Demersal Ecosystem DEMERSTEM - WP4

The ecosystem approach to fisheries: the indicators produced by DEMERSTEM.

An Indicator and ecosystem approach for West-Africa

Didier JOUFFRE and Modou THIAW

With contribution of

Ibrahima DIALLO, Brahim TFEIL and Mamour NDIAYE,

Summary

1. Introduction (Context)
2. The DEMERSTEM Indicators and Ecosystem Approach for fisheries (+ objectives)
3. Methodology
4. Results: Presentation of case studies on Mauritania, Senegal, Guinea
5. Conclusion

1 Introduction

1. Context of Ecosystem Approach to fisheries

Benefits of marine ecosystems in West Africa

Utilisation durable des ressources naturelles

Santé des écosystèmes

Bénéfices esthétiques

Revenus

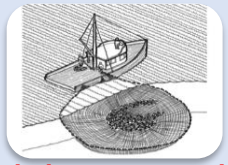
1. Context of Ecosystem Approach to fisheries

Stressors of marine ecosystems in North-West Africa

Disturbances and illegal exploitation

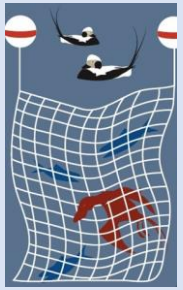
Offshore Oil & Gas Pollution

Insufficient knowledge



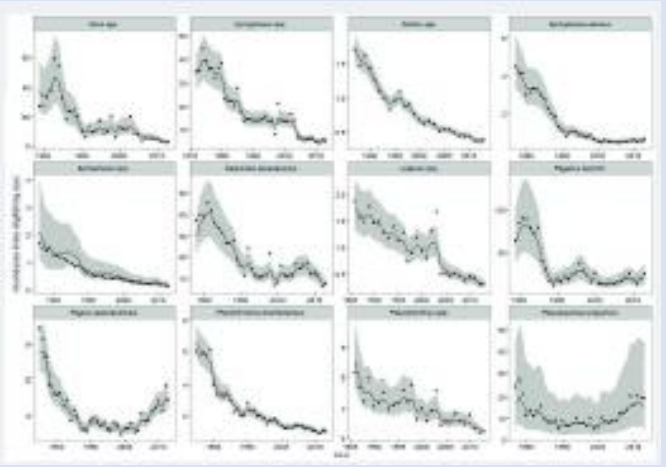
Fishery stocks overexploited

Infrastructure development



By catch

Many fishery stocks overexploited



Bâ, Thiaw, Fall et al. (2018)

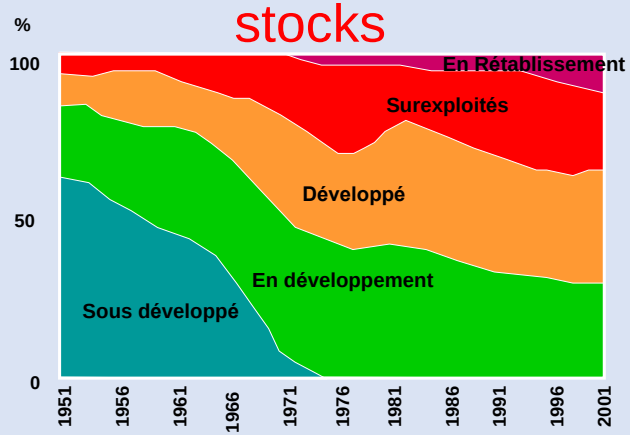
1. Context of Ecosystem Approach to fisheries

Effects: Marine ecosystems, in all their states!!!


Hoplostethus atlanticus
source : oceanwold.ord

"The emperor"
tm50%=> 20-30 years!

Overexploitation of fishery stocks



Household pollution

2. The DEMERSTEM Indicators and Ecosystem Approach for fisheries

2. The DEMERSTEM Indicators and Ecosystem Approach for fisheries

OBJECTIVES

- Monitoring the evolution and Evaluating the “health” status of west African marine exploited ecosystem.
- Quantifying the impact of fishing and to provide decision support for fisheries management in a context of climate change,
- Providing a documented methodology and scripts to compute standardized simple EAF indicators to be used in routine during Fisheries assessment working group in the West Africa region

2. The DEMERSTEM Indicators and Ecosystem Approach for fisheries

The approach:

« Indicator » is considered in a global sense

(this can be a simple index or more complex data analysis)

⇒ Indicator s.l. = numerical index or data treatement/analysis

⇒ that leads to an ecosystemic diagnosis

⇒ or simply allow to document » (inform on) the states and trends of the targeted ecosystem

⇒ (or a significant part of it)

2. The DEMERSTEM Indicators Approach

4 steps:

- Step 1: Identification, Methodological Definition and Calculation (estimates) of indicators
- Step 2: Display and interpretation of indicators
- Step 3: Search for causalities explaining the observed evolutions (observed changes and trends)
- Step 4: Summaries and global interpretations

2. The DEMERSTEM Indicators Approach

A panel of different types of indicators

- State (S) / **Trend** (T)

- From different « nature » and data sources :
- => **Scientific surveys, fisheries data**,
- Environment (Phys, Biol), socio-economy and human dimension

- Calculated at different scales

(ex: for indicators of the surveyed community):

- Local scale (station, hauls) = L
- **Global scale (Campaign, Year) = G**

2. The DEMERSTEM Indicators Approach

A panel of different types of indicators

- **Computed on a standardized way (and documented)**

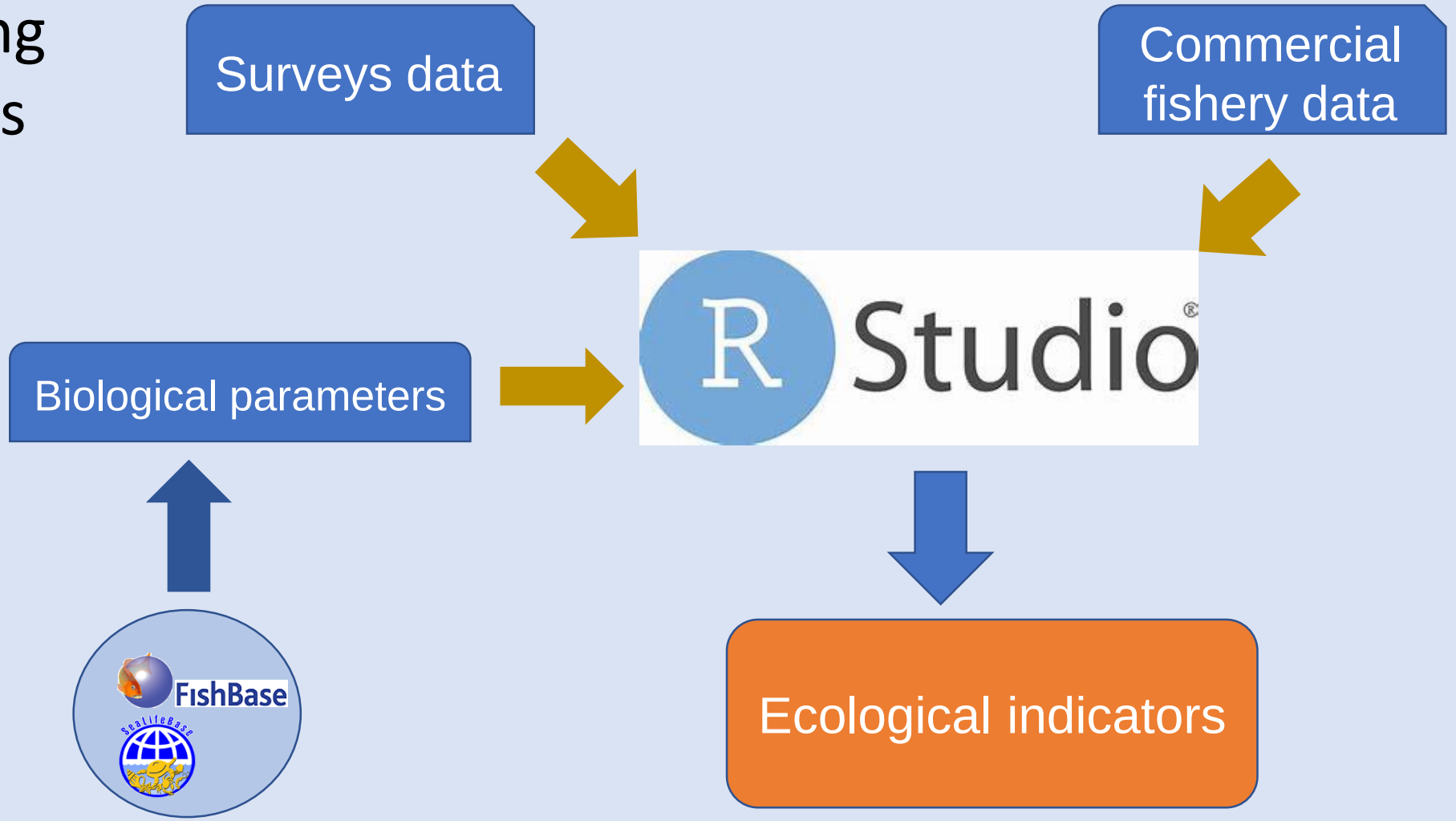
=> To allow comparisons between countries and/or periods

- **Computed using R scripts**
- => With process taking into account **the data/database « as they are »** (i.e. mistakes or imperfection in the data source)
  - Including procedures of data correction (ex correction of the scientific names in the scientific trawling databases)
  - Including procedures to evaluate the quality of the final estimates (index of representativity, sensitivity analysis)

- **Some indicators mixing different data sources**
- Sometimes involving additionnal knowledge/paramaters (ex Fishbase)

