unsustainable with a risk of stock depletion. All the other species are in a fully exploited situation and precautionary measures are recommended to mitigate the harmful effects of overfishing. The fishing pressure on small pelagic fish populations, which is obviously too high, is also characterized by bad practices such as fishing of juveniles and spawning individuals.

4.2 *Social vulnerability*

Overall socio-economic vulnerability of the fisheries sector

Tackling the different attributes of vulnerability (exposure, sensitivity and adaptive capacity), Alison *et al.* (2009) conducted a large study across 132 countries and assessed the vulnerability of national economies to potential climate change impacts on fisheries. This study enabled the calculation of a vulnerability index and a ranking of all the countries according to their level of vulnerability. With a relative vulnerability index of 0.72, Senegal is ranked fifth among the countries of the world whose national economies are the most vulnerable to climate change-driven impacts on fisheries. This study did not stress the specific case of small pelagic fisheries, but because Senegalese small pelagic fisheries are socially and economically very important and ecologically exposed to climate change and variability, they have certainly contributed in a significant way to raising the overall vulnerability of the national fisheries sector. The pelagic species account for enormous biomass but they are also known for their strong sensitivity to environmental fluctuations that determine their abundance.[36] Therefore, significant long-term climate change might have considerable ramifications for fish availability and food security, job creation and income generation in Senegal.

36. Sambe, 2012.

Potential increase of exploitation-related conflicts

Available projections and scenarios suggest that considerable long-term climate change with strong seasonal variability could occur in the Senegalese coastal areas in the future. In such a situation, Senegalese small pelagic fisheries would face great disturbance, with potentially increased exploitation-related conflicts at local, national and subregional scales. Given the socio-economic importance of small pelagic fisheries, different stakeholders and, more specifically, the fishers and the government will be involved in such conflicts. At local and national levels, owing to a reduction in the abundance of, and a spatial shift in the distribution of the major small pelagic fish stocks, conflicts will arise out of the use of incompatible and concurrent fishing gears; the coexistence and even high density of different local and migrating fishing communities; the intensification of fishing activities in very limited fishing areas; and the use of irresponsible practices by stakeholders. In a context where climate change is likely to reduce the abundance and modify the spatial distribution of small pelagic stocks (e.g. northward shifting), Senegalese fishers that are historically known to be very mobile along the national and subregional coast will have more incentives to migrate.[37] Therefore, in an open access regime where the sea and fisheries resources are seen as "public goods" without an owner and clashes within fishing communities and between fishers and governmental officers in charge of fisheries regulation, which are already common, may become more frequent and more violent.

It is also important to note that over the past decade Senegalese small pelagic fisheries have become very dependent on Mauritania and this has created more frequent bilateral problems. Given the fact that the number of small pelagic fishing licenses (only about 300) provided annually by Mauritania are insufficient to satisfy Senegalese fishing capacity, fishers tend to illegally enter Mauritanian waters. Consequently, arrests and confiscation of vessels and gears by the Mauritanian coast guard are common. More and more Senegalese fishers who target small pelagic species are also finding ways to settle in Mauritania. This situation provokes frequent social and political conflicts that, fortunately, have so far been more or less peacefully resolved by these two neighbouring countries. It is important to note however, that Senegal and Mauritania experienced deadly clashes in 1989 owing to the exploitation of the natural resources around the Senegal River that divides the two countries.

5. Small pelagic fisheries management implications in Senegal

Fighting against the ecological threats and overfishing

In a context where small pelagic fisheries will face the potentially negative effects of climate change, adequate management measures and strategies need to be urgently implemented at local, national and regional scales. The first step is to address all activities that have damaging effects on coastal ecosystems. For example, polluting activities must be banned or better regulated so as to ensure the environmental integrity that is essential for increased ecological resilience. An integrated coastal management plan is required to develop key coastal sectors (e.g. fisheries, tourism, etc.) while reducing harmful environmental impacts. Moreover, some ecologically sensitive areas, such as spawning areas and nurseries, should be protected by MPAs and seasonal closures. Tackling the issue of fishing overcapacity and bad practices is also necessary to strengthen the resilience of small pelagic species against climate change.

