The North Kenya Banks pelagic fishery in the context of climate change

By

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Seventh SAPPHIRE PSC meeting on 8 December 2023 https://solstice-wio.org/news/solstice-wio-and-sapphire-projects-support-complimentary-policy-relevant-research-around

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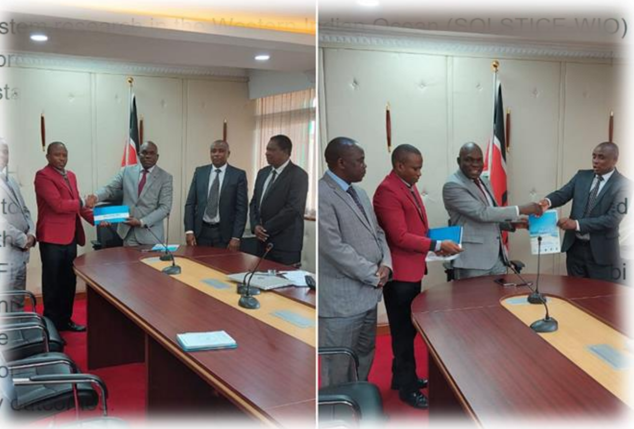
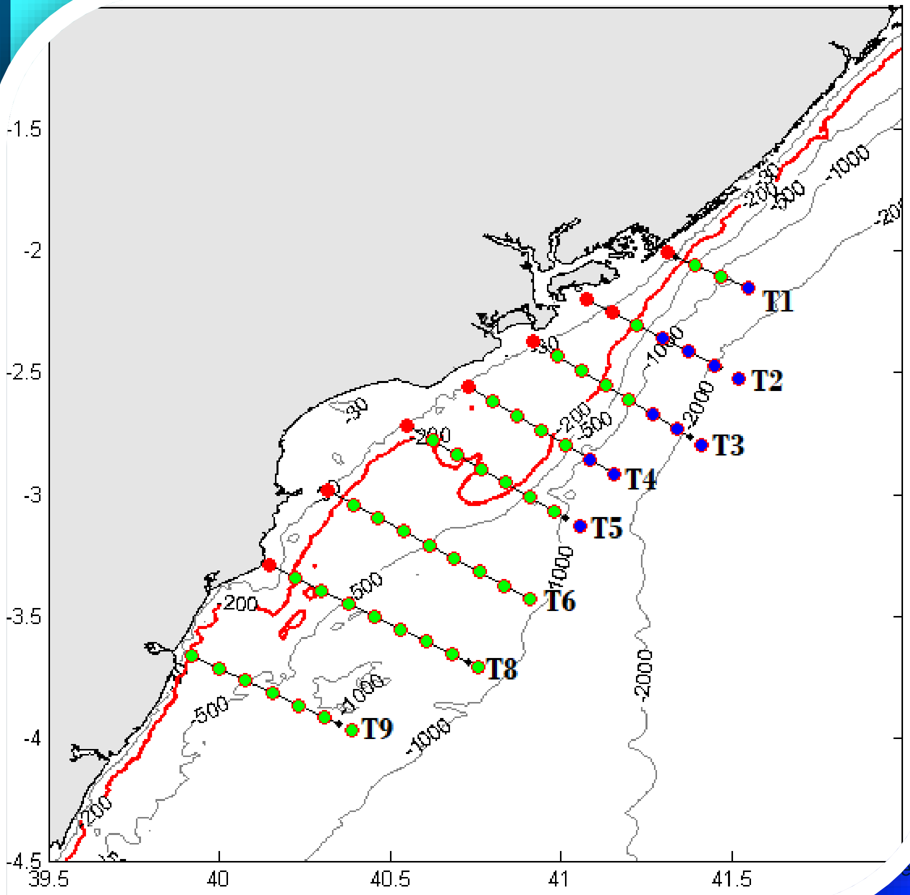
May, 2021

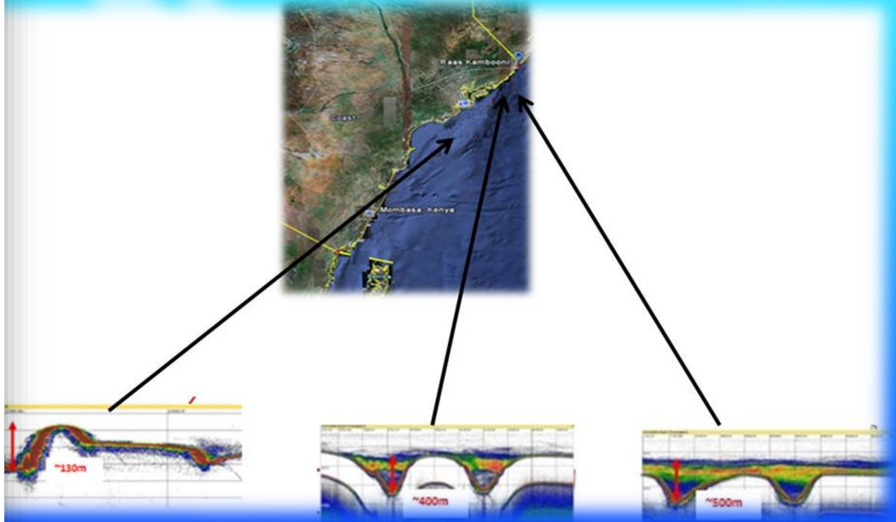
Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosyst... (SOLSTICE-WIO) is a four-year project, funded by the UK Global Challenges Research Fund (GCRF). The pr... South Africa), with the objective of undertaking novel and collaborative research to underst... future changes.



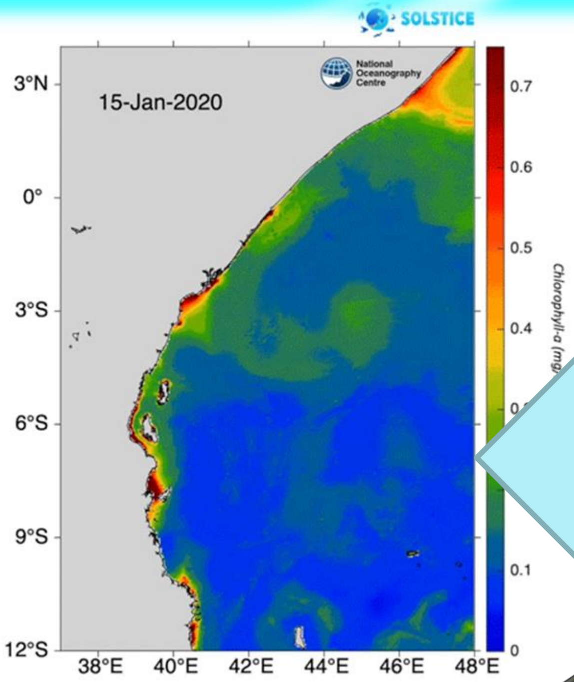
The Western Indian Ocean Large Marine Ecosystems Strategic Action Programme Policy ... SAPPHIRE) Project aims to assist and support government institutions in the WIO region t... Strategic Action Programme. This Programme has been developed by the countries with th... Current Large Marine Ecosystems (ASCLME) project, and the South West Indian Ocean F... Convention and implemented by UNDP with GEF funding. The project benefits the Govern... Mozambique, Seychelles, Somalia, South Africa and Tanzania. The overall objective of the... ecosystem management in the Western Indian Ocean LMEs in line with the Strategic Actio... has five integrated components and each of them are intended to achieve complementary ...