4. The DEMERSTEM Indicators Approach

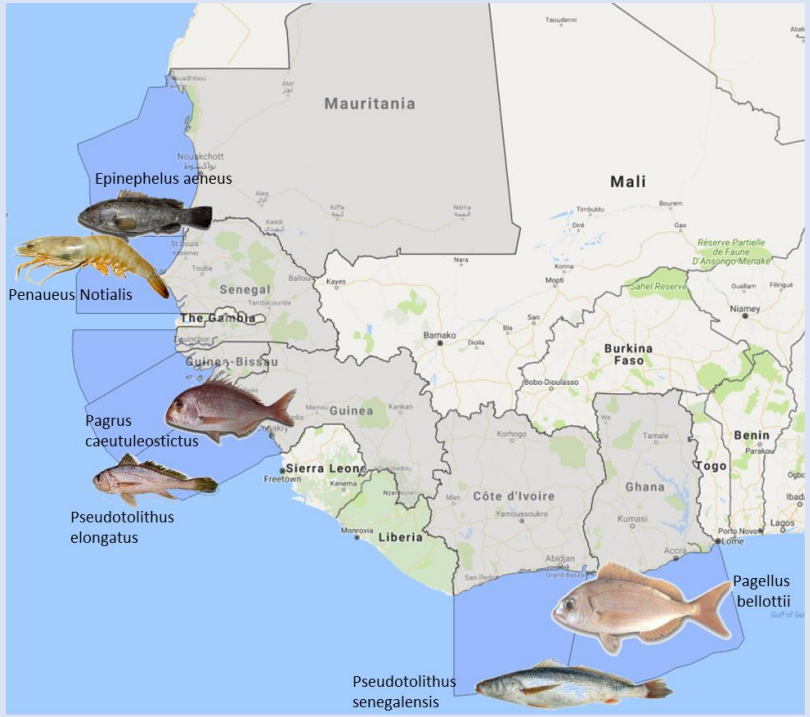
Estimating indicators

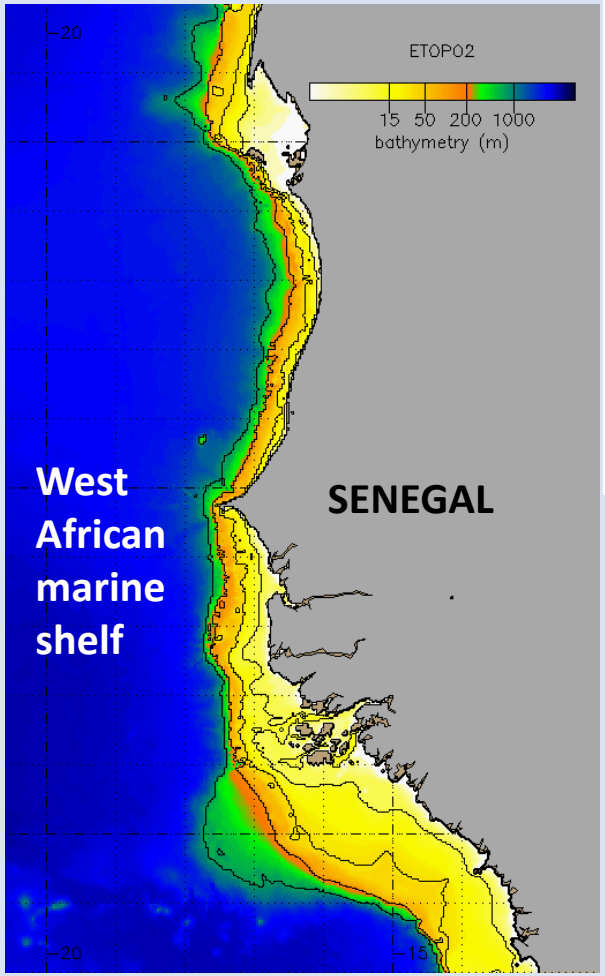


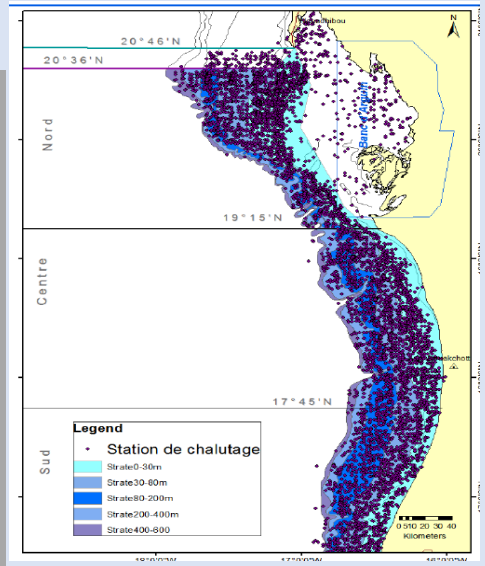
3 Methodology

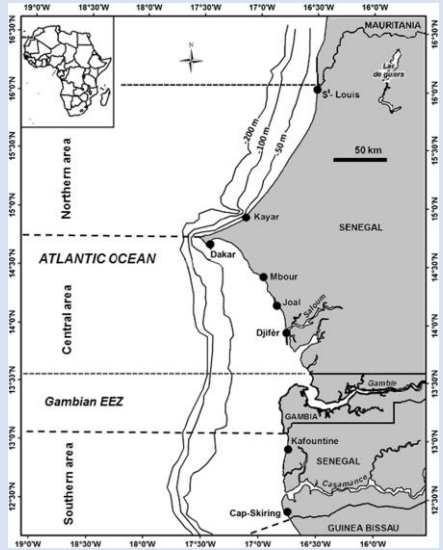
3. Methodology – The study area

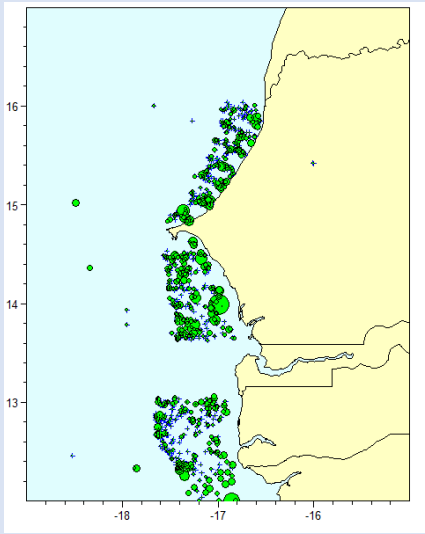
Studies areas

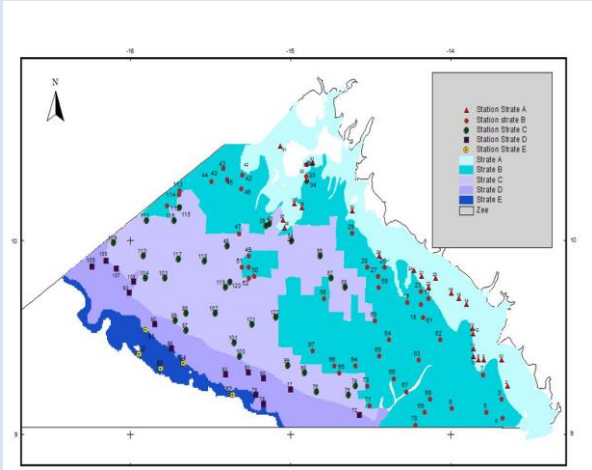












3. Methodology – The Data

Surveys data

In West Africa, there are long-term scientific research surveys and statistic data.

- Mauritanian EEZ - Data Sources surveyed catches : IMROP database
- Surveys data over the 1997-2015 period

- Senegalese EEZ - Data Sources Landings and surveyed catches : CRODT database Surveys data over the 1981 -2016 period

- Guinea EEZ - Data Sources surveyed catches : CNSHB database
- Surveys data over the 1985 -2021 period

N/O Al-Awam, depuis 1997

- Length : 37.03 m
- Width : 7.8 m
- Draft : 3.3 m
- Power : 1000 hp
- Gross reg. tonnage (GRT) : 301 Tx
- Speed : 10 knots
- 8 scientific posts

N/O Itaf DEME, depuis 2000

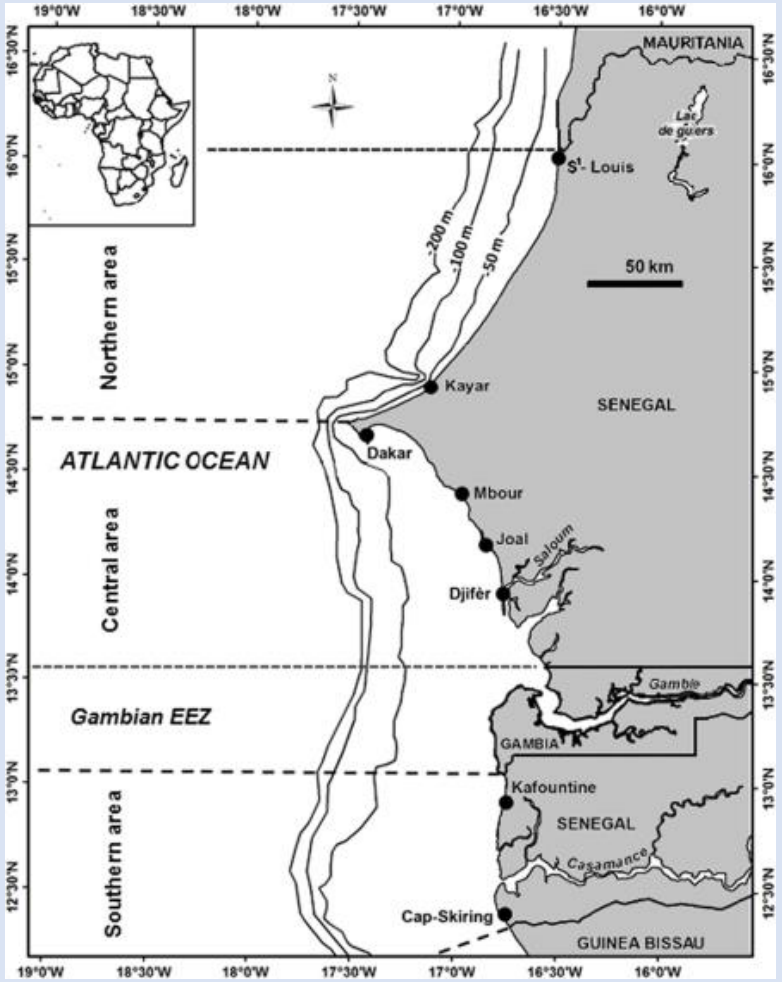
- Length : 37.4 m
- Width : 8.1 m
- Draft : 3 m
- Gross Reg. Tonnage (GRT) : 318 Tx
- Speed : 11 knots
- Engine horsepower: 1100 hp
- 8 scientific posts

N/O Général Lansana CONTE, depuis 2003

- Length : 29.93 m
- Width : 7.30 m
- Draft : 3.25 m
- Power : 750 hp
- Gross Reg. Tonnage (GRT) : 198 Tx
- Speed : 10 knots
- 8 scientific posts

3. Methodology– The Data

Fishery statistic data



Fishing statistics data used are the total annual catches by species of the artisanal and industrial fisheries provided by the CRODT and the DPM over the period 1980-2020.

Small-scale fisheries

Industrial fishery

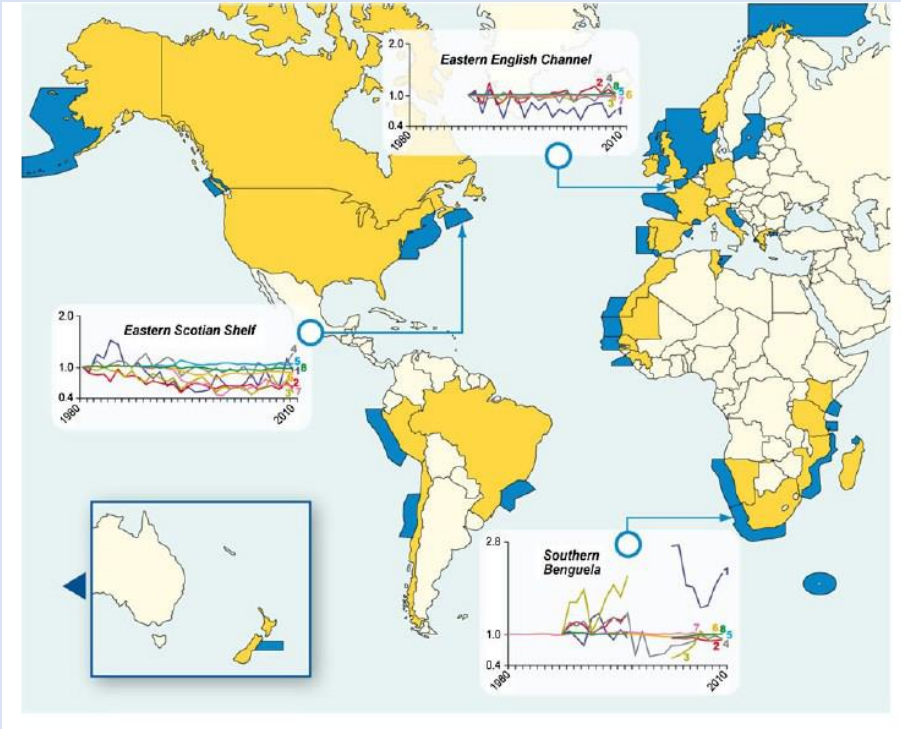
3. Methodology – the indicators

Focus on some demersal macrofauna, fisheries and ecosystem indicators

About 15 ecological indicators – derived from indiseas (http://www.indiseas.org/ and additional ones – are estimated In our DEMERSAL cases studies

From cruise data and fishing statistics mainly

their trends are analyzed along four decades.



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3. Methodology – the indicators

Focus on some demersal macrofauna indicators

Total biomass of surveyed species B

Indicator	Data needed	Calculation	State S Trend T	Comments to guide calculation of indicators
Total biomass of surveyed species	Time series of total biomass of surveyed species[1] (tons or biomass index)		*T*	*Data:* all surveyed species[1]. Specific surveys conducted for sampling eggs, larval and juvenile stages should not be considered. This B index is used only for trends so absolute biomass estimates are not needed. *Question: Do different surveys have to be combined (demersal trawl, pelagic acoustic ...)?* In some cases, considering only the demersal trawl surveys provides an adequate estimate of biomass of demersal/pelagic fish and commercially important invertebrates. However, in some systems (such as upwelling ones), small pelagic fish are not adequately sampled in the demersal trawl surveys and thus dedicated small pelagic surveys are carried out. In those cases, local experts are to decide on appropriate methods of combining different surveys to provide a single total biomass index for the ecosystem.

3. Methodology – the indicators

Focus on some demersal macrofauna indicators

Mean trophic level of the surveyed community TLco

Indicator	Data needed	Calculation	State S Trend T	Comments to guide calculation of indicators
TL of surveyed community	TL value per species Time series of surveyed species biomass (tons or biomass index)	$TL_{co} = \frac{\sum_s TL_s \; B_s}{B}$	S, T	Cf TL landings for TL_s values All surveyed species[1] must be included (exploited and non-exploited)

3. Methodology – the indicators

Focus on some demersal macrofauna indicators

Proportion of predatory fish (sp TL>3,25)

Indicator	Data needed	Calculation	State S Trend T	Comments to guide calculation of indicators
proportion of predatory fish	Time series of total biomass of surveyed species[1] (tons or biomass index) Time series of biomass of surveyed predatory[3] species (tons or biomass index)	B predatory fish surveyed/B surveyed ∈ [0,1]	*S, T*	*<u>Question</u>: Are invertebrate species to be included in the predators pool?* No, see definition of "predatory fish species"[3]. As such, this indicator can reflect a potential decrease in demersal stocks, and a parallel increase in forage or invertebrate species. B surveyed= B(demersal fish+pelagic fish+commercially imp. invertebrates)

3. Methodology

Focus on some demersal macrofauna indicators

Mean maximum life span of surveyed fish species

Indicator	Data needed	Calculation	State S Trend T	Comments to guide calculation of indicators
Mean life span	Mean maximum longevity observed per species (year) Time series of surveyed species biomass (tons or biomass index)	$\frac{\sum_S (age_{max}\ B_S)}{\sum_S B_S}$ (year)	*S, T*	*Meaning*: Proxy for turnover rate. Conveys the idea that fishing favours the emergence of species with a short life span. Fishing may affect the longevity of a given species (phenotypic plasticity and genotype selection), but the purpose here is not to track those effects at the species level, but to track changes in species composition. *Data*: Calculated for surveyed species[1]. Fixed longevity for each species. Life span may vary under fishing pressure, so we conventionally adopt the mean max longevity observed for each species.

