A6. Fisheries and ecosystem observations

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A6.1 Background

The following report only represents a general overview of issues related to fisheries and ecosystem observations and cannot be seen as a holistic synthesis of all activities, projects, programs and organizations involved in fisheries and ecosystem observation in the Southern Atlantic Ocean.

A6.2 Relevance of fisheries and ecosystems

Most fisheries are happening in the coastal and shelf areas and are thus often in the Exclusive Economic Zones (EEZs) of countries and as such are under the jurisdiction of only one country. Exceptions are transboundary stocks, which migrate between the EEZs of several countries (e.g. Sardinella spp. in North West Africa, a shared stock between Morocco, Mauritania, Senegal, Gambia and Guinea-Bissau) or are straddling stocks, which migrate between EEZs and the high seas, and highly migratory stocks. The most prominent example of the latter are tuna stocks. Management and thus monitoring are commonly done through regional agreements or Regional Fisheries Management Organizations (RFMOs). In the case of tuna species in the Atlantic, this role is played by the International Commission for the Conservation of Atlantic Tuna (ICCAT). We will present this as an extra paragraph in the following report. Coastal ecosystems can be categorized in Large Marine Ecosystems (Hempel and Sherman, 2003), which are marine areas with similar ecosystem characteristics. Neighboring countries of some of these LMEs have developed programs and conventions to regulate use and extraction of living resources. Many LME programs include extensive scientific projects and together with many national efforts these can include observations and monitoring programs. However, most of these efforts are done through individual programs and only few are maintained as consistent time series. One prominent example for LME programs is the Benguela Current Large Marine Ecosystem Programme. In recent years, the importance of monitoring and observation of commercial and non-commercial species has increased, as the realization of the impact of climate variability has been extended with a steady trend of change, which forces changes in productivity and changes in distribution alike. To understand current systems, particularly also the effect of human activities including fishing and climate change for the future development of ecosystems, an increasing number of ecosystem models have been developed, which are also in need of data to be calibrated and validated. In addition, these models also use input data from coupled climate-ocean models. It has been recognized that observations of a few essential variables (ecosystem, ocean variables) of pressures and state of the ocean are required for an ecosystem based analysis (UNESCO, 2012), and that observations systems should be organized around “essential ocean variables (EOVs),” rather than by specific observing system, platform, program, or region. Implementation of EOVs can be made according to their readiness levels, allowing timely implementation of components that are already mature, while encouraging innovation and formal efforts to improve readiness and build capacity (FOO, 2012; Miloslavich et al., 2018). Thus, there is a clear need for more integration with respect to data collection and analyses. However, there are some challenges with respect to a coordinated Trans-Atlantic observing system, namely, the need to:

- link national and regional coastal observations with open ocean observations;
- link different observation systems and programs with currently different goals;
- integrate observation systems with very different timescales between collection of raw data and availability of processed data;
- collections of a set of pre-defined essential variables that would enable ecosystem and fisheries management.

A6.2.1 Fisheries

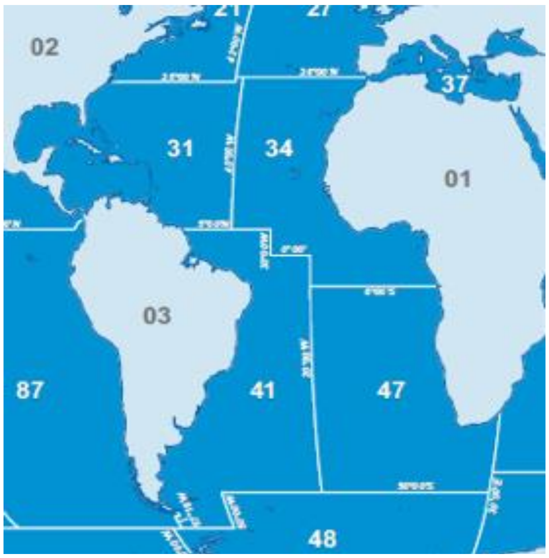

Figure A6.1: Main statistical areas of the Food and Agriculture Organization of the United Nations (FAO), (FAO 2015).