CTD stations and acoustic transects





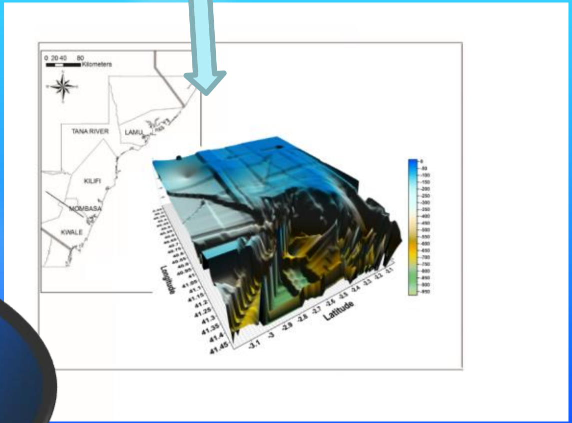
Upwelling occurrence along the Kenyan Coast



Upwelling enhance productivity

High productivity support fishery

North Kenya Banks



highlights

- There has been a growing interest in the North Kenya Banks ecosystem and the associated fishery.
- The North Kenya Banks (NBKs) has high abundance of fish larvae and are more diverse than other coastal ecosystems along the Kenyan coast.
- Some specific environmental factors need to be taken into account when developing management plans towards a sustainable North Kenya Banks resource exploitation.

highlight

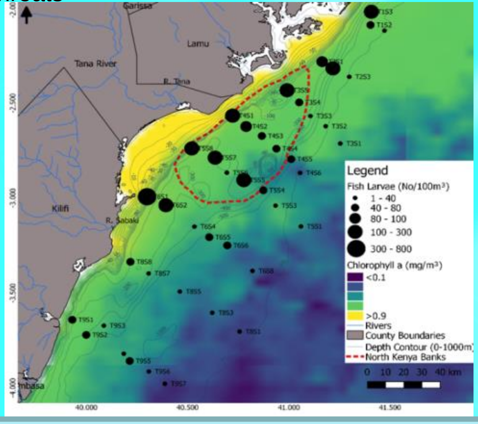
- The higher abundance of larvae, taxon richness and diversity makes the NKBs a distinct region that plays a key role providing a favorable reproductive and nursery habitat for a wide range of commercially important fish species.

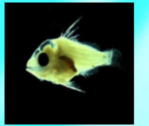
- The nearby estuaries, mangrove habitats and seagrass beds are important nursery and feeding grounds for larval fish and crustaceans that grow to recruits thereafter join offshore harvestable adult stocks.

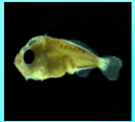
- These habitats should therefore be protected from the negative effects of human pressure and climate change to ensure sustainability of the NKBs fisheries.

Recruitment areas of NKB prevalent with fish larvae (Tunas, Snappers and Jacks 4.0-5.0 mm)

Threats







- Recent scientific research demonstrates that the NKB region contains important breeding and nursery grounds for migratory fish including tuna and tuna-like species.
- The NKB region is therefore predicted to play a crucial role in the management of commercially important migratory species in the future and requires development of a tuna and tuna-like species monitoring strategy.

Threats to this fishery associated to Climate change:

- Climate change is already altering marine ecosystems; changes in the intensity and timing of coastal upwelling will impact fish migration patterns, recruitment, growth, distribution, abundance and predator and prey relationship.


Ocean and Coastal Management 212 (2021) 105800

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

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Assemblage structure and distribution of fish larvae on the North Kenya Banks during the Southeast Monsoon season

James Mwaluma[a,*], Noah Ngisiang'e[a], Melckzedeck Osore[a], Joseph Kamau[a], Harrison Ong'anda[a], Joseph Kilonzi[a], Mike Roberts[b,c], Ekatarina Popova[b], Stuart C. Painter[b]

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[b] National Oceanography Centre, Southampton, UK
[c] UK-SA NRF/DST Bilateral Research Chair: Ocean Sciences & Marine Food Security, Nelson Mandela University, Port Elizabeth, South Africa

ARTICLE INFO

Keywords:
Fish larvae
Distribution
Abundance
Composition
Biophysical factors
Western Indian Ocean

ABSTRACT

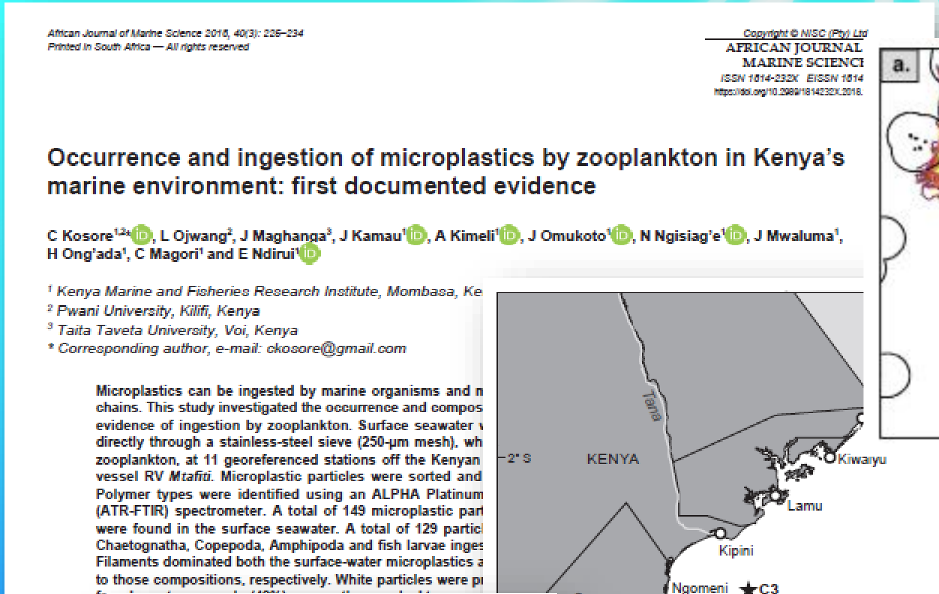
The North Kenya Banks (NKB) is the broadest area of continental shelf along the Kenyan coast, and experiences higher productivity relative to neighbouring shelf regions. It is an area of great importance to Kenya with new emerging fisheries that have the potential to improve the livelihoods of local impoverished fishing communities. Managing these emerging fisheries successfully however is challenged by insufficient data on the fisheries and the local marine environment, and the lack of a management plan specifically for the NKB region. Here, baseline information on the ichthyoplankton assemblage across the NKB region during the Southeast Monsoon season is described and analysed to understand the effect biophysical parameters have on larval composition, abundance and distribution. The dominant fish larvae families were Engraulidae (29.5% of total) followed by Sphyraenidae (8.6%), Carangidae (8.2%), Scombridae (6.2%) and Lutjanidae (5.5%), whilst the dominant species within these families were *Encrasicholina* sp., *Sphyraena* sp., *Thunnus albacares*, *T. alalunga* and *Lutjanus* sp., respectively. A high prevalence of larvae from migratory species such as *T. albacares*, *T. alalunga* and *Gempylus serpens* was found across the northern part of the NKB, suggesting that the area may be an important nursery area for migratory fish with implications for fisheries across the wider Western Indian Ocean. Zooplankton abundance, temperature and conductivity played a positive role in determining the structure and composition of fish larvae assemblages across the NKB region. The high larval densities encountered out to the shelf break (200 m contour) imply the NKB is a productive fishery and as such requires appropriate management oversight. Further…

CONCERNS

- The North Kenya Banks ecosystem has a rich and diverse fishery but it is not well harnessed.
- There is a high unique fishery located at the canyons which is totally unexploited.
- Whereas information on fish productive zones can be availed, there lacks prerequisite capacity to effectively take advantage of the information. This may be addressed through an elaborate investment on fishing capacity and fish marketing structures.

CONCERNS

- The North Kenya Banks form an important ecological habitat, however, only limited studies have been conducted. The system is highly connected to the ABNJ.
- The sea is rough during the South East Monsoon when the NKBs is highly productive. Local fishermen do not have the necessary capacity to fish in rough seas.
- Market outlets are not well developed, as such the fishermen are limited by supply and demand, limiting the extent of their catch during the high fishery seasons.
- The fishery ground lacks clear management structures to ensure sustainable exploitation.