3. Methodology

Focus on some fisheries based indicators

Annual catches / Fishing pressure

- 1/(Landings/Biomass) = Inverse Fishing Pressure (Indiseas index)
- IE = Exploitation index of Caddy (1995)

- F = fishing efforts total and/or by fisheries segment,
  - Artsanal, Industrial, Total PA+PI (stand), Nb of boats, Nb of fishing hours etc..
- C = Commercial catches (landings)
  - Total and/or per fleets per catogories : PA, PI, Total PA+PI, fishes, others groups
  - Per commercial categories

- TL(f)= Trophic level of the commercial catch
  - Mean trophic level of the catch, (Indiseas index)

3. Methodology

Focus on some demersal macrofauna indicators

Trophic level of the landed catch (TLland)

Indicator	Data needed	Calculation	State S Trend T	Comments to guide calculation of indicators
TL landings	TL value per species Time series of landings per species (tons)	$TL_{land} = \frac{\sum_s TL_s \, Y_s}{Y}$	S, T	*Data:* Fixed non-integer TL per species. All retained species[2]. TLs can be derived from Ecopath models or diet data. *Question: If there is no Ecopath model implemented nor diet data available, can this indicator be calculated?* As a stopgap, the estimates of TL in Fishbase (www.fishbase.org) are used.

3. Methodology

Focus on some demersal macrofauna indicators

Marine Trophic Index MTI

Indicator	Data needed	Calculation	State S Trend T	Comments to guide calculation of indicators
Marine Trophic Index	TL value per species Time series of landings per species (tons)	$MTI = \frac{\sum_{s / TL_s \geq 3.25} TL_s \; Y_s}{Y}$	S, T	Cf TL landings for TL_s values Only retained species[2] are considered

3. Methodology

Focus on some demersal macrofauna indicators

Mean intrinsic vulnerability of fish catch IVI

Indicator	Data needed	Calculation	State S Trend T	Comments to guide calculation of indicators
Mean intrinsic vulnerability index of fish catch	Intrinsic vulnerability index per species s Time series of species landings (tons)	$IVI = \frac{\sum_s IVI_s \; Y_s}{Y}$	S	The intrinsic vulnerability index of a species (IVIs) is based on life history traits and ecological characteristics, ranges from 0 to 100, with 100 being most vulnerable. Each species value has to be extracted from Cheung et al. 2007 (Supplementary material), or from www.fishbase.org (see end of species webpage, under vulnerability section), or can be calculated manually (with specific parameters of your species using an excel file programmed by C. William. Contact m.coll@icm.csic.es to access it). IVI will be considered as a state indicator based on trend over time (slope etc.) to facilitate cross-ecosystem comparisons.

3. Methodology

Focus on some indicators
(Mixing landings and surveyed community)

1/(landings/biomass) = B/Y of retained species

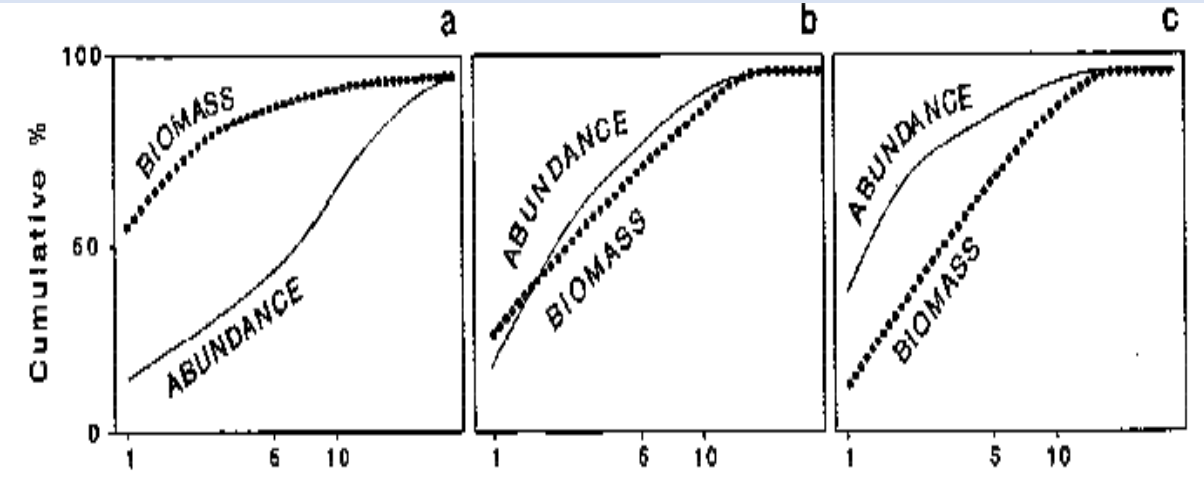
Indicator	Data needed	Calculation	State S Trend T	Comments to guide calculation of indicators
1/(landings /biomass)	Time series of total biomass of retained species[2] (tons or biomass index) Time series of total landings (tons)	*B/Y* of retained species[2]	*T*	*Meaning*: Indicates a global fishing pressure at the community level. *Data*: Use total landings and biomass of retained species[2]. Used for trends so biomass indices can be used (but must be consistent across species and over the time series).

4. Methodology

Dominance curves/ ABC curves / K-dominances

- A diagnosis of the stress level of communities
- Developped and applied intiallly to evaluate the stress level of benthic communities after a pollution (oil pollution)
- Applied to fish assemblages submitted to high fishing pressure => (Jouffre et Inejih 2004)
- Data used: Scientific campaigns

No stress **Low stress** **High stress**



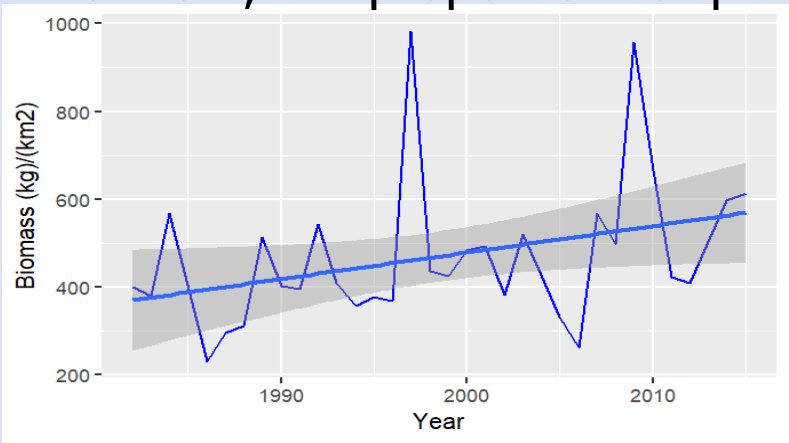
4 Results

Case studies on Mauritania, Senegal, Guinea

4. Results - Mauritania

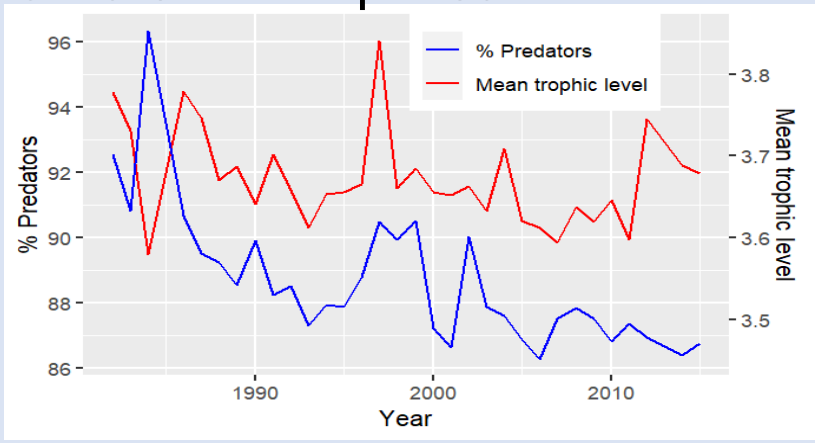
Yearly biomass index (in kg/km2) shows large variations, around 500 kg, up to 1000 kg (1997, 2009) with a long-term increasing trend.
Mean life span and trophic level of the community show fluctuations with no apparent trend. In contrast, the proportion for predators decreased over the period.

Total Biomass Index

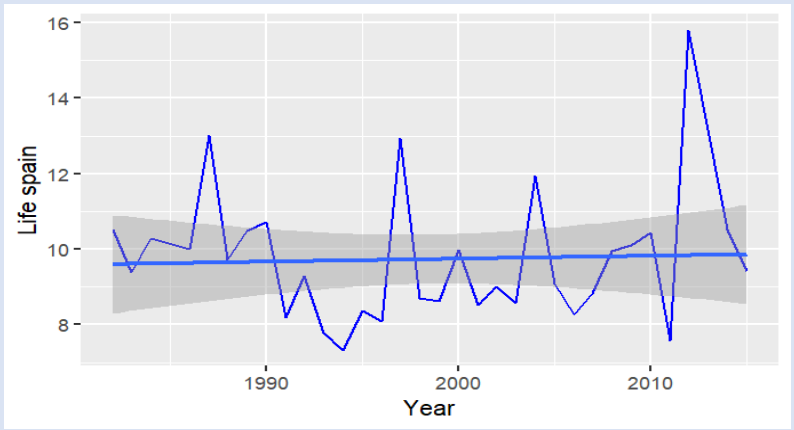


% Pred (blue)

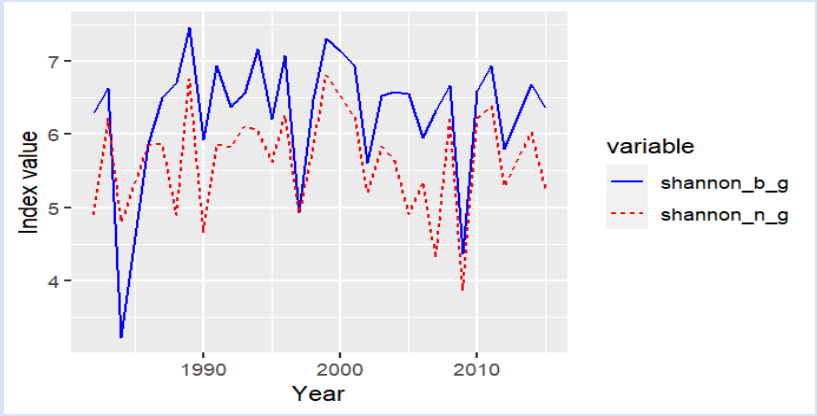
Tlco (red)



Mean Life Span Co



Div Index

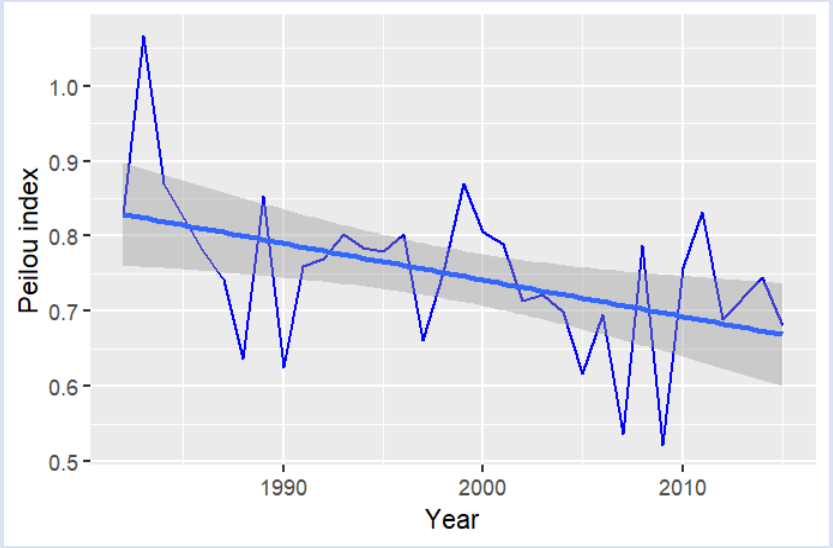


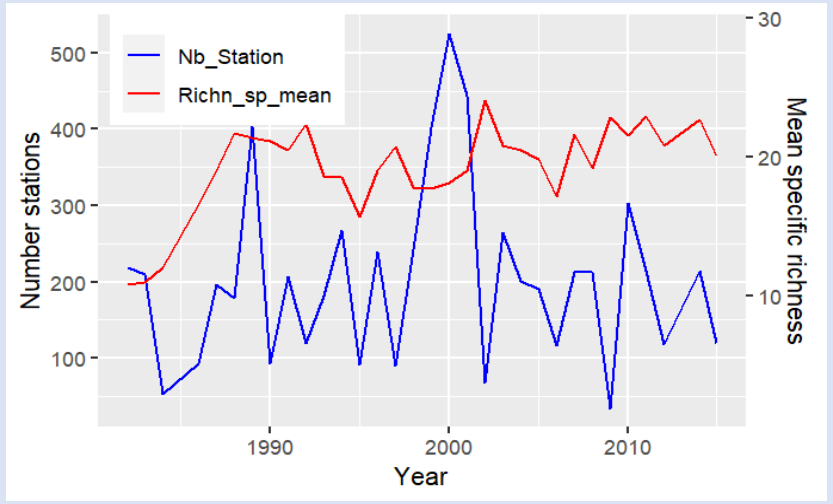
4. Results - Mauritania

Div Index (Pielou) decreasing

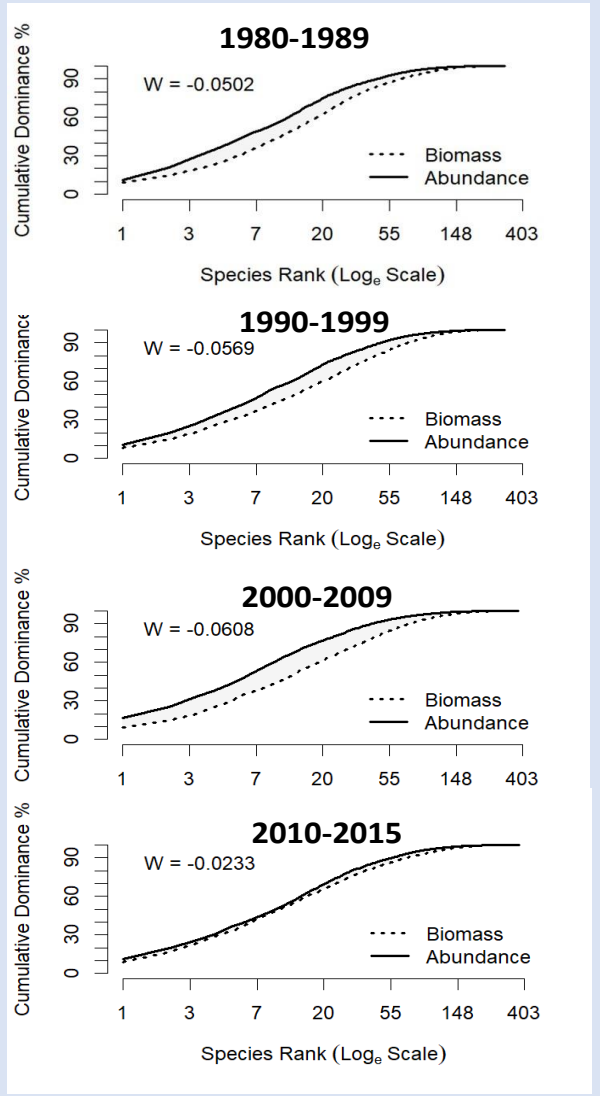
Species richness (L) remained relatively stable since the 1990.