The importance of fisheries in the Tropical Atlantic can most easily be demonstrated by the total catch and the dependence on the sector in the region. Almost ten million tons of seafood (from 87.2 million global marine capture) were harvested in the Central and South Atlantic (FAO major areas 31, 34, 41 and 47, Figure A6.1) in 2016 (FAO 2018).

In addition, the fishing sector has a high importance in the tropical Atlantic coastal countries. The total amount of fishers in Africa, Latin America and the Caribbean is eight Million, although not all of them are operating in the Atlantic. But not only these countries fish here, many foreign fleets (e.g. Korean, Chinese, Russian, European) also target the resources.

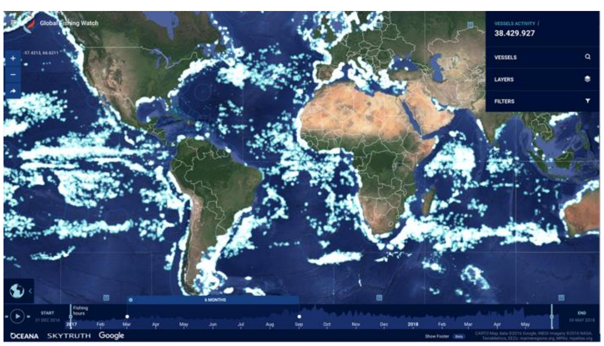

Figure A6.2: Fishing activities cumulated from March 2017 to September 2017; taken from Global Fishing Watch (http://globalfishingwatch.org/map/)

The fishing activities cumulated over a period of 6 months from March 2017 to September 2017 was shown by Global Fishing Watch, which is a good example for a global remote sensing observation system for fishing activities (Figure A6.2). However, it only shows vessels with an Automatic Identification System (AIS), which only vessels above 300 BRT need to install and run (IMO, SN/Circ.227). Thus, smaller fishing vessels, especially those close to the coast, cannot be detected. Moreover, the system can be easily switched off by the crew, even if it appears efficient on e.g. the European fleet operating in the tropical area. More efficient system to monitor fishing activities is the use of Vessel Monitoring System (VMS) even if we can report contrasted operationalization in developing countries. The use of embarked fishing observers remains the more reliable monitoring system to report location and catch.

A6.2.2 Ecosystems

(1) Relevant ecosystems in the tropical Atlantic

Depending on the definition of tropical Atlantic, the area contains roughly 7 – 9 LMEs (Hempel and Sherman, 2003) and 4 – 5 Longhurst provinces in the open Ocean (Longhurst, 1998) (Figure A6.3). Most of the LMEs are shared between different countries, with some of them having developed programs and conventions to coordinate scientific efforts, harmonization of national legislations and to regulate some shared activities, e.g. fisheries.

(2) Role of coastal and shelf sea ecosystems in provision of direct benefits

Most living resources are extracted in coastal and shelf areas and thus these ecosystems are supporting the livelihoods for millions of people directly by providing income, employment and food through artisanal and industrial fishing. In addition, coastal ecosystems also support income generating activities including tourism, industry, diving, game fishing, recreational fishing among others. In all tropical areas as everywhere, the marine ecosystem management is a trade-off between conservation and exploitation (Brehmer et al., 2011), usually in disfavour of the conservation targets. Even if both goals must be considered for management purposes, considering that an ecosystem in bad health or not sustainably exploited by the fishers, is less productive.