Although there is a real political will to act on these issues, many gaps and constraints continue to undermine the decision-making process and the implementation of concrete and effective actions. For instance, even if five MPAs have been officially created in Senegal since November 2004, there is a fundamental lack of surveillance and enforcement. Some of these MPAs, especially the ones located in Joal-Fadjouth and Saint-Louis seem to be ecologically suitable to protect sensitive habitats of small pelagic species (e.g. *S. aurita, S. maderensis* and *E. fimbrita*) and reduce fishing pressure on juveniles and spawning individuals. However, in addition to a lack of surveillance and enforcement, none of the existing MPAs are monitored regularly so that their effectiveness may be assessed and improved. Seasonal closures pertain to a very

37. Binet, Failler & Thorpe, 2012.

limited number of species, including octopus (*Octopus vulgaris*), shellfish (*Cymbium pepo*) and coastal shrimp (*Penaeus notialis*). The extension of such seasonal closures to other species, particularly small pelagic species, remain at the hypothetical[38] stage because of the socio-economic implications for the fishing communities that depend mostly on marine resources and have no alternative livelihoods. To date no seasonal closures have been implemented in the small pelagic fisheries.

A priority is to eradicate unsustainable overcapacity and bad fishing practices, as recommended by the FAO Code of conduct for responsible fisheries.[39] For that purpose, fisheries management strategies should strive towards the development of management plans that take into account the dynamic balance between fishing pressure and the ecological carrying capacity of small pelagic stocks. Such a management system requires the establishment of catch limits and the termination of the open access regime that still characterizes Senegalese fisheries. However, the Government of Senegal is required to overcome serious socio-economic and managerial constraints if it is to reduce fishing pressure. In recent years, it has tried to implement some measures to reduce overcapacity, but these measures have met with limited success. For example, a fishing permit system was established in 2006 for the artisanal fishery subsector, a sector that has always been difficult to regulate.[40] The principle behind this initiative was to issue a limited number of fishing permits per year, taking into account the state of the main stocks. Fishing permits for vessels that target small pelagic fish are the most expensive because of the large size of the vessels involved and their considerable potential to impact the stocks. The fishing permit system was initially considered a bold move to regulate the considerable fishing pressure that is exerted on the stocks, but it has been ineffective because of resistance from the fishing communities, in spite of the legal sanctions they face. With respect to catch limitation, no concrete action has yet been taken to implement the management recommendations that have been made by different FAO/CECAF working groups in recent years. Other classic measures, such as mesh size and fish size limits, also need to be updated and enforced. In the current Fisheries Code,[41] fish size limits are defined for seven small pelagic species (12 cm for *S. aurita, S. maderensis* and *Scomber japonicas*; 15 cm for *E. fimbriata, Decapterus rhonchus, Trachurus trecae* and *Trachurus trachurus*). The mesh size limits for the main small pelagic fishing gears are 28 mm for the purse seine, 60 mm for the gillnet and 50 mm for the pelagic trawl. Unfortunately, all these limits are ineffective because of low levels of compliance by fishers and limited capacity for monitoring, control and surveillance.

Given the different management experiences mentioned above, it is apparent that the main challenge in managing small pelagic fisheries is related to a lack of enforcement. Although updated and adapted management measures are necessary, the key issue is how to ensure they are effective. In such a situation, it is absolutely essential to strengthen the MCS system by focusing more specifically on the main small pelagic fishing zones and landing sites. Because of potential social and political pressure from the fishing communities and other lobby groups, the Senegalese government needs to reaffirm its authority and commitment to enforcing the fisheries law and regulations. The government may realize benefits from the co-management approach currently being promoted in the country which is raising public awareness of the need for small pelagic fisheries to be sustainably managed. In order to improve ecological resilience and mitigate potential climate change impacts, the available scientific knowledge at national and international levels must be incorporated into the new Fisheries Code and the small pelagic fisheries management plan that is currently being developed.