Biodiversity indices fluctuated showing different trends.





The diagnosis from dominance curves showed stressed communities except in the last decade.

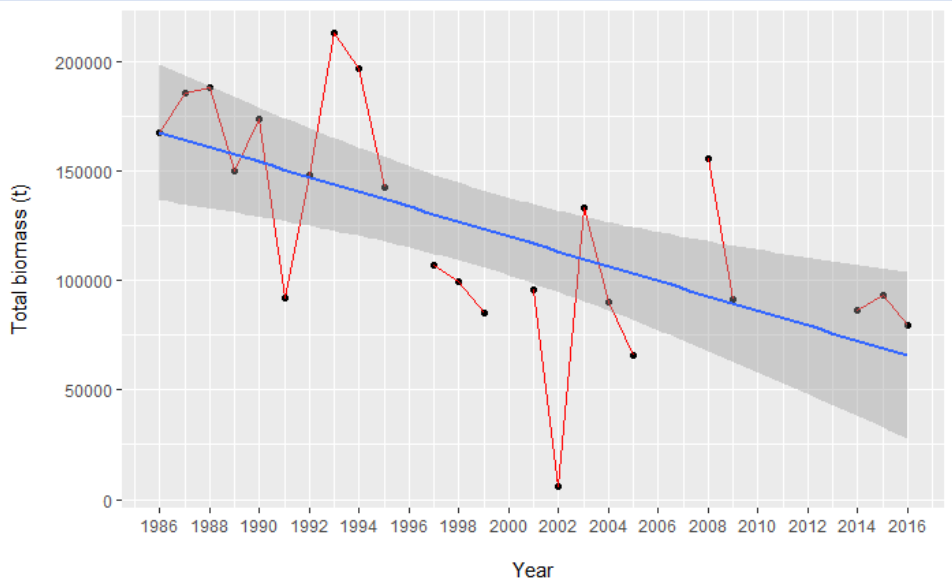


4. Results – Senegal

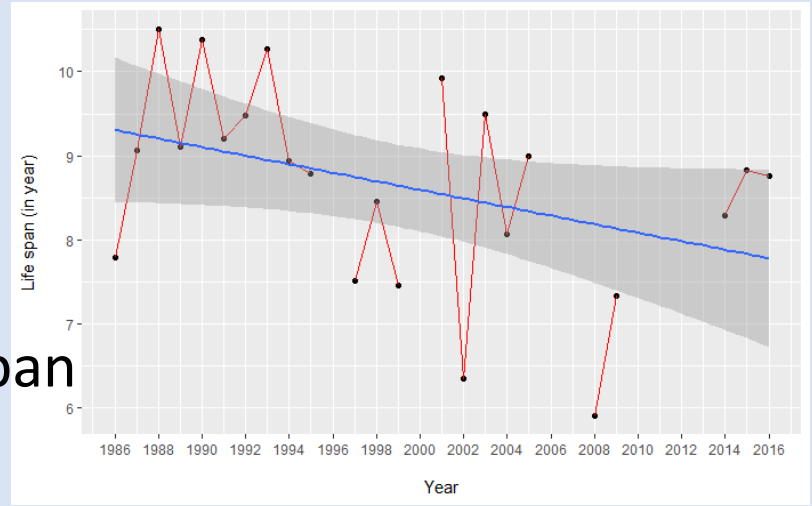
Biomass varies from year to year with an decreasing trend over the 1986-2016 period.

Mean life span and trophic level of the community showed decreasing trends over the period.