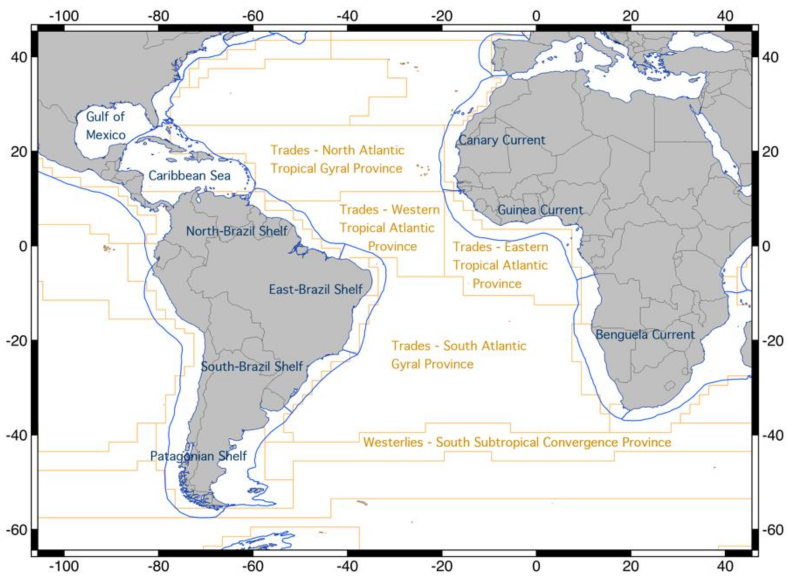

Figure A6.3: Tropical Atlantic large marine ecosystems (LME), map by J.O.Schmidt

A6.3 Observations of Fisheries and Ecosystems

Together, fishing and changing environmental conditions (e.g., chemical contamination, hypoxia, toxic algal blooms, ocean warming and acidification) are placing wild fish stocks under unprecedented stress (Nellemann et al., 2008). This problem is being addressed by transitioning from traditional single species management of capture fisheries to an ecosystem-based approach to fisheries management (EBFM) in which fishing is managed in the context of interactions of fish stocks with other organisms (prey, predators, and competitors) and their environment (Garcia & Cochrane, 2005). The success of applying an ecosystem-based assessment to inform Ecosystem Based Fisheries Management (EBFM) depends on (1) simultaneously monitoring multiple pressures and ecosystem states; and (2) rapid detection and timely predictions of changes in ecosystems states and their impacts on carrying capacity.

Table A6.1 Specification of observing system requirements guided by the data and information needed for ecosystem-based assessment of fisheries (reproduced from UNESCO, 2012).

Observations: *In Situ*	Fisheries dependent catch statistics (observers & landings) • Species, biomass, numbers, size & mean trophic level • By-catch Fisheries independent surveys of harvestable fish stocks • Distribution & abundance of fish eggs, larvae, juveniles & year classes (cohorts) of adult spawners (age structure) • Migration routes between feeding & spawning grounds Environmental data • Water temperature & salinity • Chlorophyll-a • Zooplankton (macro- & meso-) abundance • Abundance of predators
Observations: Remote	• Sea surface temperature, salinity, wind & current fields • Phytoplankton biomass (chlorophyll-a), primary productivity, and frontal products (ocean color radiometry derived) • Spatial mapping of fishing vessels
Model Requirements	• Computation of phytoplankton productivity from chlorophyll-a, photosynthetically active radiation and temperature. • Stock assessments ○ Virtual population analysis (VPA) requiring data on the number of fish in each cohort & algorithms for relating the variable of interest to the variable measured (e.g., stock size estimated from CPUE) and estimating errors; ○ Multi-species virtual population analysis (MSVPA) requiring additional data diet (stomach contents) and predation rates. • Ecosystem & trophic dynamics ○ Ecopath with Ecosym ○ Atlantis, SEAPODYM, GADGET
Reporting	• Delayed mode (≤ 1 month) for stock assessments used to set annual & seasonal total allowable catches & quotas • Near real-time (< 12 hours) for monitoring compliance & anomalies from historical trends during the fishing season to support adaptive management

A6.3.1 Observations in fisheries

(1) Stock taking of species

The most basic observations that happened over the last centuries are related to stock taking of species, i.e. the exploration of their habitats and related species and their description and categorization. Still in many areas not all species are scientifically described and thus it is difficult to assess the impact of human activities, including fisheries, on these species. Thus, a continued effort is necessary in almost all tropical Atlantic areas, which are still understudied.