African Journal of Marine Science 2018, 40(3): 225–234
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AFRICAN JOURNAL
MARINE SCIENCE
ISSN 1814-232X EISSN 1814
https://doi.org/10.2989/1814232X.2018.

Occurrence and ingestion of microplastics by zooplankton in Kenya's marine environment: first documented evidence

C Kosore[1,2*], L Ojwang[2], J Maghanga[3], J Kamau[1], A Kimeli[1], J Omukoto[1], N Ngisiag'e[1], J Mwaluma[1], H Ong'ada[1], C Magori[1] and E Ndirui[1]

[1] Kenya Marine and Fisheries Research Institute, Mombasa, Ke
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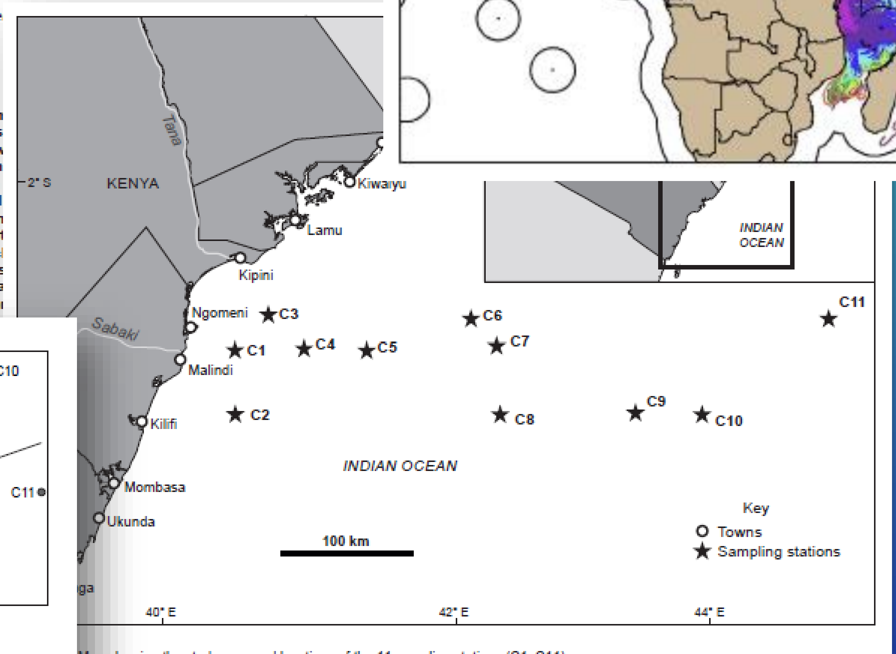


Map showing the study area and locations of the 11 sampling stations (C1–C11)

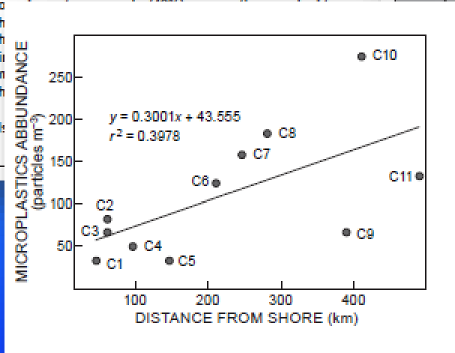
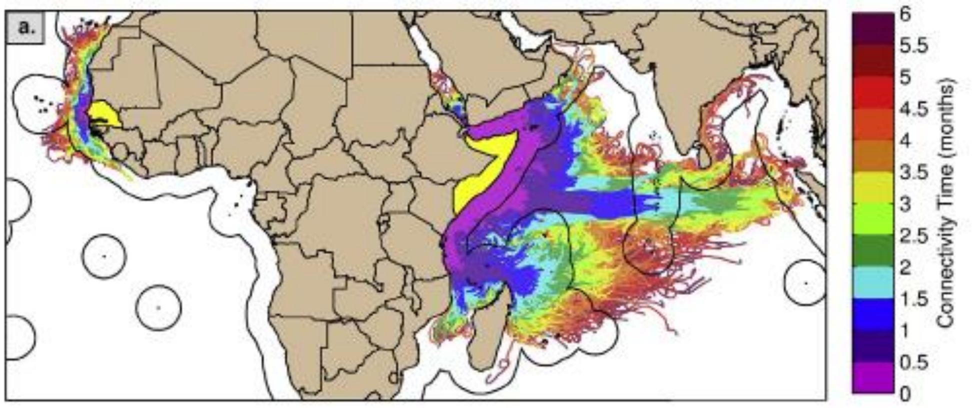


Figure 2: Linear regression showing the association between microplastics abundance and distance from shore



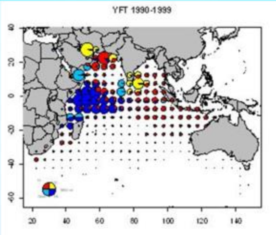
Source Popova et al 2019

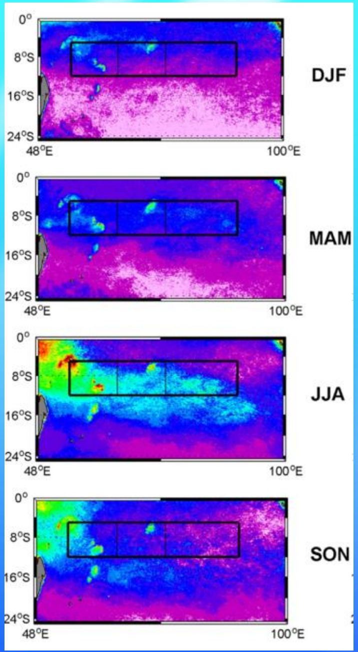
RECOMMENDATIONS

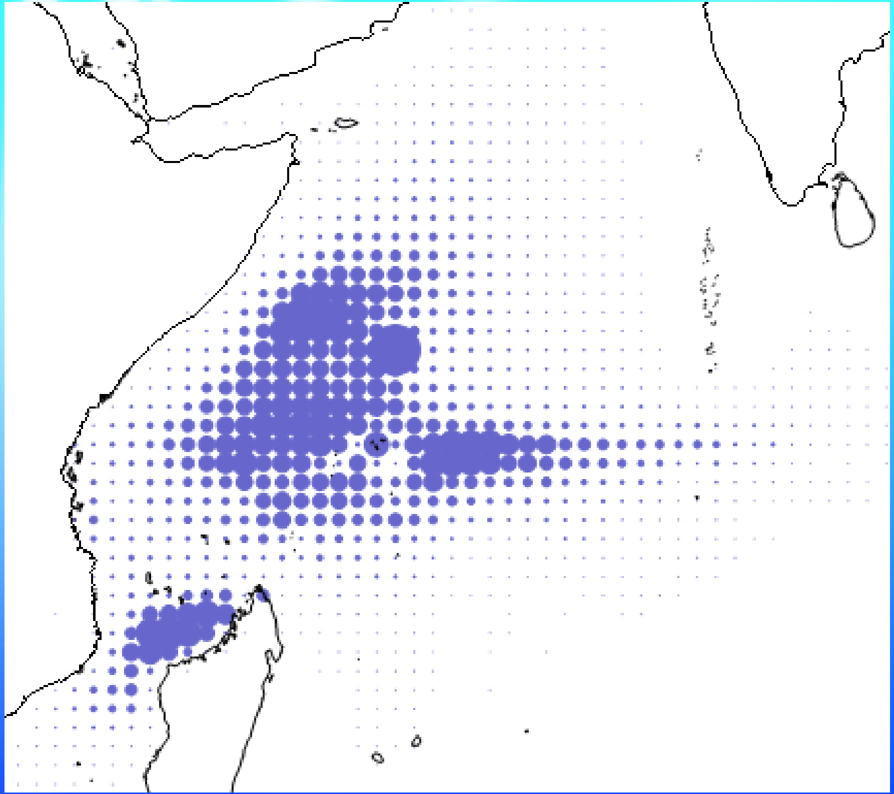
- Develop fisheries management plans which consider strong variability in the North Kenya Banks upwelling, its associated productivity and uncertainty of its response to climate change. Allow for adjustment of management measures as new information becomes available.
- Evaluate the overall exposure of the fishery to climate stressors and expected impacts, including uncertainty in response of the NKBs upwelling strength and location as climate change progresses.
- Ensure adaptive capacity of the emergent fleet to anticipate and respond to natural variability and to minimize, cope with, and recover from the consequences.
- Strengthen expertise in operational remote sensing. Investigate feasibility of remote sensing data guiding fishing fleets to locate fish schools more efficiently.
- Develop risk-based management approaches to cope with ‘good’ and ‘bad’ years for productivity and fisheries yield.
- Establish management mechanisms that protect stocks from overfishing during the ‘bad’ years, as well as the livelihoods of all actors involved.