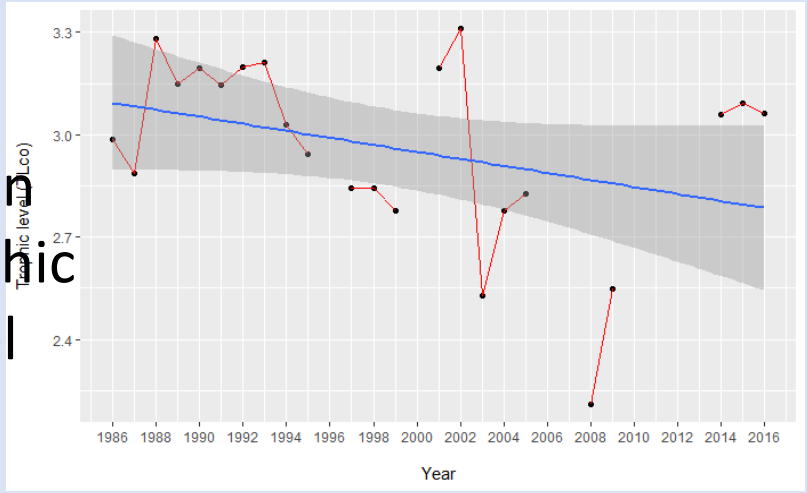
Total Biomass Index



Mean Life Span Co

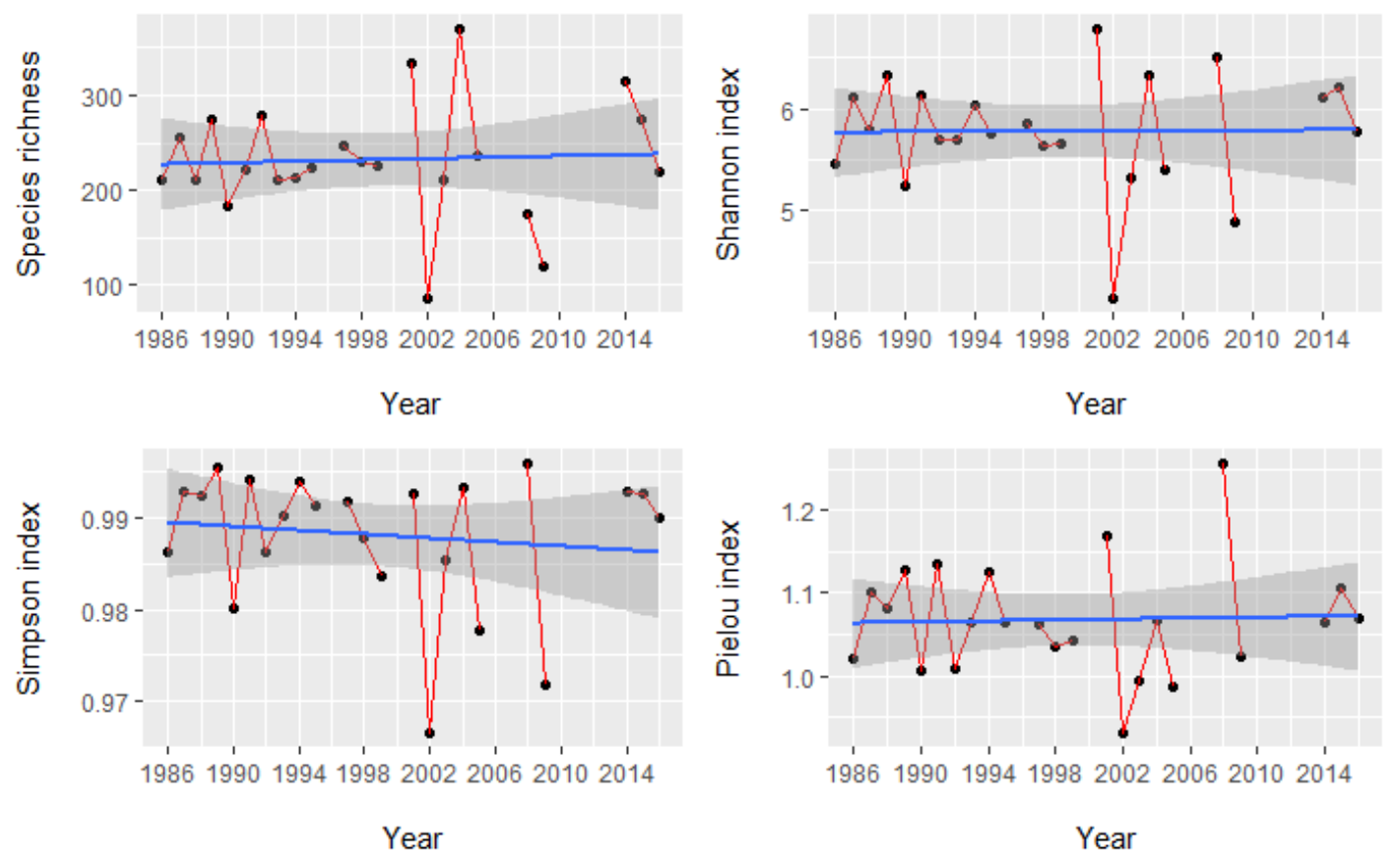


Mean Trophic Level Co

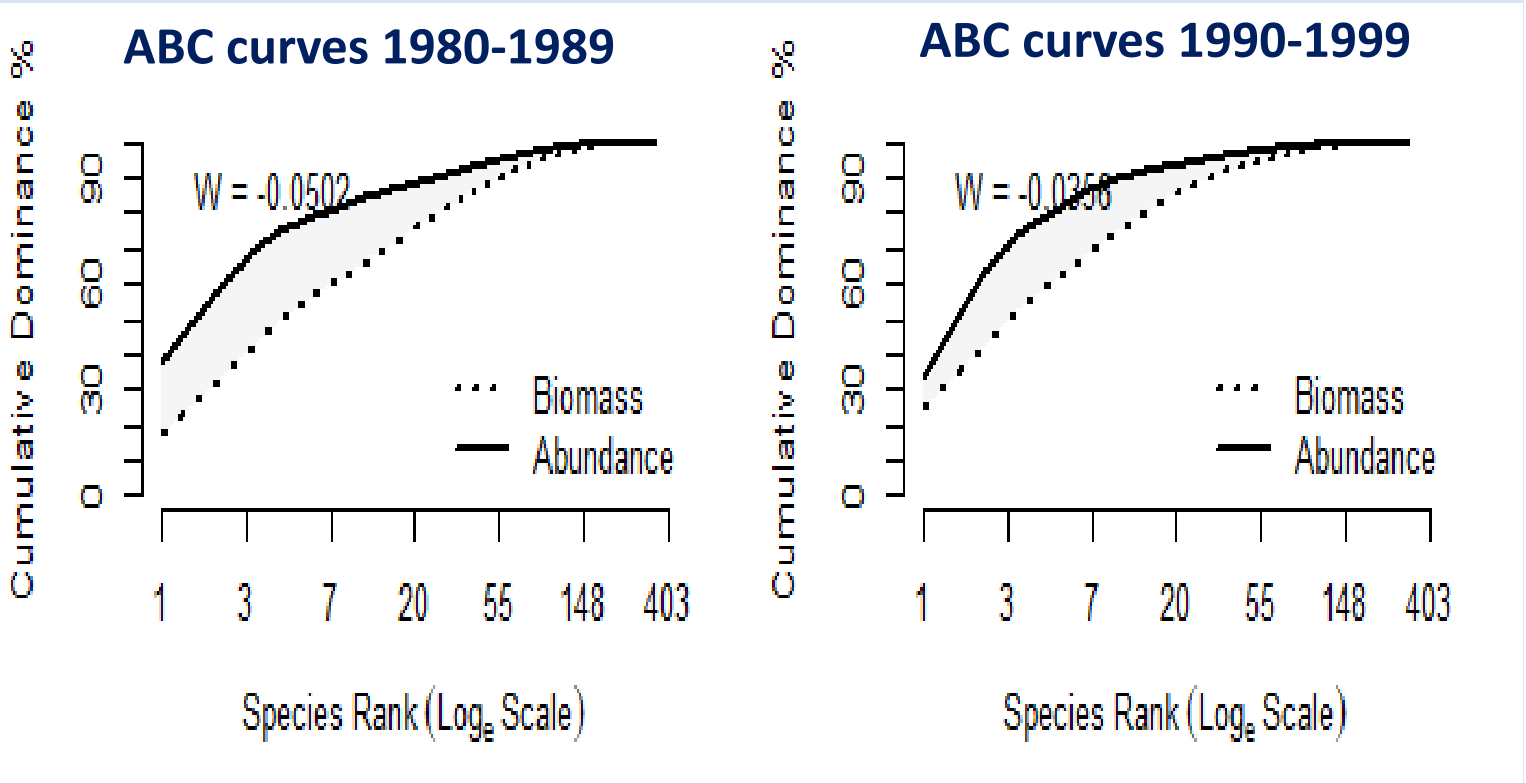


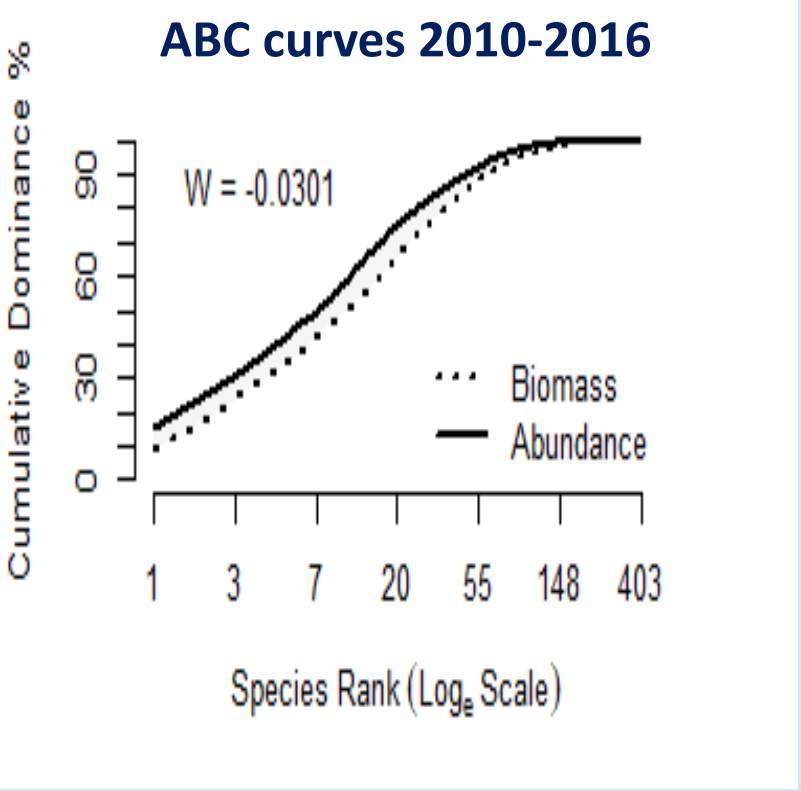
4. Results – Senegal

Diversity indices are highly variable from year to year, without clear trends over the period 1980-2018.



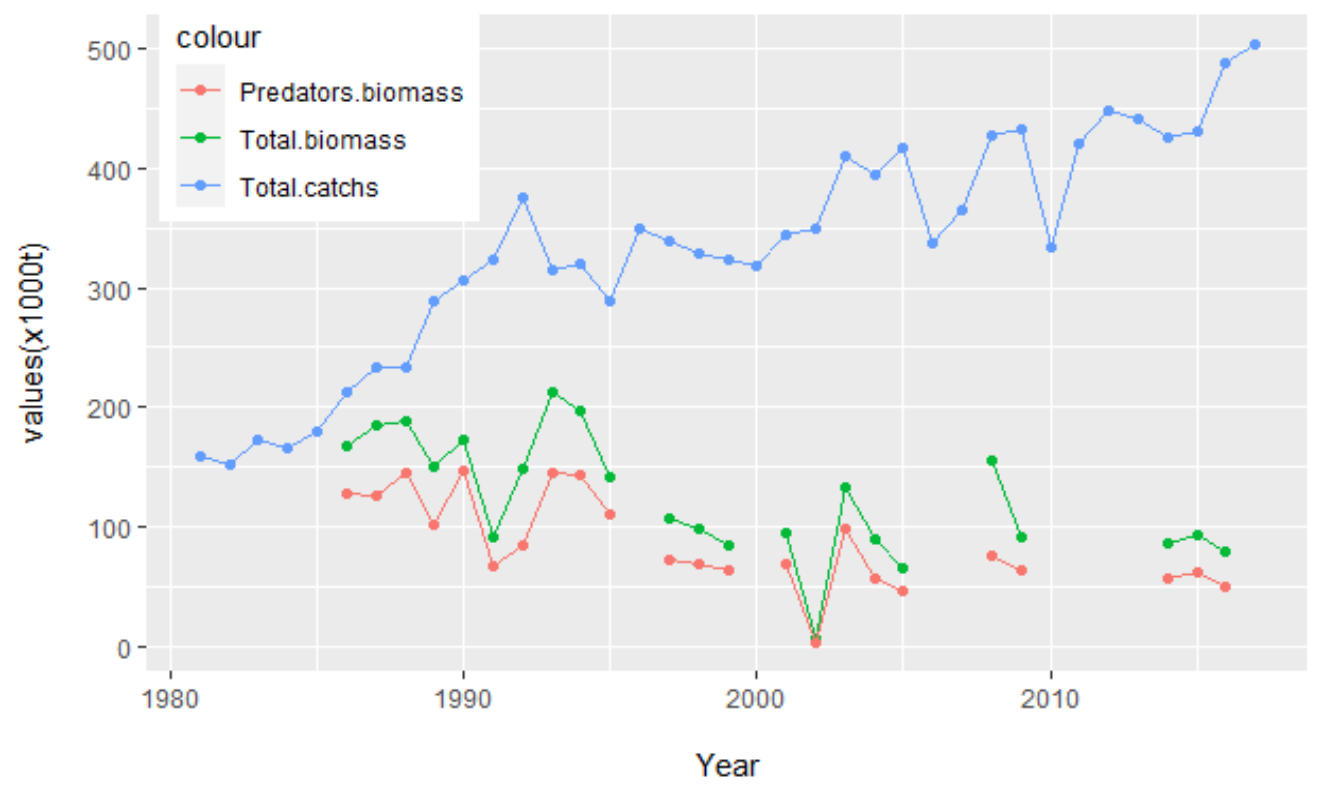
4. Results – Senegal





The diagnosis from dominance curves showed stressed communities with lower stress in the last decade (210-2016).

4. Results – Senegal



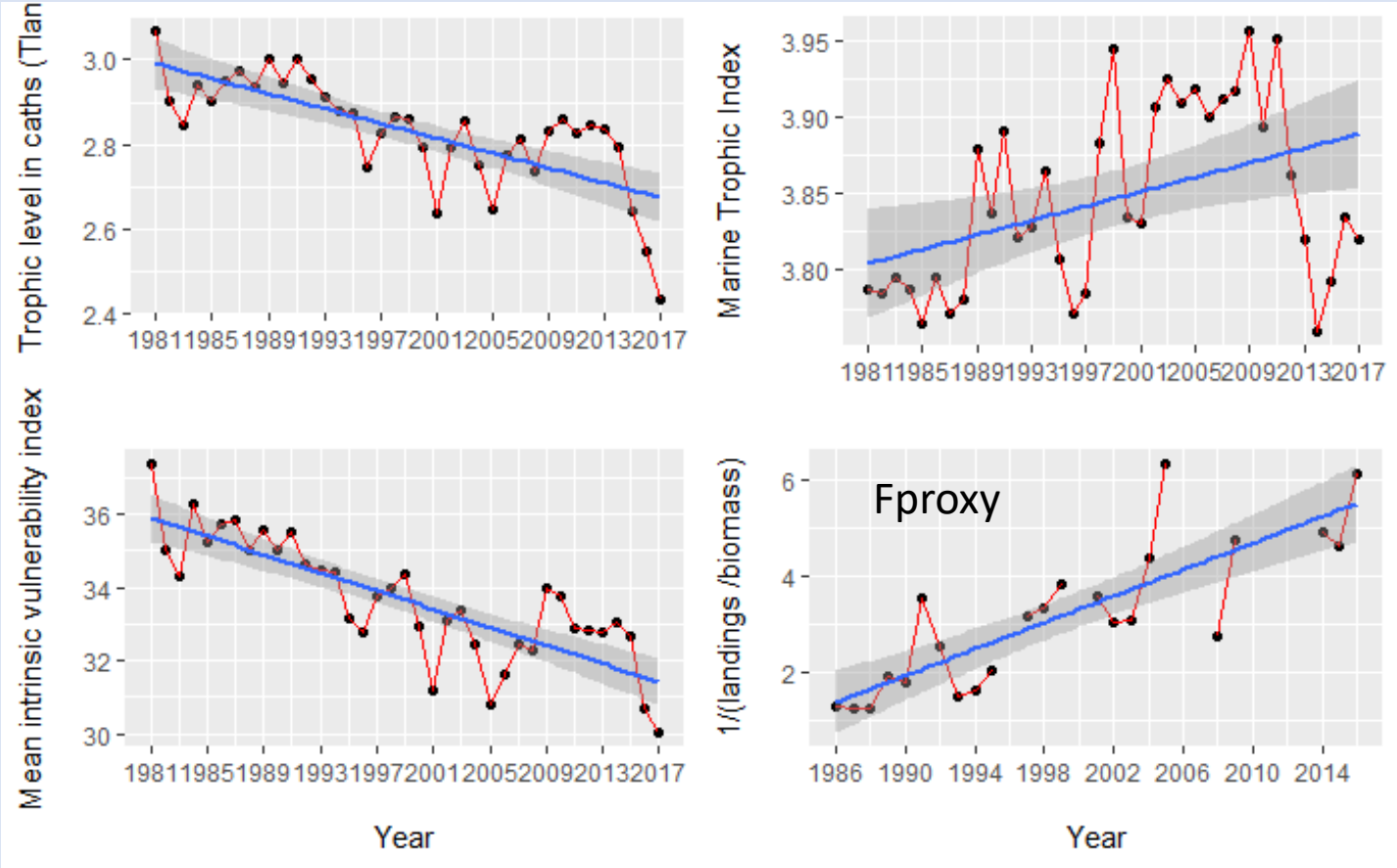
The increase in fishing pressure and catches (blue) results in different trends of the indicators based on the ecosystem or demersal communities =>

Here: Total Demersal Biomass (green) and Predators Biomass are decreasigng)

4. Results – Senegal

Fisheries data based indicators

Increasing of Marine Trophic Index
Decreasing of Trophic Level and intrinsic vulnerability.



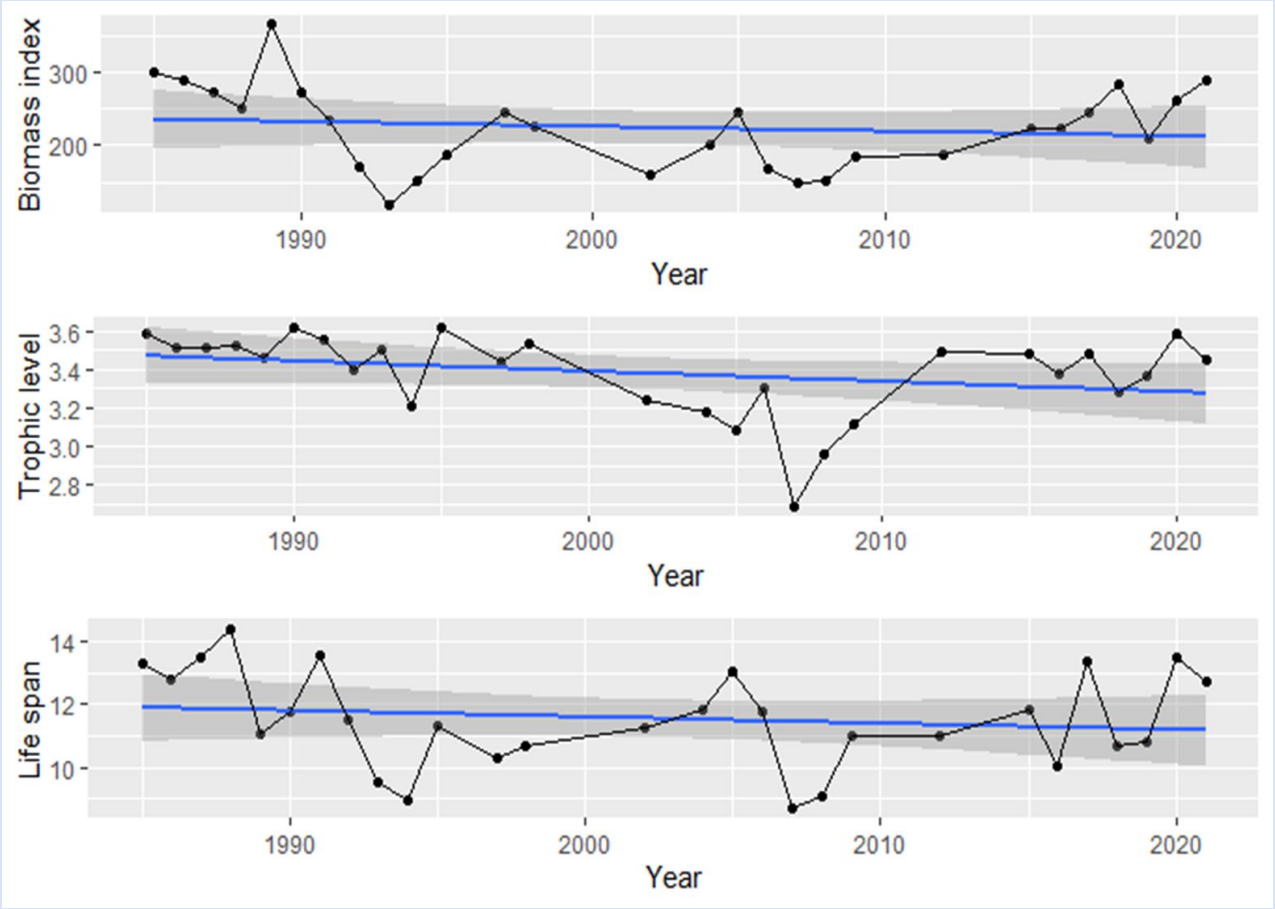
4. Results – Guinea

- Biomass varied from year to year with an increase since 2008. Trophic level and life span of the communities are slightly decreasing with high interannual variability.

