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# Observed and Projected Climate Change Effects on Tuna Fisheries in the Western Indian Ocean

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- Observed Changes (IOD)
- Response to IOD changes
- Projected Changes
- Vulnerability of SIDS economy



#### Importance of tuna fisheries in WIO, especially for SIDS

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#### **Economic importance of fisheries** in the Western Indian Ocean (WIO)

- **9%** of the gross marine product in WIO.
- 87 % is from large-scale commercial and industrial or semi-industrial fisheries
- **Tuna** is the most important source of national revenue.
- WIO contributes ~18% of the 5 million tons of annual global tuna catch (Obura et al. 2017).
- For the **SIDS**, **fisheries rank high** in historical and cultural importance, and to national economies.
- e.g. **30% of gross domestic** product in the Seychelles comes from industrial fisheries
- Exports: ~95% of the domestic exports value in Seychelles and ~19% in Mauritius









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#### The Indian Ocean Dipole (IOD) phases





The IOD informs on the east-west temperature gradient across the tropical Indian Ocean. It is associated to wind and rainfall anomalies (Saji et al., Nature, 1999)

# **Dipole Mode Index : time series 1950-2020**

- 1950-1999 : a rather periodic occurrence of Dipole events, with a dominant 5-year periodicity, and 40% of periodogram below 2-year signals
- Since 2000 : shorter periodicity (dominant 4-year cycle) and a more « noisy » DMI signal with 55% of periodogram below 2-year signal



# **DMI – SOI** interactions

- Colinearity between SOI and DMI : Positive dipoles with El Niño events, and negative dipoles with La Niña events (with some lag)
- However, the 1961/62 occurred with no El Niño, and 1994/95 strong positive DMI coincided with a weak El Niño
- DMI depicts processes that are internal to the IO (Saji et al., Nature, 1999)





### **Trend over the 20th century**

DMI is gradually trending towards positive dipoles since the 1960s ...

...whereas no trend is detected with the SOI











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# The WIO has remained the core of the purse seine fishery since its beginning, with highest catches recorded west of 55°E



#### Catches (tons)



Heat maps of purse seine catches by decade (data source IOTC)

# **Ocean Response to Positive Dipoles**

- Higher SST in the West Indian Ocean, including a less intense Somali upwelling

Marsac & Demarcq, 2019

Oct 2019 Source: IOSSTv -10 --20 -1 ₄°C Dec 2019 20 10 -Source. IOSST -10 -

20

60

100 m

-20 👝

-100

-60

 Deeper thermocline in the south equatorial zone of the West Indian Ocean



### **Ocean Response to Positive Dipoles**

- Reduction of the primary productivity in the West Indian Ocean ...
- ... and productivity enhancement in the East Indian Ocean





The Chlorophyll-a concentration has fluctuated greatly in the WIO, with alternating phases

## **Ocean Response to Positive Dipoles**

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- ... and productivity enhancement in the East Indian Ocean







Tuna catch distribution in January 1998

# Fluctuations in the recruitment of tunas in the fishery can be driven by the variability in chlorophyll concentration



- The link is mediated by the tuna prey component (small pelagic fish, crustaceans, cephalopods) which is driven by the production at the base of the food web
- The 2001-2005 golden years

Skipjack recruitment (RecDev) is estimated by the Stock Synthesis 3 model (Fu, 2020, IOTC/WPTT)

Chlorophyl-a is derived from SeaWifs and Modis color data





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Projected Climate Change in stressor intensity in 2090–2099 relative to 1990–1999 (Bopp et al., 2013)

The case of the RCP8.5 (highest CO<sub>2</sub> scenario).

Sea surface temperature (°C)



A warmer North Western IO

Subsurface dissolved oxygen change (average 200–600 m, mmol m<sup>-3</sup>)



Vertically integrated Net Primary Production change (gC m<sup>-2</sup> yr<sup>-1</sup>).



A more well-oxygenated water column in the Western IO

A dramatic depletion in NPP in the North Western IO

# Expansion of unsuitable thermal habitats for tropical tunas from years 2040 to 2099, through a range of RCP scenarios



Temperature threshold : 31°C

(Dueri et al, GCB, 2014)

#### Projections for skipjack tuna over the 21<sup>st</sup> century (Dueri et al., 2014)

2050

2010

-2010 -2050

-20

2095

----2095

20

Simulations conducted with APECOSM ecosystem model (Maury, 2010)



First half of 21st century

Second half of 21st century



Mean biomass anomaly at the surface (0-10m) million tons

Projected changes by ocean, and by latitude

Latitude

- Overall increase of SKJ abundance until the middle of the 21<sup>st</sup> century
- Increase due to poleward shifts
- Sharp decline of biomass in the second half of the 21<sup>st</sup> century

Synoptic sketch of possible relocation of the purse seine fleets operating for tropical tuna in the WIO by 2100, under the highest  $CO_2$  scenario (RCP8.5)



- Seychelles may see its strategic position for PS fleets challenged by other countries
- The longline gear would not be affected as much as purse seine
- Favorable conditions for longline could be maintained around Seychelles
- Opportunity for Seychellesbased longliners

Marsac, 2017





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#### **Economic impacts of the 1998 Positive Dipole in Seychelles**



(Robinson et al, Climate Res, 2010)

Model of spillover incurred by tuna fleet expenditure

Effects of the Tuna Industry Expenditures Benefiting the Seychelles economy



#### **Economic impacts of the 1998 Positive Dipole in Seychelles**





The 40% cut in landings and transshipments during 2 quarters resulted in a 34% loss for the local economy

Another major spatial shift of the tuna fishing fleets similar to the one that was observed during the 1997/98 El Nino/Positive Dipole, would have a devastating impact on SIDS which have developed economies that are strongly dependent on tuna fisheries.

## Take home messages

- **Observable impacts** on fisheries throughout the WIO.
- Warmer habitats with declining productivity and major shift in distribution of Tuna species will induce strong socio-economic impacts in the WIO.
- Management measures should be adjusted periodically to account for the spatial patterns of tuna species.
- Monitoring programmes + modeling feasible with existing capacities, complemented by Earth Observations have the potential to support adaptive and more holistic management of Tuna Fisheries
- Partnerships at all levels (local, regional and international) is a key to achieving capacity development for effective management, and building adaptive capacity and resilience to Climate Change in the WIO region.