Western Indian Ocean Tuna Cates

Tuna Catches







The North Kenya Bank ecosystem has a rich and diverse fishery but it is not well harnessed. Whereas information on fish productive zones can be availed there lacks perquisite capacity to effectively take advantage of the information. Requiring elaborate investment on fishing capacity and fish marketing structures.

Management challenges

- The absence of a comprehensive management plan for the small and medium pelagic fishery creates a key management obstacle in the endeavor to expand the fishery offshore.

Recommendations

- Inform IOTC on recent scientific advances in characterization of the North Kenya Banks upwelling and its potential importance for regional fisheries.

- Initiate and develop a monitoring plan for the North Kenya Banks upwelling system that includes oceanographic and socio-economic components.

- Initiate a regional scientific “upwelling-watch” working group via WIOMSA or the Nairobi Convention to facilitate sharing of information on responses of regional upwelling systems to extreme events. Ensure the North Kenya Banks upwelling is represented in such a group along with Somali, South Madagascar and Pemba Channel upwelling systems.

African Journal of Marine Science 2018, 40(3): 225–234
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AFRICAN JOURNAL
MARINE SCIENCE
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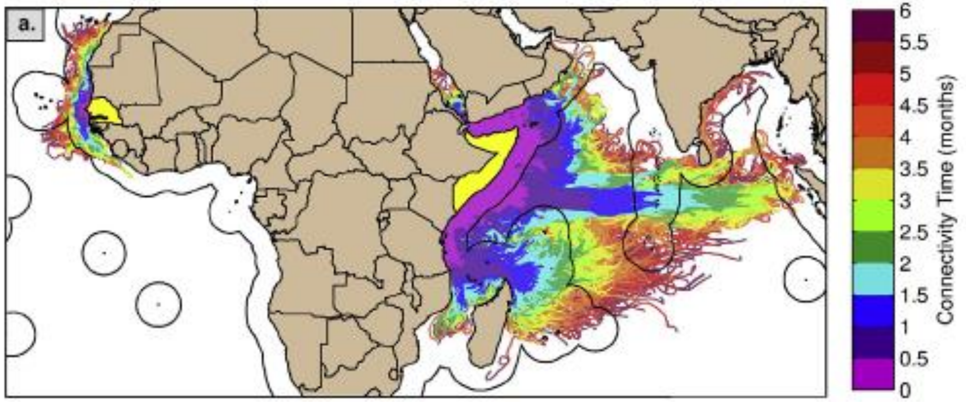

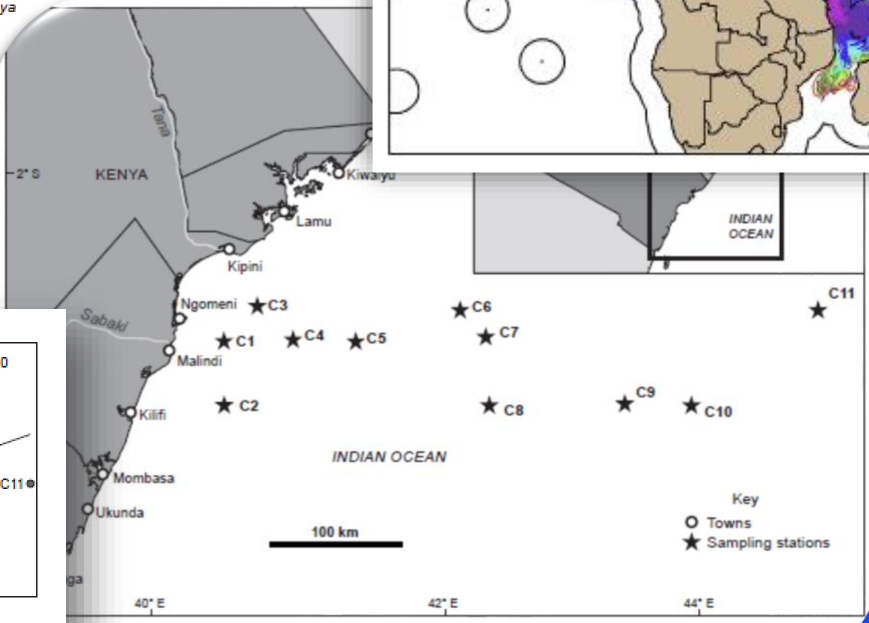

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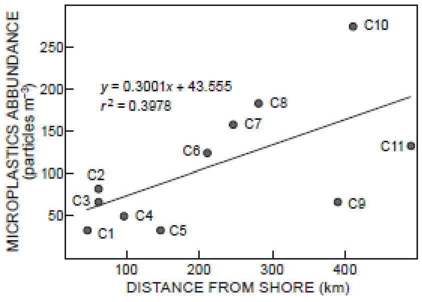
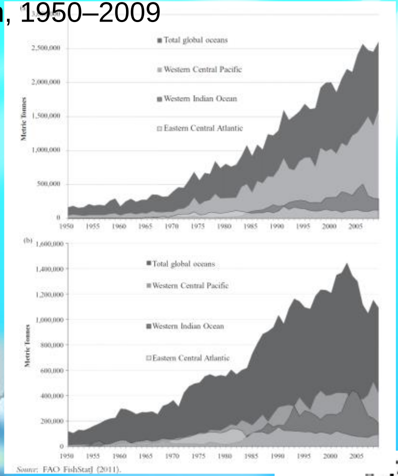
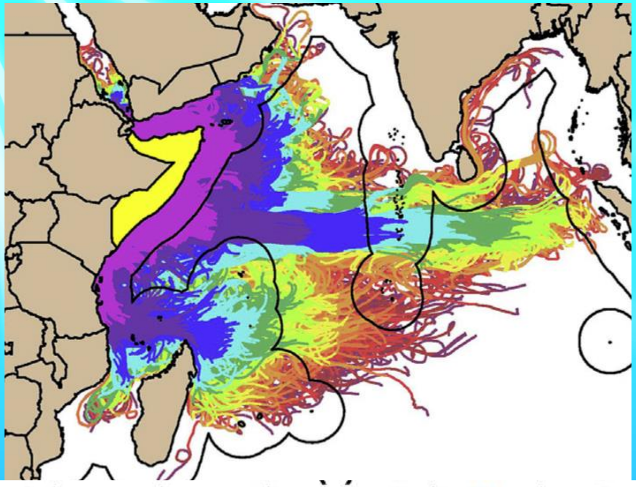
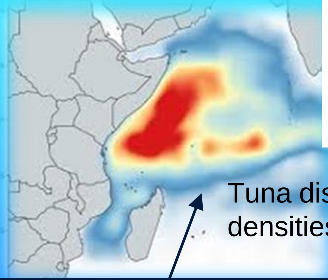


Figure 2: Linear regression showing the association between microplastics abundance and distance from shore