Total Biomass

Trophic Level

Life span

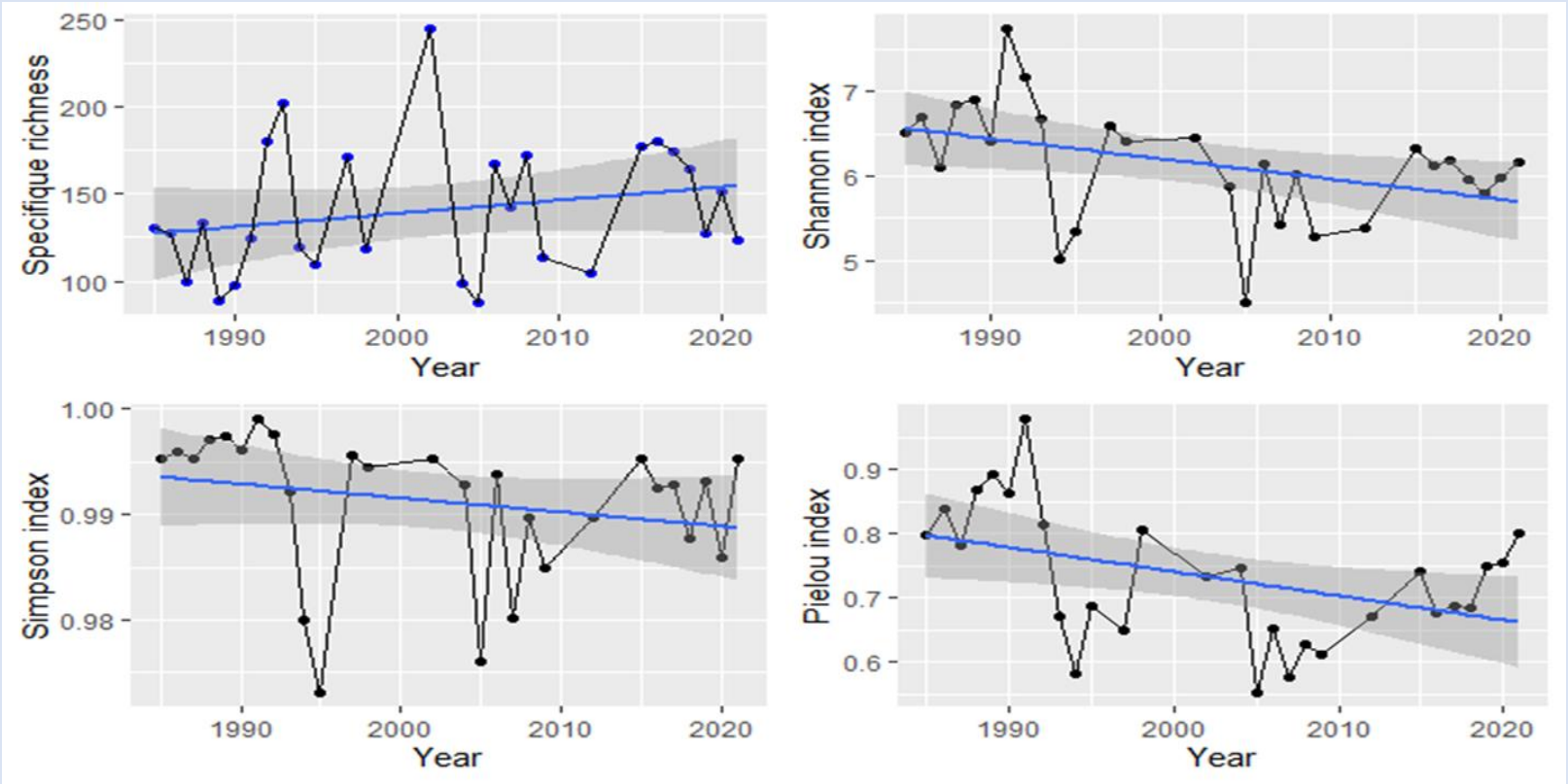


4. Results – Guinea

Biodiversity indices

Diversity indices are highly variable from year to year with slight trends over the period.

Richness



Shannon Div

Simpson Div

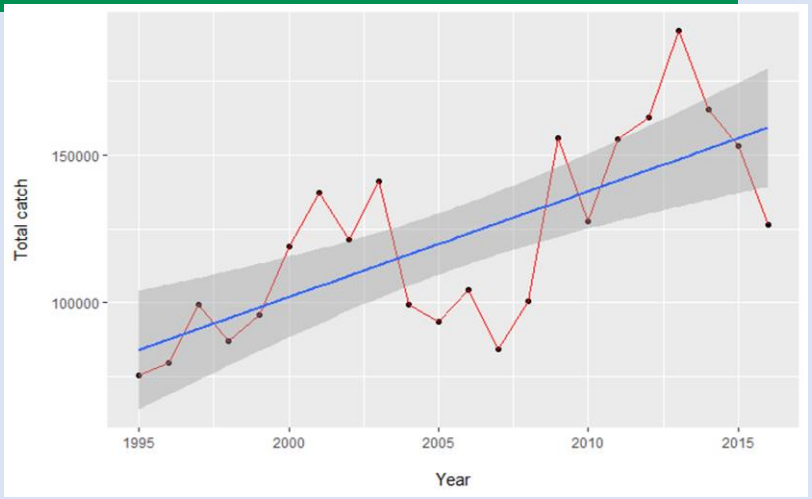
Pielou Div

4. Results – Guinea

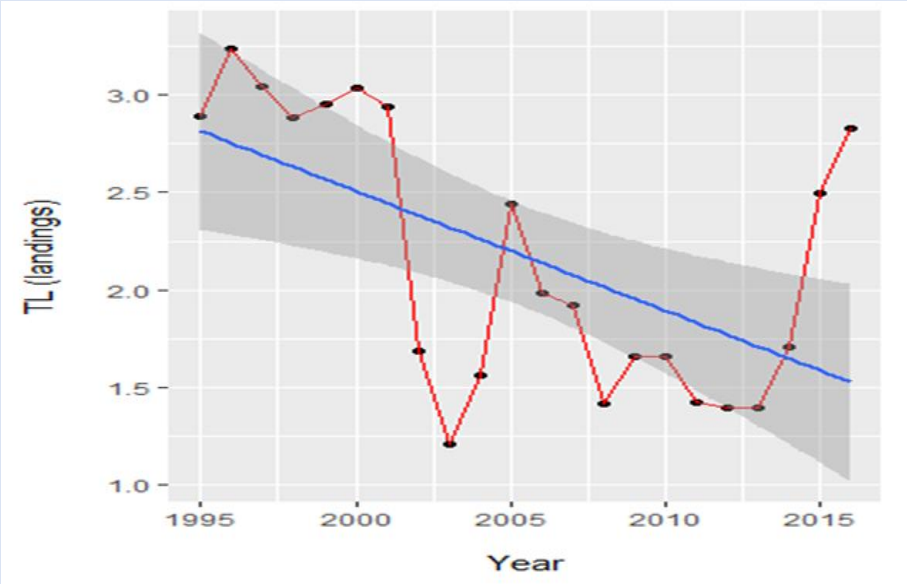
The landings,
The marine trophic index et trophic level

The landings and Marine Trophic Index are increasing over the 1995-2016 period.
In contrast the Trophic Level are decreasing.

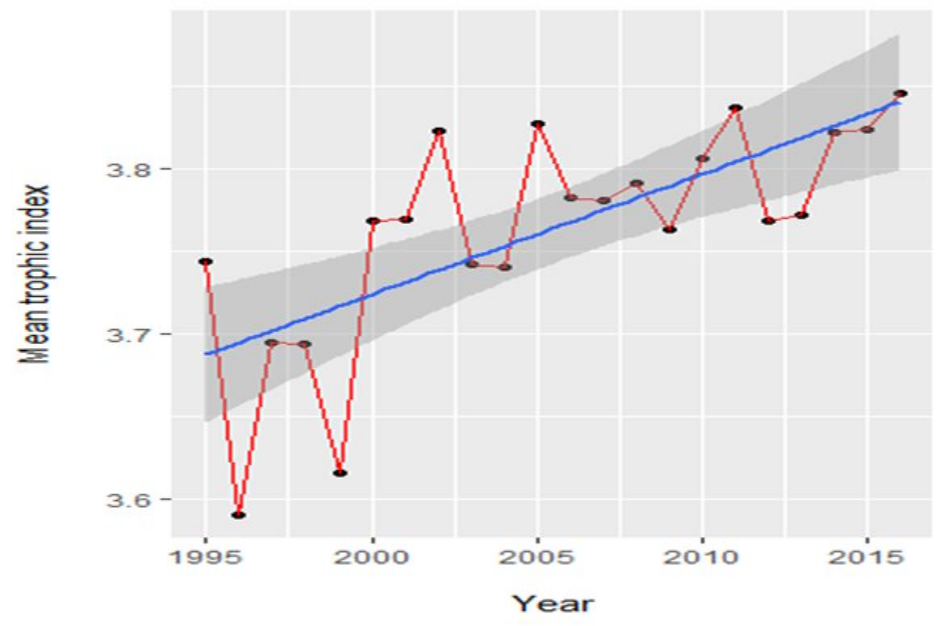
Total landings



Trophic Level Of Landings



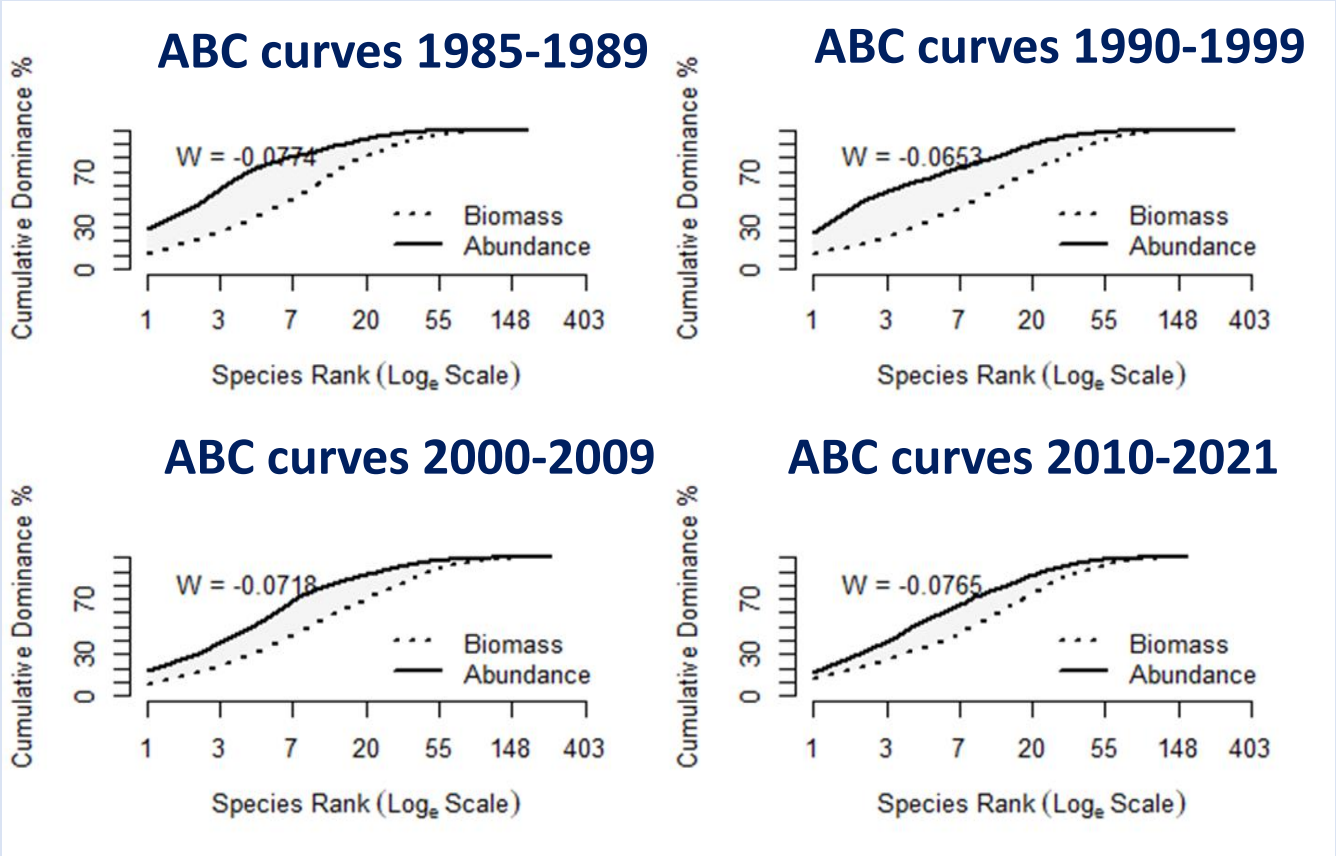
Marine Trophic Index (MTI)