(2) Assessing the status of stocks

The most basic observational need in relation to management of living resources is the assessment of the fisheries themselves, including fishing capacity (i.e., how many boats of which types and fishing gear), effort (how many days at sea, how many trips, how many hooks deployed per day, etc.) and catch (which species and how much of each species). To assess a given stock, additional information on length, weight and age of caught individuals of a given species and how much of each length, weight or age are caught, is needed. These are information that are normally collected through national fisheries institutes or respective government fisheries agencies, with representative fish sampling done either directly on board or through landing in ports, and market sampling schemes. In some countries fisheries independent data are collected through trawl and hydroacoustic surveys on the adult and juvenile individuals of a stock or egg and larvae surveys on the early life stages of a stock.

(3) Population dynamics

To get information in relation to population dynamics, regular annual surveys are necessary, which collect information on the development of a cohort in a given stock, estimating migration, growth and mortality through tagging studies and performing nested studies on the influence of environmental variables on life history parameters. In addition, stomach content analysis gives insight into the role of species in the ecosystem and the dependence on specific prey species and susceptibility to predators. Many of these studies are normally not carried out regularly and often done with financial support of projects which do not allow to constitute efficient time series to monitor population dynamics of exploited fish populations.

A6.3.2 Monitoring Technologies

Operational delivery of data and information on the status of the ecosystem requires greater time-space resolution than can be provided by current ship-based surveys and *in situ* sensors alone. While additional sampling from these platforms (ships and sensors on moorings, gliders, and instrumented pelagic animals sometimes called Animal oceanographers or Animal-Borne Sensors) are clearly needed, these observations by themselves will not provide the time-space resolution of essential biological variables required for EBFM (Wang et al, 2019). To address this limitation, additional sampling platforms and autonomous robust sensors are needed, e.g., satellite-based remote sensing (Mouw et al. 2017) and autonomous acoustic sampling (Lembke et al. 2018; Brehmer et al. 2019b).

Satellite-based remote sensing is and will play a critical role in providing data with sufficient time-space resolution to elucidate linkages between climate-driven changes in marine ecosystems and the dynamics of fish and phytoplankton productivity in open sea and non-cloudy areas, as major drawbacks appear in shallow water near the coast. Quantifying stock-recruitment relationships and identifying the environmental factors modifying them is not possible using traditional oceanographic methods by themselves. Satellite-derived estimates of ocean surface currents and frontal zones, sea surface temperature (SST), salinity (SSS), ocean colour radiometry (e.g., phytoplankton biomass and phytoplankton productivity proxies) have made these objectives achievable, and the results can be used to inform ecosystem-based stock assessments. The challenge is in quantifying relationships between these satellite-derived estimates of the distributions of SST, SSS and phytoplankton productivity and the abundance and distribution of higher trophic levels from zooplankton to fish (e.g. Thiaw et al., 2017; Diankha et al. 2018). Four general approaches are available to estimate the production and biomass of fish and other high trophic level organisms from primary production: statistical models (e.g., regressions to Generalised Additive Model of fish landings on primary production), size spectra models, energy mass-balance models and 'end-to-end' or 'physics-to-fish' ecosystem models (Fulton 2010, Kaplan and Marshall 2016) that all depend on or benefit from the provision of satellite data. In addition to stock assessment applications, remote sensing can be used to help fishers locate target species, such as tuna, through the detection of hydrographic features, such as fronts. This approach has the advantages of improving the efficiency of the catch, reducing fuel use and thereby greenhouse gas emissions, as well as potentially reducing bycatch, but should not be considered on fisheries already over exploited. An example of this is Dynamic Ocean Management, where models and real time tagging information are used to derive preferred habitat of by-catch species to identify areas of low-bycatch and high target catch (Hazen et al., 2018). However, it also risks increasing the potential for overexploitation of fish stocks. Clearly, implementation needs to be considered alongside other conservation-based management tools, such as quota systems and using remote sensing to enumerate and track fishing vessels for enforcement purposes.