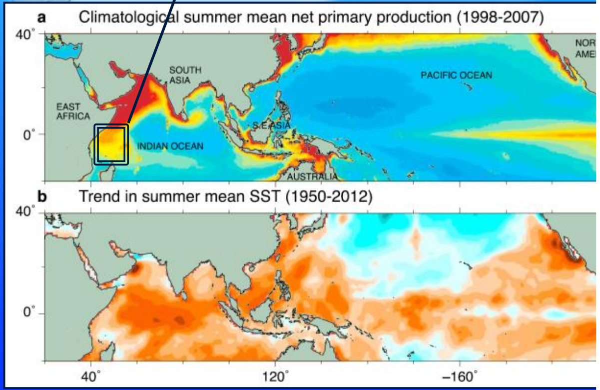
The global skipjack (a) and yellowfin (b) catch by all gear types and by major oceanic region, 1950–2009

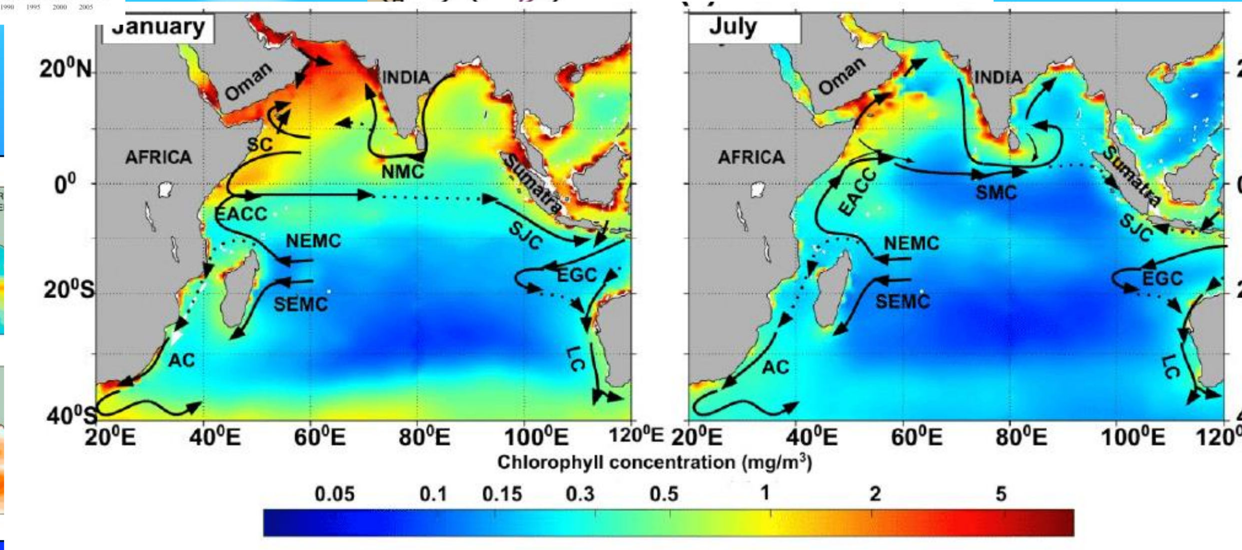






Tuna distribution densities

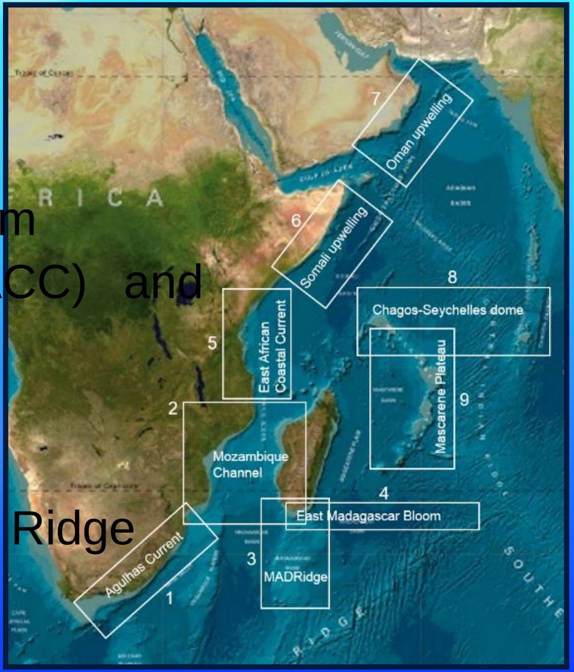




Upwelling systems supporting the Western Indian Ocean Tuna Fishe

The varying upwelling systems in the WIO can be grouped into 9 systems

1. Upwelling in the Mozambique Channel
2. Madagascar Ridge and seamounts upwelling
3. Southeast Madagascar shelf and (SICC) chlorophyll bloom
4. Upwelling in the East African Coastal Current (EACC) and influence of major islands (Mafia, Zanzibar, Pemba)
5. Upwelling Somalia Current system
6. Oman/Arabian Sea upwelling system
7. Chagos-Seychelles upwelling dome (SCTR) and Chagos Ridge
8. Mascarene Plateau induced upwelling