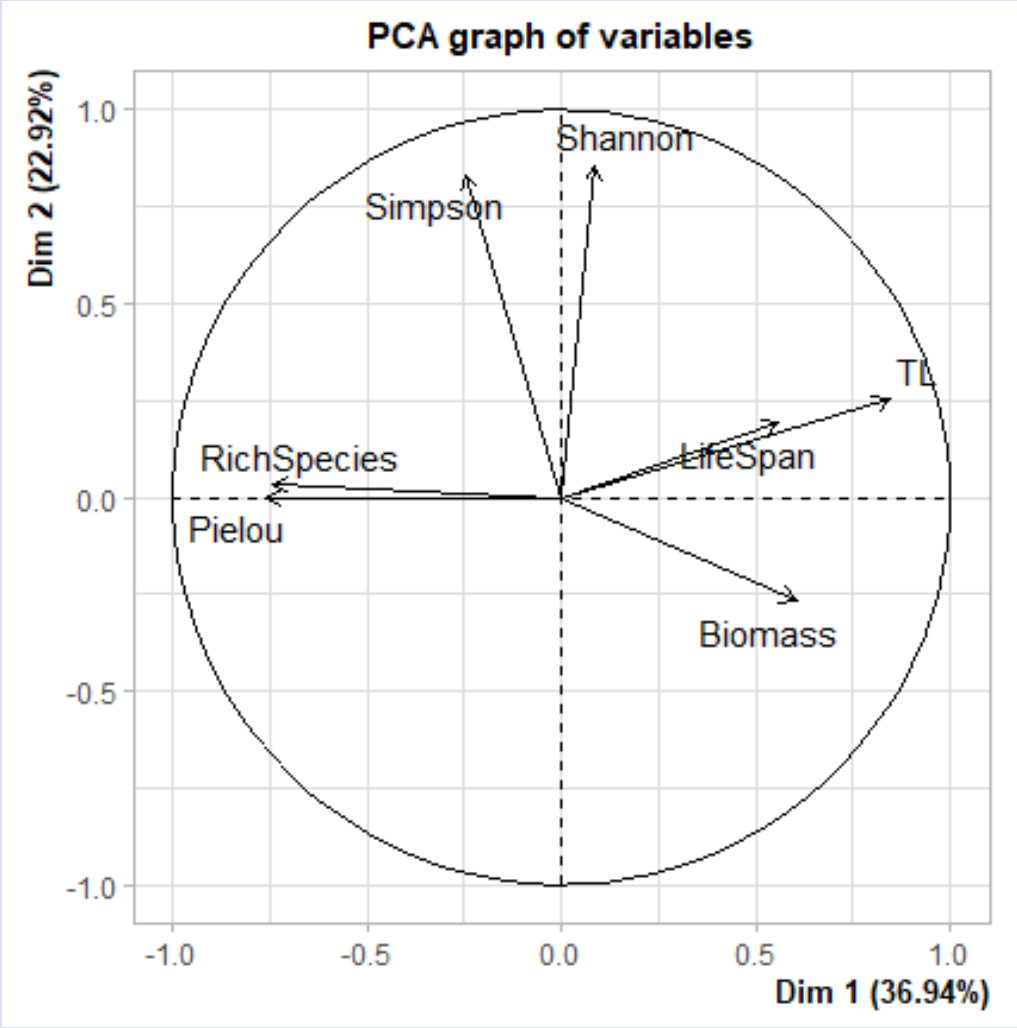
4. Results – Guinea

ABC curves

Dominance curves showed stressed communities. More or less constant stress intensity along decades



4. Results – North-West African Continental Shelf

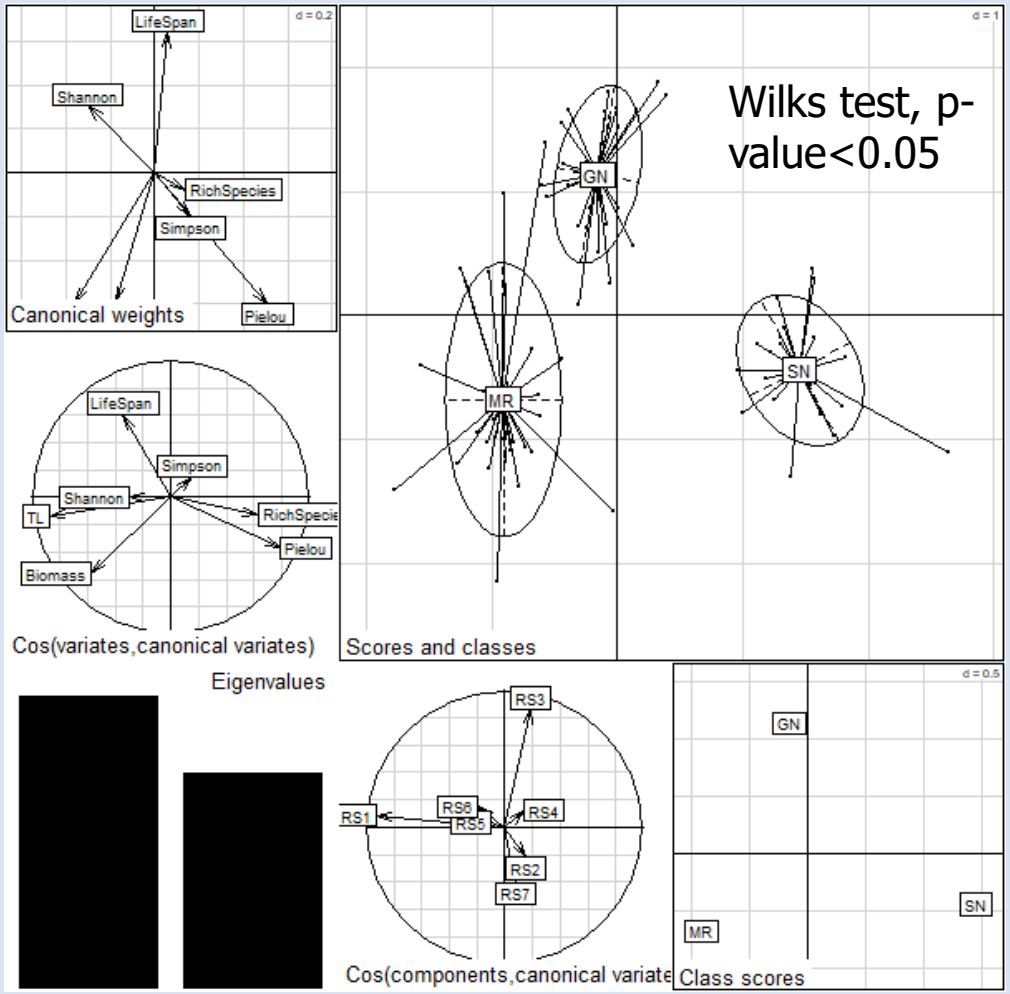


A multifcaorial analysis of the indicators estimates in G, M, S:

Coastal marine ecosystems are characterized by Biodiversity and ecological indicators:

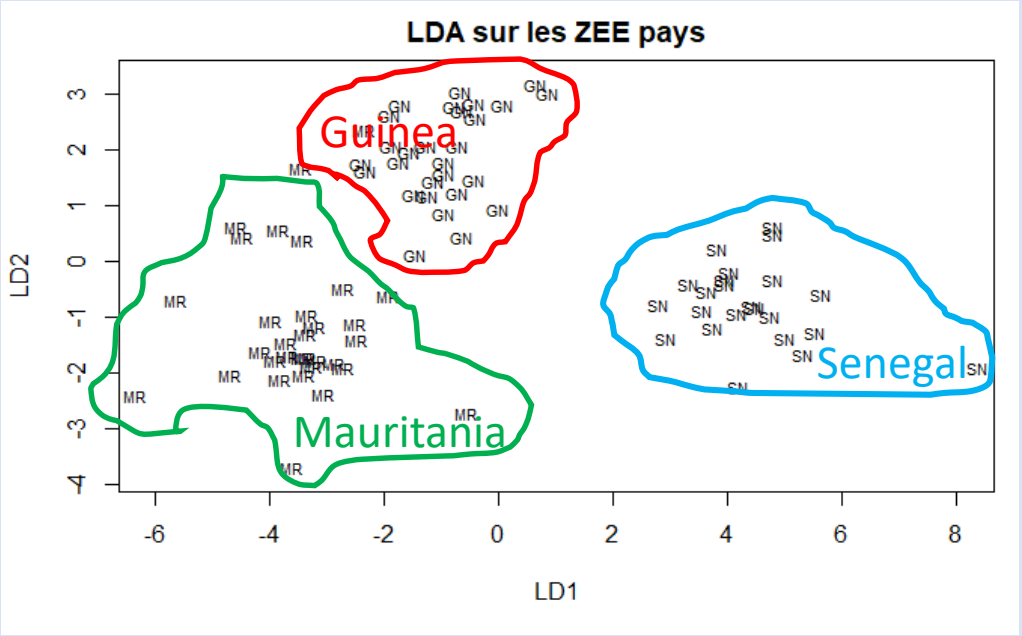
- ✓ Lifesapan
- ✓ Biomass
- ✓ Trophic level
- ✓ Species richness
- ✓ Shannon Div
- ✓ Simpson Div
- ✓ Pielou Div

4. Results – North-West African Continental Shelf



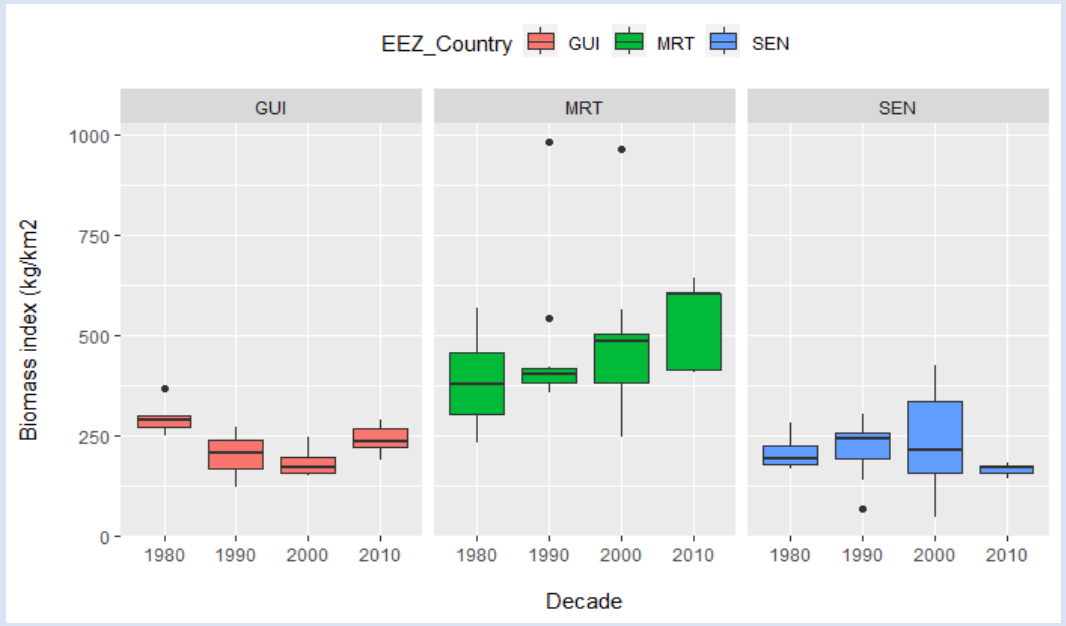
As revealed by the multifcaorial analysis of the indicators estimates,

Structure of West African ecosystems is different.