Combined with satellite-based remote sensing and Continuous Plankton Recorder (CPR) surveys, acoustic technologies have the potential to provide an observing system for marine food webs from phytoplankton to zooplankton to fish. The goal of the proposed Mid-Trophic Automatic Acoustic Sampling (MAAS) Network is to implement a network of platforms (ships of opportunity and fixed platforms) equipped with multi-frequency acoustics (now rather wide band acoustics) that can monitor the distribution and abundance of macrozooplankton (1 – 1000 mm in size) basin wide (Handegard et al., 2013).

A major challenge to sustainable fisheries is maintaining long term and consistent data sets on the vital statistics of population dynamics in order to quantify trends in pressures, states and impacts. The regular collection and acquisition of consistent data (in terms of geographical distribution, temporal sampling and methods of collection) for establishing long term time series of essential variables requires a consistent technical capacity in terms of platforms, sensors, skills and budget. Temporal and geographical gaps and changes to data specifications can cripple and weaken assessments, analyses and model outputs. This remains a challenging problem for managing fisheries and other living marine resources, especially in developing countries with limited resources. As data are collected from autonomous instruments such as those described above, careful consideration must be given to data compatibility and capacity to maintain, service and operate them cost-effectively. The latter will require cost benefit analyses (in particular, their potential saving of ship-time). For successful implementation of EBFM, restructuring of institutions (in many instances) and the implementation of ecosystem modelling capacity, multi-species model development and the improvement of relationships among scientific communities, fishing industries and relevant authorities will be required in many instances.

A6.4 Current or Recent Coordinated Observations

A6.4.1 Nansen Survey

One example of a survey, which started as a pure fisheries survey and turned into an ecosystem survey is the EAF Nansen Programme. Since 1975 this joint initiative of Norway and the Food and Agriculture Organization of the United Nations (FAO) is performing surveys with the research vessels, R/V *Dr Fridtjof Nansen*, which were specifically built for the programme, around the

African continent (Figure A6.4). The second EAF Nansen Programme started in 2017 to implement an ecosystem approach to fisheries (EAF) for the management of selected fisheries in Africa and collect data on fisheries and ecosystems, pollution and climate variability and change.

The Nansen Program also supports the Large Marine Ecosystem Programmes (Bianchi et al 2016) and in 2017 the new *Dr Fridtjof Nansen* vessel has been launched to support the envisaged survey program for the coming years. The vessel is equipped with state-of-the-art technology to sample environmental biotic and abiotic variables, and at least in their strategic plan should consider the shallow part of the continental shelf (0-20 m) which is until now almost completed under studied (Brehmer et al., 2006), even if this area constitute the main fishing ground for the most part of the small scale fishing fleets operating in the tropical Atlantic.

A6.4.2 Census of Marine Life

The Census of Marine Life was a 10-year, US $650 million scientific initiative, involving a global network of researchers in more than 80 nations, engaged to assess and explain the diversity, distribution, and abundance of life in the oceans. The world's first comprehensive Census of Marine Life — past, present, and future — was released in 2010 in London. Initially supported by funding from the Alfred P. Sloan Foundation, the project was successful in generating many times that initial investment in additional support and substantially increased the baselines of knowledge in often underexplored ocean realms, as well as engaging over 2,700 different researchers for the first time in a global collaborative community united in a common goal, and has been described as "one of the largest scientific collaborations ever conducted". Census of Marine Life (Costello et al., 2010) has collected biodiversity data in the global ocean, including the Tropical Atlantic (Figure A6.4).