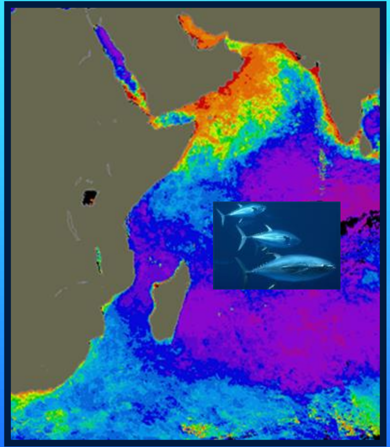


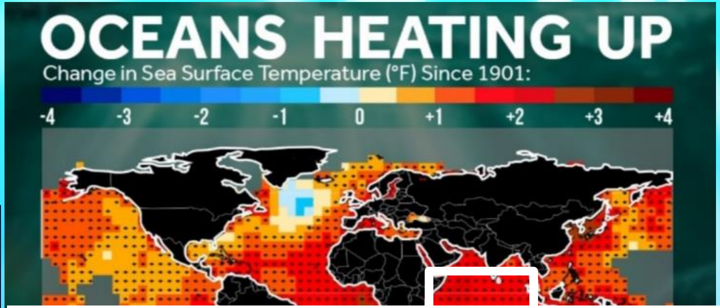
Source Mike Roberts

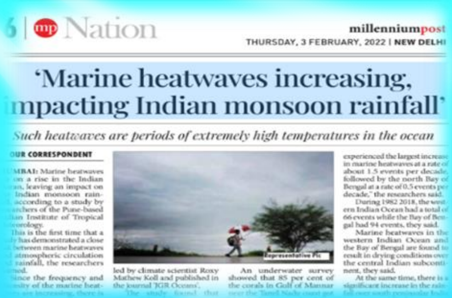
Current and projected scenario

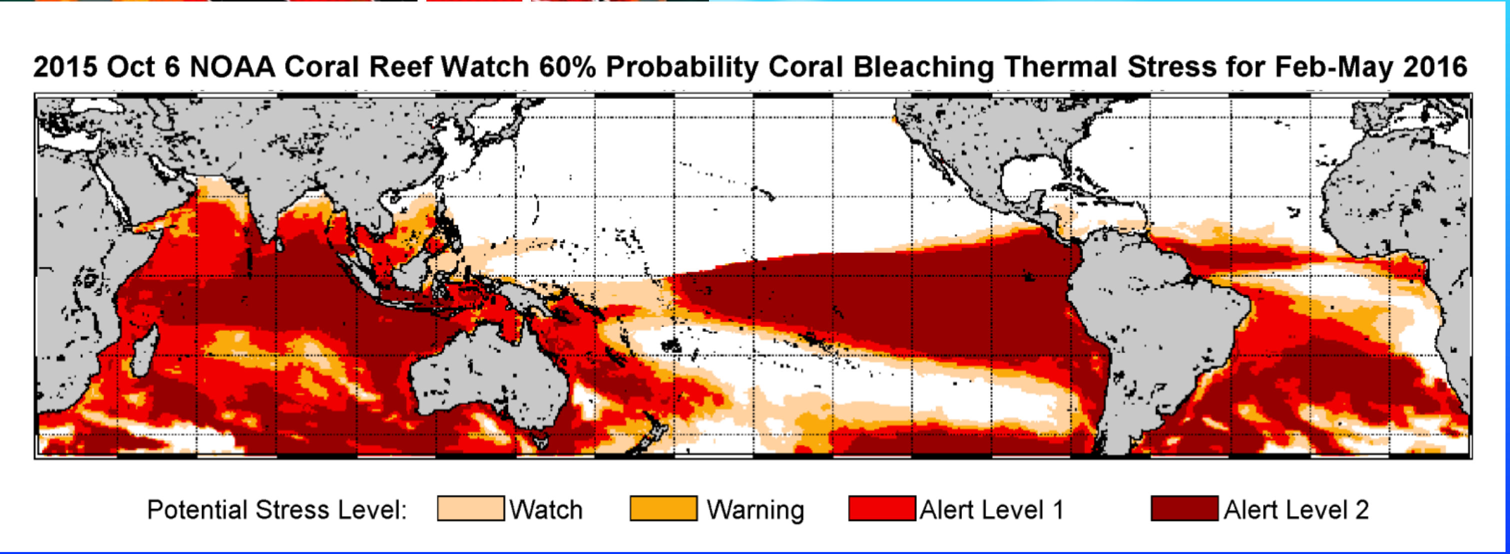
- Studies have shown that the whole Indian Ocean has been warming throughout the past half century.
- During 1901-2012, the western Indian Ocean experienced anomalous warming of 1.2°C
- However in comparison with the rest of the Indian Ocean, the western Indian Ocean generally has cooler mean SSTs in summer, owing to the strong monsoon winds and the resultant upwelling over the western Indian Ocean (Rao et al. 2012; Swapna et al. 2013).
- The western Indian Ocean is also one of the most biologically productive regions during the summer due to the intense upwelling (Ryther and Menzel 1965). Hence a significant change in the SSTs of this region can also alter marine food webs (Behrenfeld et 42 al. 2006).
- The migration of several coastal and oceanic pelagic fishes is also known to follow changes in ocean circulation pathways
- Large projected reductions in marine fish biomass for Kenya and Tanzania in the absence of climate mitigation
- Studies have implied local ocean-atmosphere coupled mechanisms for the continuous

Indian Ocean is Changing!



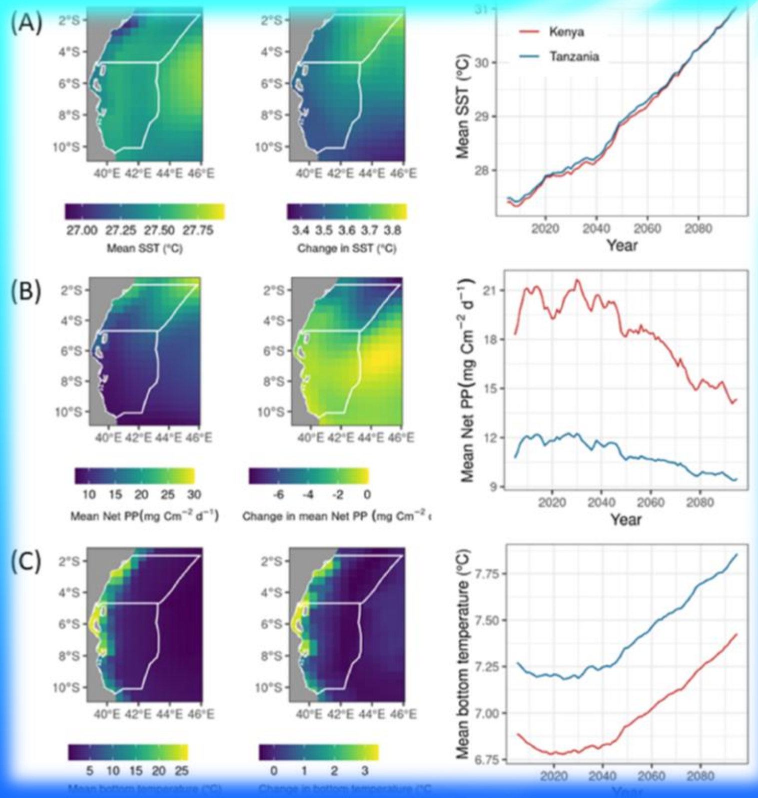






Ecosystem shift

- A multi-species fish model (Size Spectrum Dynamic Bio-climate Envelope Model; SS-DBEM) for 43 species of commercial and artisanal importance was run, to investigate the effects of climate change.
- Future changes in fish biomass have been projected for the EEZs of Kenya and Tanzania
- Forty-three fish species that are representative of exploited fish species were modelled, and the species choice aims to represent both commercial and sustenance types of species.
- Changes in key physical and biogeochemical properties such as temperature, salinity, pH, chlorophyll and velocities were taken from version 2.0 of the NEMO-MEDUSA model
- The model was forced at the surface using air temperature projections from the HadGEM2-ES Earth System Model (Collins et al., 2011).
- The outputs from NEMO-MEDUSA were used to drive a dynamic bioclimate envelope model (DBEM), which projects changes in fish species distribution and biomass while explicitly considering known mechanisms of population dynamics and dispersal (both larval and adult), as well as eco-physiological changes caused by changing ocean conditions (Cheung et al., 2011).



A) annual mean sea surface temperature (SST), B) water column integrated net primary productivity (Net NPP), and C) sea bottom temperature. Column 1 shows climatological mean values (2000–09),

Ocean and Coastal Management 215 (2021) 105921

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

ELSEVIER

Large projected reductions in marine fish biomass for Kenya and Tanzania in the absence of climate mitigation

Robert J. Wilson[a], Sévrine F. Sailley[a,*], Zoe L. Jacobs[h], Joseph Kamau[d], Said Mgeleka[f,g], Gladys M. Okemwa[d], Johnstone O. Omukoto[d,j], Kennedy E. Osuka[b,c], Melita Samoilys[b], Warwick Sauer[e], Mathew Ogalo Silas[f,g], Joseph S. Sululu[f], Michael J. Roberts[h,i]

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[c] Department of Environment and Geography, University of York, Heslington, York, YO10 5NG, UK
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[f] Tanzania Fisheries Research Institute (TAFIRI), P.O. Box 78850, Dar Es Salaam, Tanzania
[g] Department of Ecology, Environment and Plant Sciences, Stockholm University, Stockholm, Sweden
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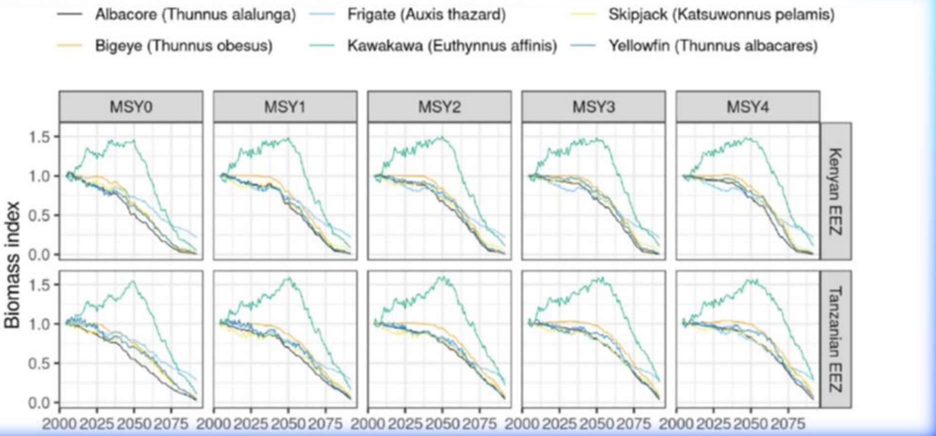


Century-long trends in biomass indices for six tuna species (subset of 41 species) in the Kenyan and Tanzanian EEZs for varying catch scenarios.