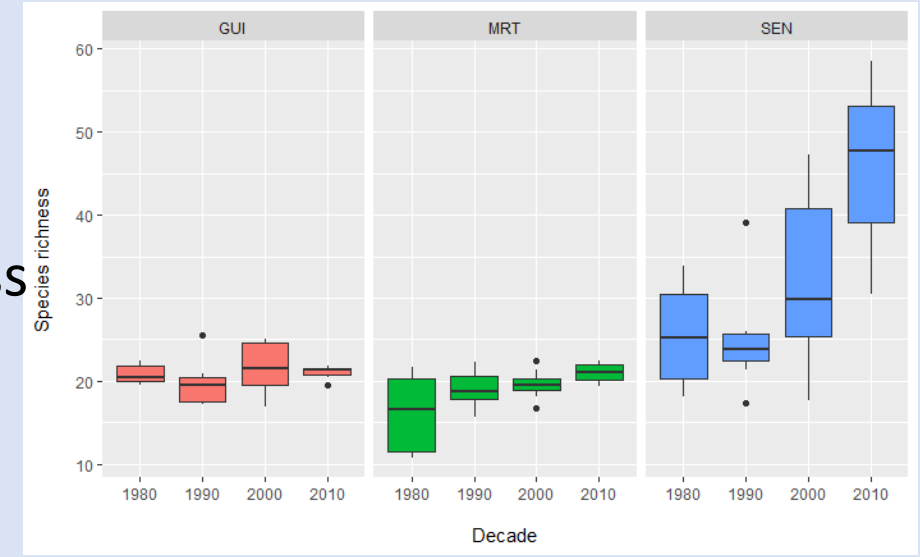


4. Results – North-West African Continental Shelf

Total Biomass Index

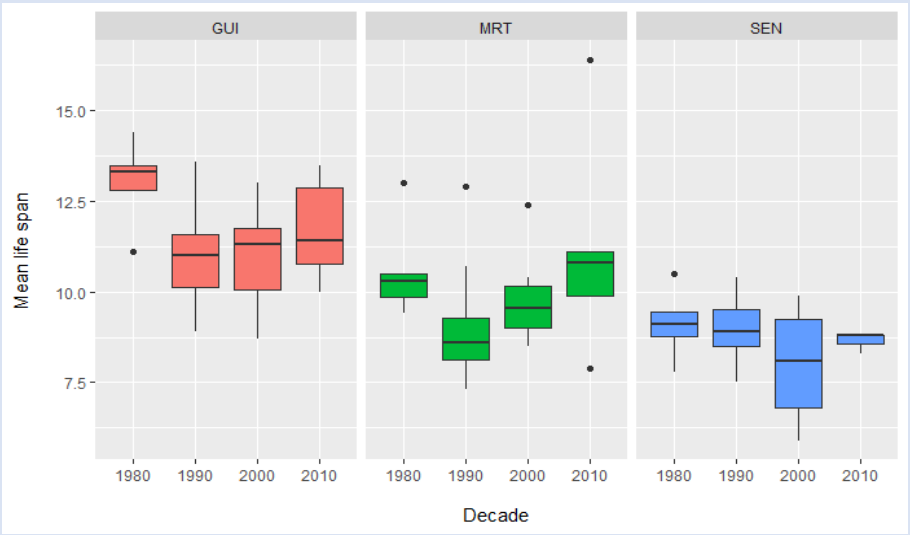


Sp Richness



The Mauritanian ecosystem is characterized by high biomass,
the Guinean ecosystem by large predators and
the Senegal ecosystem by shorter-lived species (not here) and high species richness (increasing)

Mean Life Span

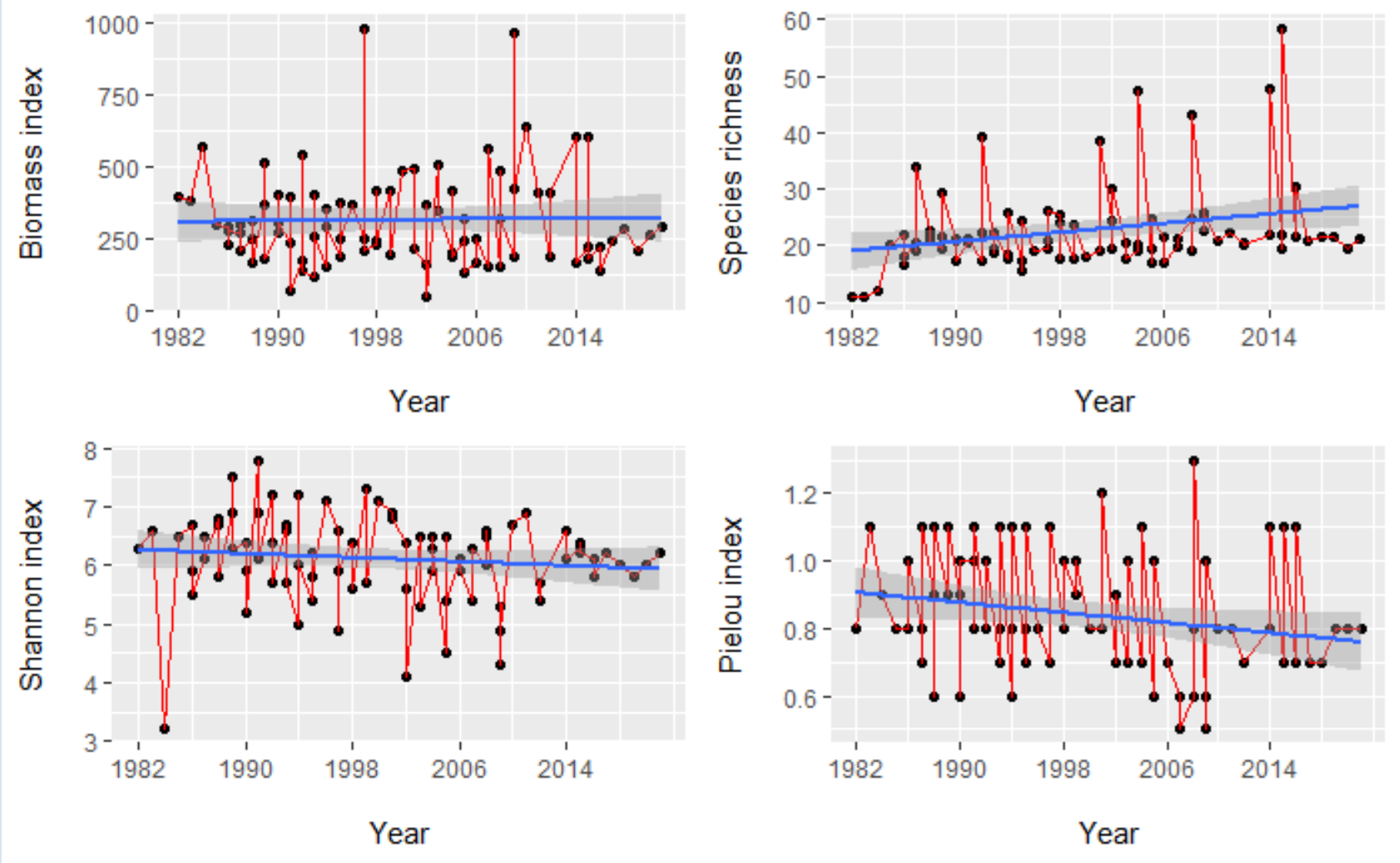


4. Results – North-West African Continental Shelf

At the scale of the West African region,

biomass and biodiversity index

are variables but without clear trends.



5 Conclusion

5. CONCLUSION

Mauritanian ecosystem

The diagnosis of the Mauritanian ecosystem reveals the following key facts:

- an overall trend of increasing biomass over time,
- a decrease in community stress over the last decade,
- a relative stability of the trophic level and the average life span of the communities,
- and a decrease in the proportion of predators.

5. CONCLUSION

Senegalese ecosystem

- Biomass varies from year to year with an decreasing trend over the whole period 1986-2016.
- Mean life span and trophic level of the community showed decreasing trends over the period.
- Diversity indices are highly variable from year to year and relatively stable over the period 1980-2018.
- Most of biodiversity and conservation-based indicators are decreasing along time

5. CONCLUSION

Senegalese ecosystem

- The increase in fishing pressure and catches results in different trends of the indicators based on fishing data: increasing of Marine Trophic Index and decreasing of Trophic Level and intrinsic vulnerability.
- The Senegalese marine ecosystem is globally overexploited.
- We also need to keep on mind that there are lack of information on other impacts caused by pollution and climate change.
- The study on Senegalese ecosystem illustrates that indicators analysis provides potential pathways that could be useful for the implementation of an Ecosystem Approach to Fisheries EAF in West Africa.

5. CONCLUSION

Guinean ecosystem

- There has been an increase in the biomass of demersal resources since 2008. This occurs after a decade of biomass decrease of some demersal resources, particularly the coastal ones.
- The coastal marine ecosystem appears to be still stressed (dominance curves) probably due to the fishing pressure (TL_landings).
- The analysis of the results confirms the recommendation for the implementation of ecosystem-based fisheries management that respects the sustainability of resources and the state of health of the Guinean ecosystem.

5. CONCLUSION

Regional ecosystem (North West-Africa Shelf)

- On the long term (3-4 last decades) indicators are showing a relatively stable state of biomass and biodiversity in the West African zone (not true locally, Senegal)
- The structure of West African ecosystems is different from place to place, probably in part due to the different environment and also due to the fact that the level of exploitation is different, according to the fishing pressure and fisheries management systems occurring in the different countries.
- This indicators analysis provides potential pathways that could be useful for future research and development aiming to improve the ecosystem indicator approach in the operational context of Ecosystem Approach

5. CONCLUSION

- The intensification of fishing seems to have significant effects but no homogenous and synchronic trends in the different ecosystem characteristics and related indicators
- On the abundances notably, whole abundance and main targeted species shows differents evolutions but no global and clear trends
- Decrease of some structural indexes as biodiversity and conservation-based indicators, along time (3-4 last decades)
- Effects of overexploitation of the ecosystem well known and tracked here but to keep in mind the lack of information on other impacts caused by pollution, climate change etc...
- An indicator approach demonstration for West Africa

Thank you
Merci

Additionnal material

5. CONCLUSION

- The comparative assessment of the three marine ecosystems indicate that the structure of West African ecosystems is different, which proves the different level of exploitation according to the fisheries management system.
- Indicators analysis results show a relatively stable state of biomass and biodiversity in the West African zone.
- The analysis of the results recommends the implementation of ecosystem-based fisheries management that respects the sustainability of resources and the ecosystems state of health in West Africa.

2. Indicators and Ecosystem Approach to fisheries

4 steps:

Step 1- Identification, Methodological definition and Calculation of indicators

- Indicators of taxonomic and functional biodiversity of demersal macrofauna assemblages: S and T
- + Documentation and Methodological Justification of the Calculation of indicators based on data and Sensitivity Analyzes (DMJC-AS)
- Indicators of fishing activity and/or from fishing activity: S and T
- Environmental Indicators: S and T
- ABC curves or K-dominance method (diagnosis of the state of stress of demersal communities at a given time) S and T

2. Indicators and Ecosystem Approach to fisheries

4 steps:

Step 2: Display and interpretation of indicators

- Representation and spatial analysis of ecosystem indicators
- Representation and temporal analysis of ecosystem indicators
- *Spatio-temporal analyzes of ecosystem indicators by combining spatial analysis methods with statistical methods or multivariate data analysis*

2. Indicators and Ecosystem Approach to fisheries

4 steps:

Step 3: Search for causalities explaining the observed evolutions (the observed changes and trends)

- Correlations analysis between the different (sets of) indicators,
- testing of hypotheses
- search for causalities

Long term objective: In progress on the Guinea Senegal and Mauritania case study

2. Indicators and Ecosystem Approach to fisheries

4 steps:

Step 4: Summaries and global interpretations

- Summary and synthesis of observed evolutions (multi-indicators),
- Interpretation in terms of impact of fishing / impact of climate change

4. Data and methodology

1.1. Indicators of the demersal macrofauna (surveyed community)

- TBI = Indicateur de biomasse totale = Total Biomass of the surveyed assemblage = Biomass

  Total Biomass index of the surveyed demersal assemblage => S,T

  (indiseas index, Shin et al. 2010), L, G
- TNI = Densité en Nombre = Density in numbers of the surveyed assemblage = Number

  Total Biomass index of the surveyed demersal assemblage => S,T

  (Jouffre) , L, G
- FL = Taille moyenne des poissons = Mean Length = Fish Size

  Mean length index of the surveyed demersal assemblage => S,T
  (indiseas index; Shin et al. 2010), L, G
- SB = Indicateur de stabilité de la biomasse = 1/CV of total Biomass = Biomass stablity

  => T, (indiseas index, Shin et al. 2010), G

4. Data and methodology

1.1. Indicators of the demersal macrofauna (surveyed community)

- S = Richesse spécifique = Nombre d'espèces (ou taxons)
  S of the surveyed demersal assemblage => S,T, (), L, G
- Ds = Diversité spécifique de Shannon = Shannon index
  of the surveyed demersal assemblage => S,T, (), L, G
- E = Equitabilité (Simpson) = Simpson Eveness

=> Alternative index = Equitabilité de Pielou (Pielou 1953)
  of the surveyed demersal assemblage => S,T, (), L, G

- Ppred= Proportion de poissons prédateurs = Proportion of predatory fish (TL≥3.25)
  of surveyed demersal assemblage => S,T,
  (indiseas index) L, G
- TLe= Indicateur de Niveau Trophique moyen = Trophic level of the demersal assemblage
  Mean trophic level of surveyed demersal assemblage => S,T,
  (adapted from an indiseas index) L, G

4. Data and methodology

1.1. Indicators of the demersal macrofauna (surveyed community)

- FM = indicators to explore
- Indiseas phase 2
- (DEB => mixte ou 1.2.)
- Others (cf biblio)

4. Data and methodology

1.1. Indicators of the demsersal macrofauna

For memory: Indicators of fonctionnal diversty
(vs spécific/taxonomic)

- la richesse fonctionnelle (FRic),
  of the surveyed assemblage => S,T, (Villeger 2008), L, G
- la régularité fonctionnelle (FEve),
  of the surveyed assemblage => S,T, (Villeger 2008), L, G
- la divergence fonctionnelle (FDiv),
  of the surveyed assemblage => S,T, (Villeger 2008), L, G
- la spécialisation fonctionnelle (FSpe)
  of the surveyed assemblage => S,T, (Villeger 2008), L, G
- l'originalité fonctionnelle (FOri).
  of the surveyed assemblage => S,T, (Villeger 2008), L, G

4. Data and methodology

1.1. Indicators of the demersersal macrofauna

- Indicateurs calculés à partir de données de « statistiques de pêche » (efforts et captures principalement)

- Pour certains indicateurs: données additionnelles
  - sur les caractéristiques biologiques des espèces (Fishbase),
  - Sur la valeur économique des captures
  - Données socio-économiques générales sur le secteur
  - Etc…