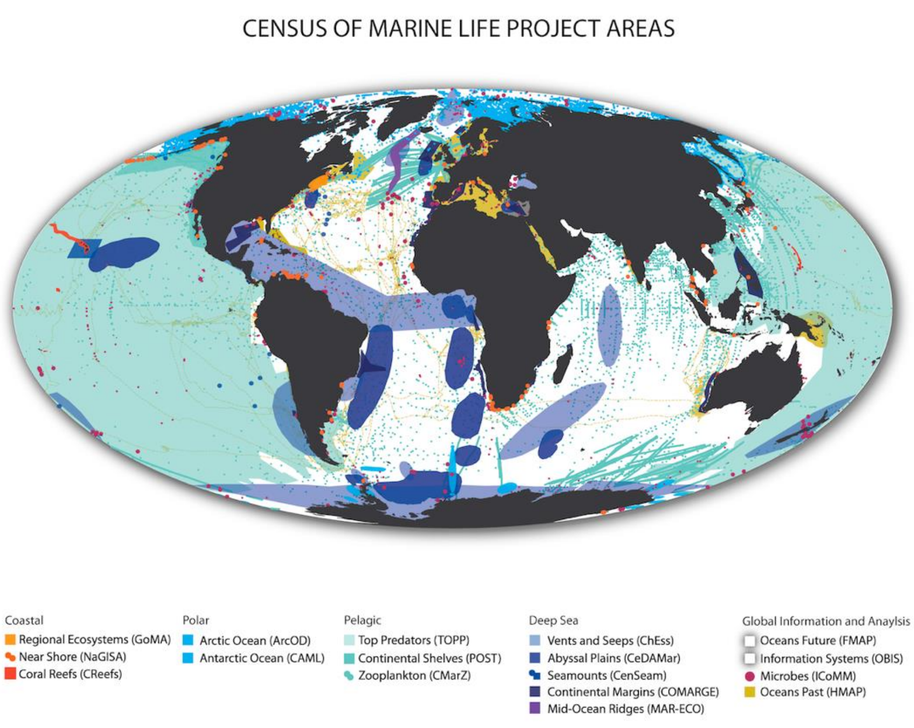

Figure A6.4: Sampling of the Census of Marine Life Project (from http://www.coml.org).

A6.4.3 Benguela Current LME

The Benguela Large Marine Ecosystem Programme (BCLME) was initiated in the Benguela region between 2002 and 2008 (Shannon et al. 2006). The objective was to support Angola, Namibia and South Africa in developing capacity to tackle marine environmental issues in the region, across national boundaries. The ecosystem-based regional programme was funded by the Global Environment Facility (GEF) and supported 75 projects and activities in the region. It also facilitated other projects and initiatives and thus contributed to the generation of a wealth of scientific work, increasing the understanding of the Benguela system and supporting the management of fisheries. The implementation of the Ecosystem Approach to Fisheries (EAF) in the region requires a sustained fisheries and ocean observing strategy (Augustyn et al. 2014).

A6.4.4 Tunas in the Tropical Atlantic

Tunas and the other large pelagic fishes, including the swordfish, billfishes, wahoo and oceanic sharks, such as the blue shark and mako sharks, are highly migratory species and, therefore, the management of their fishery needs to be done by Regional Fisheries Management Organizations, a task in the Atlantic Ocean and Mediterranean Sea undertaken by the International Commission for the Conservation of Atlantic Tunas - ICCAT. Founded in Rio de Janeiro, Brazil, in 1966, the ICCAT Convention entered into force in 1969. Presently, it has 52 Contracting Parties and 5 Cooperating Non-contracting parties (CPCs), being, thus, one of the largest and oldest RFMOs in the World. Article IX of ICCAT Convention requires that all CPCs provide statistical, biological and other scientific information to the Commission, so that it may assess the condition of the exploited stocks and adopt management measures to ensure their conservation and thus the sustainability of the tuna fisheries in the Atlantic Ocean. The task of compiling all data submitted by CPCs and assessing the status of the stocks pertains to the SCRS- the Standing Committee on Research and Statistics, made by the scientists from the different ICCAT Members. Based on the recommendations provided by the SCRS, the Commission, in its yearly meetings, agrees and adopts several management and conservation measures, including definition of Total Allowable Catch (TAC) for different stocks, and the quota allocated to each country.