Confluence shift

We define the Confluence Zone (CZ) as the latitude where the northward flowing EACC meets the southward flowing SC.

Model analyses presents evidence that the position of the confluence zone is highly variable

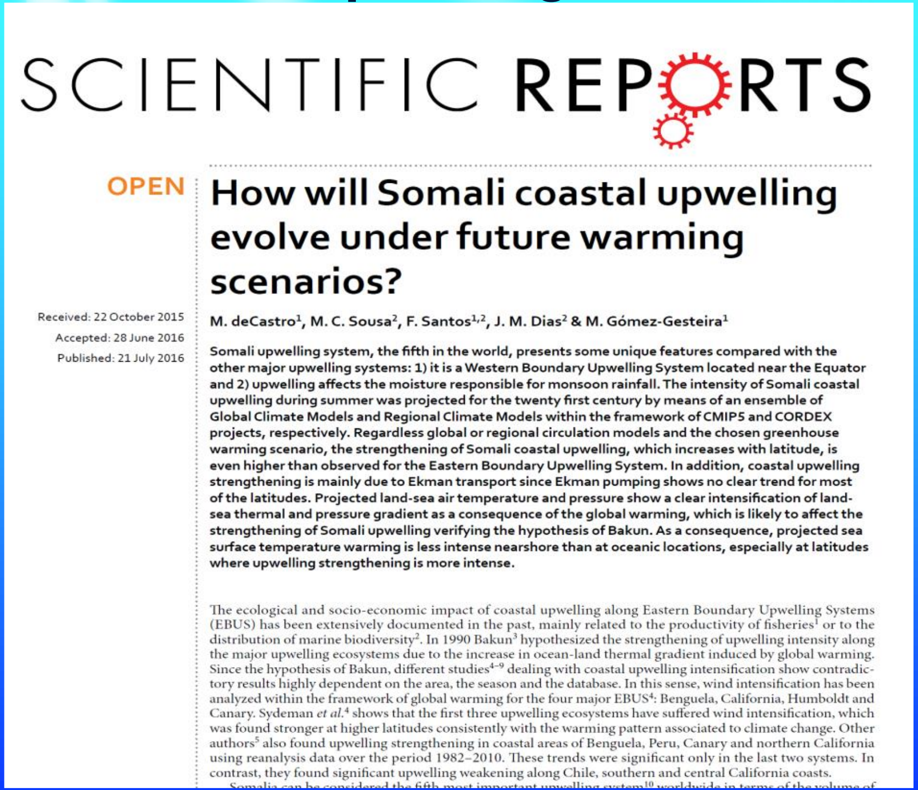
The departure of the SC and EACC from the coast induce upwelling at the shelf-edge, observed in both model and remotely sensed SST and chlorophyll.

The major monsoonal variability of the surface circulation is apparent during the NEM with reduced velocities visible in the Northeast Madagascar Current (NEMC) and EACC, specifically a reduction of more than 0.5 ms^{-1} in AVISO

The model circulation shows a fast (>1.25 ms^{-1}) SC meeting a weak EACC, likely pushing the confluence south wards away from the productivity region of the North Kenya Banks.

Enhance productivity in the Somali Upwelling

- Regardless of global or regional circulation models and the greenhouse warming scenario a significant upwelling increase ranging from 0.05 to 0.07m2 s−1dec−1 was projected for the whole Somali upwelling ecosystem along the twenty first century.
- Projected land-sea air temperature and air pressure differences along the twenty first century show a clear intensification as a consequence of the global warming. This intensification has a strong influence on coastal upwelling strengthening
- The most direct implication of a coastal upwelling strengthening is a projected nearshore SST warming less intense than at the adjacent ocean



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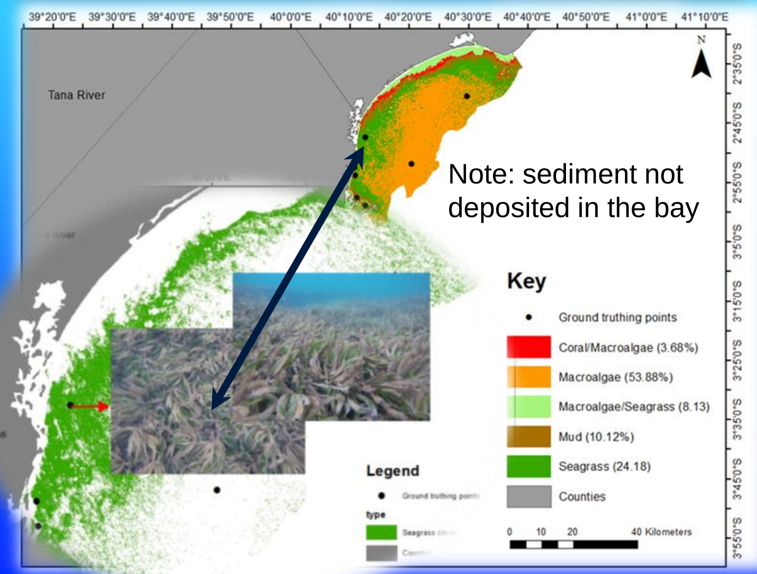
How will Somali coastal upwelling evolve under future warming scenarios?

Received: 22 October 2015
Accepted: 28 June 2016
Published: 21 July 2016

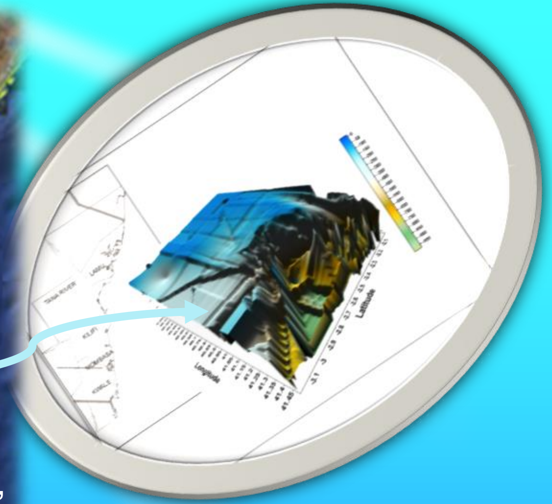
M. deCastro[1], M. C. Sousa[2], F. Santos[1,2], J. M. Dias[2] & M. Gómez-Gesteira[1]

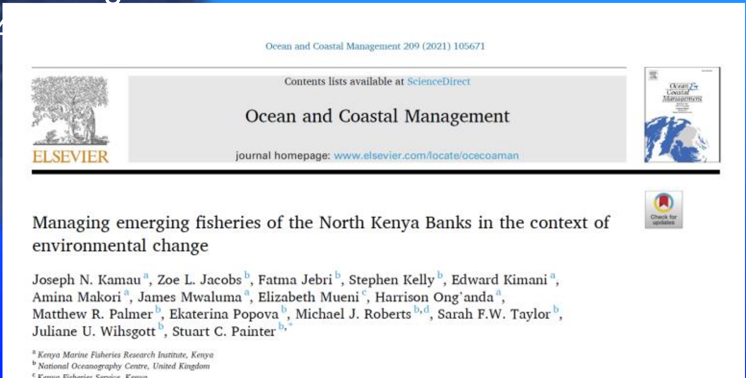
Somali upwelling system, the fifth in the world, presents some unique features compared with the other major upwelling systems: 1) it is a Western Boundary Upwelling System located near the Equator and 2) upwelling affects the moisture responsible for monsoon rainfall. The intensity of Somali coastal upwelling during summer was projected for the twenty first century by means of an ensemble of Global Climate Models and Regional Climate Models within the framework of CMIP5 and CORDEX projects, respectively. Regardless global or regional circulation models and the chosen greenhouse warming scenario, the strengthening of Somali coastal upwelling, which increases with latitude, is even higher than observed for the Eastern Boundary Upwelling System. In addition, coastal upwelling strengthening is mainly due to Ekman transport since Ekman pumping shows no clear trend for most of the latitudes. Projected land-sea air temperature and pressure show a clear intensification of land-sea thermal and pressure gradient as a consequence of the global warming, which is likely to affect the strengthening of Somali upwelling verifying the hypothesis of Bakun. As a consequence, projected sea surface temperature warming is less intense nearshore than at oceanic locations, especially at latitudes where upwelling strengthening is more intense.