Integrating the subregional dimension in the management strategies

Small pelagic fish populations off Northwest Africa are shared by different countries. Therefore, beyond the local and national level, regional management measures and strategies are required to mitigate the negative impacts of climate change on small pelagic fisheries. States that share these resources should find the best way to harmonize management policies and combine efforts to implement suitable adaptation strategies. The Sub-Regional Fisheries Commission in West Africa could play an important role in encouraging a harmonized approach. However, because Morocco and Spain (Canary Islands) are not members of this

38. Thiao *et al*., 2012.

39. FAO, 1995.

40. Thiao *et al*., 2012.

41. *République du Sénégal*, 1998.

Commission, it could be difficult to find solutions that cover the entire distribution of populations of small pelagic fish. For this reason, this issue might be tackled with the assistance of FAO through the CECAF.

Because small pelagic fish stocks are characterized by time–space instability, it is very difficult to establish an equitable system to share the total maximum catch recommend by the FAO/CECAF working groups between countries. Strategies at subregional scale should focus more on some specific concrete actions. For example, in recent years the CCLME and the EAF-Nansen projects have combined efforts to assist the countries in building the basis of a subregional management initiative – in addition to the Sub-Regional Fisheries Commission project on small pelagic resources. These projects rely on scientific inputs from the FAO Working group that has been in place for several years; they need to be maintained and strengthened, even after they come to an end. Joint MCS activities also need to be promoted so as to facilitate the use of all available equipment and experience and the exchange of data and information about, for example, illegal, unregulated and unreported fishing across the different EEZs. The countries that share small pelagic fish stocks should also harmonize some of their fishing regulations and make sure they are enforced. This would include mesh size limitations and minimum fish sizes, while coordinated seasonal closures that take into account the spawning cycles and migration trajectories of small pelagic species should be initiated. Such a harmonized approach needs to follow the national and subregional management plans for small pelagic resources that were developed under the subregional small pelagic fisheries project, but which are unfortunately not operational . Moreover, it is important to put in place an official subregional framework on the issue of fishing agreements and licenses to DWFNs that target small pelagic species off Northwest Africa (e.g. European Union, Russia and China).

Building capacity for climate change adaptation

The impacts of climate change on small pelagic fish abundance and distribution must be taken into consideration in Senegalese management policies and legal frameworks. Moreover, owing to the uncertainties that characterize climatic and ecological systems, and a lack of data and knowledge, a precautionary management approach is necessary. Climate change requires fisheries managers to manage for resilience in ecological and social systems.[42] Hence, managing small pelagic fisheries in a context of climate change requires the building and strengthening of the capacity of national stakeholders. The staff of the Ministry of Fisheries and Marine Affairs, scientists and professional organizations need to be better sensitized and trained to be able to assess and monitor climate change impacts and integrate them into fisheries management policies and adaptation strategies.

Specific actions have to be undertaken for the coastal communities whose livelihoods are strictly dependent on small pelagic fisheries. The basic idea here is to create a favourable context where coastal communities have the opportunity to diversify their activities outside the fishery sector. Although this idea is currently very popular among decision-makers and other stakeholders involved in the sector, its implementation has met with limited success. A lack of funds is obviously a major constraint. In order to overcome this problem, the WARFP is testing an alternative livelihoods to fishing and poverty reduction fund (about USD200 000) called the "Reconversion Fund". It aims to provide financial support to fishers at 12 pilot localities who want to leave the fishery sector and invest elsewhere. The achievements of this initiative have not yet been evaluated. In addition, the sustainability of this initiative after the completion of the project is the primary consideration. Moreover, in Senegal, the WARPF project targets mainly the coastal demersal fisheries and it does not properly cover the small pelagic fisheries sector.

In the case of small pelagic fisheries, most fishers come from rural localities. It would therefore make sense to develop agriculture and livestock opportunities for these communities, given that adequate and suitable land is available. An issue to consider is that some coastal communities involved in the small pelagic fisheries (e.g. Niominka, Lebou and Guet Ndar communities) are so traditionally linked to the aquatic resources that their alternative livelihoods options are very limited.[43] In these cases a suitable adaptation strategy could be to develop aquaculture activities to create jobs and contribute to fish supply in the country. Building community capacity, including the skills of the youth, through targeted training will also be a major enabling condition to help them to succeed in new business in the long-term.

42. Fluharty, 2011.

43. Thiao, Dème, Bailleux, Failler & Sall, 2012.

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