Besides the more classical collection of catch and effort data, ICCAT has initiated the Atlantic Ocean Tropical tuna Tagging Programme (AOTTP, 2015-2020) in 2015 to tag at least 120,000 tropical tuna fish (mostly bigeye, skipjack and yellowfin) across the Atlantic, during 5 years, using a range of conventional and electronic tags. Additionally, the Programme is collecting, collating and analyzing tag-recapture data. All the data collected are being stored in databases maintained by the ICCAT Secretariat and used to improve the estimation of key parameters needed for input to stock assessments. Fisheries scientists from Atlantic coastal states have been trained in tagging, data collection and the use of tag-recapture data in stock-assessment models.

Activities of AOTTP include the chartering of professional fishing vessels, liaison with recreational anglers, the deployment of tagging and tag-recovery teams, data collection, scientific interpretation, the development and execution of training courses and the instigation of awareness campaigns to promote tag-recovery.

Focal countries are Ghana, Côte d'Ivoire, Senegal, Republic of South Africa, Venezuela, Trinidad and Tobago, Brazil, EU-Spain (Canaries), EU-Portugal (Azores), Cabo Verde and the USA. Commercial baitboats (also known as pole & line vessels) and boats operating with handlines are being used for most of the tagging work since longline and purse seine gears are known to cause more stress to the fish and increase mortality rates. Since there are no baitboats working off the North American east coast, AOTTP has depended on cooperation with recreational game fishers, to tag fish in that area.

The AOTTP is funded by the European Union (DCI-FOOD/2015/361-161), ICCAT CPCs and Contributors.

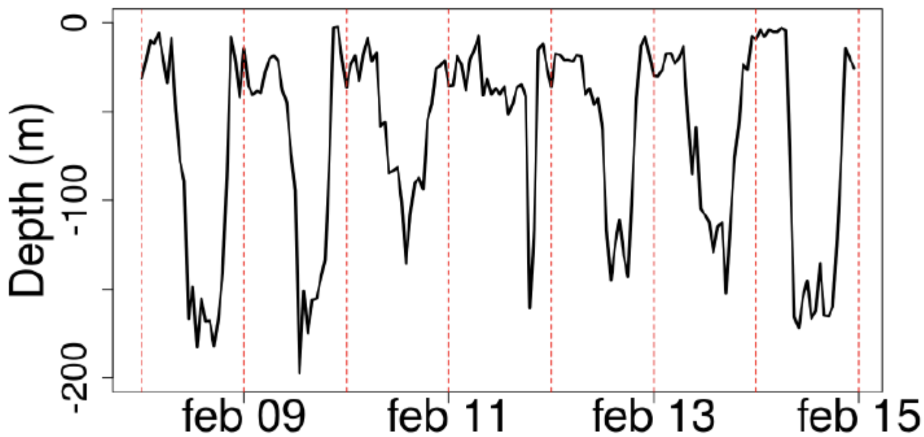

Figure A6.5: Example of data collected by data-logger tag, showing a week of diving behavior of a yellowfin tuna. Temperature data is collected alongside, however the exact position of the data is difficult to estimate, because the data has no link to GPS data (from ICCAT/AOTTP NEWSLETTER No.2, https://www.iccat.int/aottp/AOTTP-Document-Library/Reports/Newsletters/EU-AOTTP-Newsletter-02.pdf)

A6.4.5 Other tagging programmes

Animal tracking networks are spreading around the Atlantic Basin, and will become an important tool to support the understanding of ecosystems and fisheries. The Ocean Tracking Network (OTN) is a GOOS pilot project that combines technologies developed for tagging apex pelagic predators with those developed for smaller animals (Hussey et al., 2015). The former uses satellites to determine where large animals travel in the oceans and monitors the environment (temperature, salinity and chlorophyll) they experience while the latter uses “curtains” of acoustic receivers across continental shelves and near islands to monitor fish migrations and receive and transmit data from larger animals. In Europe, the formation of a European Tracking Network (ETN) is underway. In the US, as part of the Integrated Ocean Observing System (IOOS), an Animal Tracking Network (ATN) is being implemented. In the South Atlantic, Brazil and South Africa are active OTN partners. Thus, once fully deployed, the animal tagging networks will have the capability of tracking the movements of spawning populations that represent three upper trophic levels of the ocean’s food webs.