The ecological and socio-economic impact of coastal upwelling along Eastern Boundary Upwelling Systems (EBUS) has been extensively documented in the past, mainly related to the productivity of fisheries[1] or to the distribution of marine biodiversity[2]. In 1990 Bakun[3] hypothesized the strengthening of upwelling intensity along the major upwelling ecosystems due to the increase in ocean-land thermal gradient induced by global warming. Since the hypothesis of Bakun, different studies[4–9] dealing with coastal upwelling intensification show contradictory results highly dependent on the area, the season and the database. In this sense, wind intensification has been analyzed within the framework of global warming for the four major EBUS[4]: Benguela, California, Humboldt and Canary. Sydeman *et al.*[4] shows that the first three upwelling ecosystems have suffered wind intensification, which was found stronger at higher latitudes consistently with the warming pattern associated to climate change. Other authors[5] also found upwelling strengthening in coastal areas of Benguela, Peru, Canary and northern California using reanalysis data over the period 1982–2010. These trends were significant only in the last two systems. In contrast, they found significant upwelling weakening along Chile, southern and central California coasts.



- The Tana, Kenya’s largest river, extends 950km inland with a catchment of 95,000km2 and
- Discharges freshwater and sediment annually into Ungwana Bay in the order of 4





Ocean and Coastal Management 209 (2021) 105671

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Managing emerging fisheries of the North Kenya Banks in the context of environmental change

Joseph N. Kamau[a], Zoe L. Jacobs[b], Fatma Jebri[b], Stephen Kelly[b], Edward Kimani[a], Amina Makori[a], James Mwaluma[a], Elizabeth Mueni[c], Harrison Ong'anda[a], Matthew R. Palmer[b], Ekaterina Popova[b], Michael J. Roberts[b,d], Sarah F.W. Taylor[b], Juliane U. Wihsgott[b], Stuart C. Painter[b,*]

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Associated publications on the North Kenya Banks Fishery under climate change

1. Gladys M. Okemwa, Almubarak A. Abubakar, Fatuma Mzingirwa, Edward N. Kimani, Joseph N. Kamau, James M. Njiru,Warwick Sauer **(2023)** Characterizing gear-based exploitation patterns of artisanal tuna fisheries in the western Indian Ocean: A snapshot from Kenya. Regional Studies in Marine Science 61 (2023) 102877.
2. Charles Mitto Kosore, Loice Ojwang, Justin Maghanga, Joseph **Kamau**, Daniel Shilla, Gert Everaert, Farhan R. Khan, Yvonne Shashoua **(2022)** Microplastics in Kenya's marine nearshore surface waters: Current status. Marine Pollution Bulletin 179 (2022) 113710
3. **Joseph N. Kamau**, Amina Makori, Edward Kimani, Ekaterina Popova, Elizabeth Mweni, Fatma Jebri, Harrison Onganda, James Mwaluma, Juliane Wihsgott, Matthew Palmer, Michael J. Roberts, Sarah F.W. Taylor, Stephen Kelly, Stuart C. Painter, Zoe L. Jacobs (**2021**) Managing the emerging fisheries of the North Kenya Banks in the context of environmental change -Ocean and Coastal Management https://doi.org/10.1016/j.ocecoaman.2021.105671
4. Damaris Mutia, Stephen Carpenter, Zoe Jacobs, Fatma Jebri, **Joseph Kamau** et al., **(2021)** Productivity driven by Tana river discharge is spatially limited in Kenyan coastal waters. Ocean and Coastal Management 211 (2021) 105713
5. James Mwaluma, Noah Ngisiang'e, Melckizedeck Osore, **Joseph Kamau** Stuart C. Painter, Michael J. Roberts (**2021**). Assemblage structure and distribution of larval fish on the North Kenyan banks during South East Monsoon Season. Ocean and Coastal Management 212 (2021) 10580
6. Matthew R. Palmer, Yohana W. Shagude, Michael J. Roberts, Ekaterina Popova, Juliane U. Wihsgott, Shankar Aswani, Jack Coupland, John A. Howe, Brian J. Bett, Kennedy E. Osuka, Colin Abernethy, Sofia Alexiou, Stuart C. Painter, Joseph N. Kamau. **(2021)** Marine robots for coastal ocean research in the Western Indian Ocean. Ocean and Coastal Management 212 (2021) 105805. https://doi.org/10.1016/j.ocecoaman.2021.105805

7. Robert J. Wilson, S´evrine F. Sailley, Zoe L. Jacobs, Joseph Kamau, Said Mgeleka, Gladys M. Okemwa, Johnstone O. Omukoto, Kennedy E. Osuka, Melita Samoilys, Warwick Sauer, Mathew Ogalo Silasf, Joseph S. Sululu, Michael J. Roberts. Large projected reductions in marine fish biomass for Kenya and Tanzania in the absence of climate mitigation. Ocean and Coastal Management 215 **(2021**) 105921. https://doi.org/10.1016/j.ocecoaman.2021.105921

8. Joseph Kamau, Noah Ngisiange, Oliver Ochola, James Kilionzi, Amon Kimeli, Shigalla B. Mahongo, Harrison Onganda, Charles Mitto, Boaz Ohowa, Charles Magori , Edward Kimani, Melckzedeck Osore. **(2020)** Factors influencing spatial patterns in primary productivity in Kenyan territorial waters. WIO Journal of Marine Science Special Issue 1/ 2020 9-18

9. Joseph Kamau, Oliver Ochola, Boaz Ohowa, Charles Mitto, Charles Magori, Chepkemboi Labatt, Melckzedeck Osore, Shigalla B. Mahongo, Margaret S. Kyewalyanga. **(2020)** Employing multivariate analysis to determine the drivers of productivity on the North Kenya Bank and in Kenyan territorial waters. WIO Journal of Marine Science Special Issue 1/ 2020 33-41

10. Jacob Ochiewo, Fridah Munyi, Edward Waiyaki, Faith Kimanga, Nicholas Karani, Joseph Kamau, Shigalla B. Mahongo. **(2020).** Livelihood impacts and adaptation in fishing practices as a response to recent climatic changes in the upwelling region of the East African Coastal Current. WIO Journal of Marine Science Special Issue 1/ 2020 105-125.

11. Z. L. Jacobs, F. Jebri, D. E. Raitsos, E. Popova, M. Srokosz, S. C. Painter, F. Nencioli, M. Roberts, J. Kamau, M. Palmer, and J. Wihsgott **(2020)** Shelf-Break Upwelling and Productivity Over the North Kenya Banks: The Importance of Large-Scale Ocean Dynamics. Journal of Geophysical Research: Oceans, 125, e2019JC015519.

Next proposed research interventions

- Endorsement of Decade Action entitled “No.11.4. The Western Indian Ocean (WIO), Productivity under climate change” as a project forming part of the UN Decade of Ocean Science for Sustainable Development 2021-2030.

- Project attached to “No. 63. Fisheries Strategies for Changing Oceans and Resilient Ecosystems by 2030 (FishScore)”

- KMFRI sponsoring research to determine the fate and pathway of Tana river sediments as well as determine their nutrient pool.

- Currently developing a proposal with Plymouth University, UK to provide easy access climate prediction tools that combine global modelling and monitoring data and Artificial Intelligence to improve the accessibility of predictive models to support marine and fisheries managers and policy-makers.

Acknowledgement

HARAMBEE

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