A6.5 Conclusions

In conclusion, not all existing programs and projects have been listed here only the most illustrative, but overall, it becomes clear that no holistic observation program exists for the Tropical Atlantic with respect to biological and specifically fisheries data even less to relate physical, biogeochemical and ecological components of the marine ecosystems. Thus, the general requirements are better use of existing data, extending surveys for commercial and endangered species (giving more attention on key species for food security), and integration in a larger observation system, considering the requirements of different user groups, decision makers, society, private sector and the scientific communities. Current gaps include missing or not enough communication between different scientific communities collecting data, missing data exchange protocols and missing survey protocols.

Specific recommendations

1) Linking and supporting existing coordinated programmes like the EAF Nansen Programme, the LME Programmes and Regional Fisheries Management Organizations like ICCAT;

2) Linking and supporting coordinated national survey program, maintaining at least the current survey effort, identifying gaps and supporting the development of extensions where necessary;

3) Linking coordinated communities like the Ocean Tracking Network;

4) Reaching out to governmental bodies, both national and international like the Ministerial Conference on fisheries cooperation among African States bordering the Atlantic Ocean (ATLAFCO) as well as regional bodies as the Sub Regional Fisheries Commission (SRFC) in the CCLME, the Fisheries Committee for the West Central Gulf of Guinea (FCWC) in the GCLME, and the Benguela Current Commission (BCC) in the BCLME.

5) Develop and carry out a broad consultation on current observing efforts and observing needs.

Tropical Atlantic Observing System (TAOS)

REVIEW REPORT

Full Report

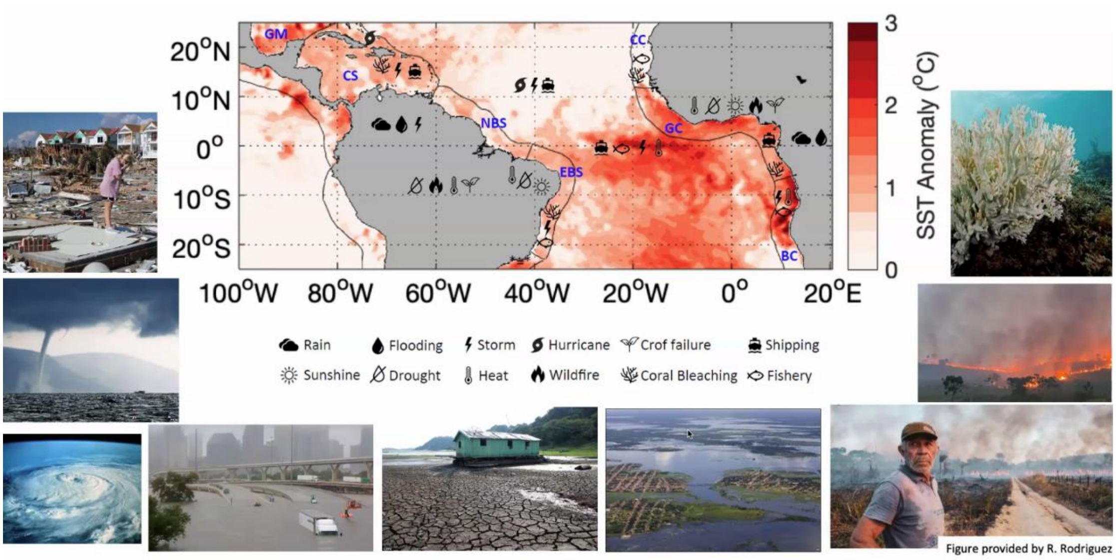

Figure provided by R. Rodriguez

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