Steve Kirkman

Established with funding from Norwegian government through NORAD

**Goal** of identifying and describing possible **trends in ocean climate** and corresponding **changes in marine biodiversity and fisheries** in the Benguela current system

**Research guided by 5 key objectives**

1. To identify **ecosystem changes** as a result of climate variability,
2. To document **changes in the distribution and abundance of species and communities**
3. To identify **potentially useful species as indicators** of change
4. To identify **sensitive areas or hotspots** of change
5. To document **changes in productivity** related to climate variability
Research proceeded in 3 task teams

Task 2.1 Climate variability and change
Leader: P. Tchipalanga (Angola)
Members: M. Ostrowski, C. Bartholomae, A. van der Plas, L. Hutchings, A. Jarre, Q. Fidel, B. Bazika Sangolay,

Task 2.2: Responses of pelagic ecosystem to climate change
Leader: H. Verheye (South Africa)
Members: E.K. Stenevik, B. Tjizoo, A. Kreiner, N. Mhlongo, J., V. Estevao

Task 2.3: Climate effects on the biodiversity of the demersal community
Leader: P. Kainge (Namibia)

Cross cutting: D. Yemane
Synthesis aims

• Highlight the major findings of the three task groups and link these to each other
• Place in context with other relevant findings for the region and the international literature
• Discuss possible implications for biodiversity conservation and ecosystem-based management
• Identify gaps in knowledge and future research needs
Findings

• Much of the oceanography across the region has been changing since around 1990
• E.g. the Angolan subtropical waters and the northern Benguela have been warming since the early 1990s

Warming trend: 0.03°C per year

Sea surface temperature anomaly (deviation from the seasonal cycle) 1982-2010. Data obtained from the Pathfinder SST time series (v 5.0), extracted for up to 25 km from the coast along between 6°30 to 11°30 S of the Angolan coastline
Temperature anomalies at 23°10, near Walvis Bay, Namibia
- The southern Benguela off Namaqualand north of Hondeklip Bay has likewise warmed.
- The observed regional warming coincides with a southward shift of the centre of the South Atlantic High Pressure Cell in summer by two degrees latitude, to 31.5°S (just north of St Helena Bay).
• St Helena Bay in southern Benguela: no significant warming or cooling over 55 years but decadal-scale variability

• “Muted climate signals” in St Helena Bay (Hutchings et al. 2012, AJMS)
STARS analyses for mean annual summer upwelling from Cape Columbine to Cape Agulhas (Blamey et al. 2012, Progr. Oceanogr.)
Time-space plot of chlorophyll index: $\Sigma$chlla coast $\rightarrow$ 1mg/m3 isoline
(Updated from Demarcq et al. 2007, SOO, DEA Mar 2013)
• An apparent increase in phytoplankton biomass in the northern Benguela, but not significant (STARS analysis)
• Why should there be increased phytoplankton biomass when there has been warming and increased stratification related to reduced upwelling?
Northern - Southern Benguela comparison:
total copepod abundance \( \{\log_{10}[(\text{No. m}^{-2})+1]\} \)

Verheye et al

(Verheye & Kreiner 2009)
Virtual removal from the northern Benguela ecosystem of the ‘wasp-waist’ species (anchovy and sardine) during the 1970s - 1980s potentially resulted in irreversible shift to a less efficient and less environmentally robust regime, dominated by gobies, jelly fish and horse mackerel.
Change in distribution of bearded goby and horse mackerel in the north and central Namibian shelf estimated from logistic GAM analysis. The lines represent the annual effect relative to the average and the shaded areas the 95% confidence bands. (Salvanes et al. in review, FOG)
• Southward shift in spawning location of sardine (Kreiner et. al. (2011, FOG))

• But generally few links between fish and oceanography in Northern Benguela
Both sardines and horse mackerel show signs of stressed populations in Northern Benguela, indicating lower productivity than previously therefore lower expected yields.

Horse mackerel size distribution 1973-2012 (U. Uanivi)

Sardine size distribution, Northern Benguela, 1950’s-2000’s (Kreiner et al. 2011)
Anchovy

Sardine

Maximum and minimum annual preferred SST of spawning habitat for anchovy and sardine in the southern Benguela, 1988-2009. Loess smoothers illustrate temporal trends (Mhlongo et al. in review, FOG)
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**Legend:**
- Red indicates a change point.
- Green indicates a change point analysis.
- Blue indicates a chronological clustering analysis.
- Black indicates a change point analysis.
Relative catch rates of bottom dwellers (Monk, Sole) in Namibia (old vs new Nansen)

Axelsen et. al. (in review, FOG)
Temporal trend (GAM function) in mean latitude and mean depth: Angola

Species showing significant change in mean latitude

Species showing significant change in mean depth

Yemane et al. (in review, Reviews in Fish Biology and Fisheries), Kainge et al. (in review, FOG)
Conclusions and potential implications for ecosystems based management within the BCLME

• Changes across the system in the 1990s (warming in the north, increased variability in upwelling in the south etc) – effect of South Atlantic High Pressure Cell?

• Large human impacts cannot be ignored as drivers of several changes

• E.g. The loss of two major epipelagic species in N. Benguela led to a restructuring of the entire pelagic/demersal food web to a less efficient structure in terms of resource yield for pelagic and demersal fisheries.

• Fisheries-induced changes in the pelagic subsystem (eg towards smaller/younger fish) have been documented for both the northern and southern Benguela, and decreased resilience to warming is expected, requiring more conservative management.

• A sustained increase in depth of fish populations in BCLME will have ecological (via trophic interactions) and economic consequences (increased fishing cost to the fishing industry)
Cont.

• Consequences of **distributional shifts** within and across subsystems (e.g. transboundary shifts, mismatches between predators and prey or fisheries and resources, require **national or transboundary management responses** across different sectors, i.e. an ecosystem approach. For example, shifts in pelagics, seals, between and within the three countries.

• **Future scenarios** of possible consequences of **continued environmental change** need to be updated/developed, including further warming and stratification, increased low oxygen on the shelf, weakened or altered boundaries, emphasising the need for adaptive management, including spatial approaches.
Recommendations for future surveys

• The comprehensive monitoring programmes (in place since the 1980s/1990s) need to continue, and will benefit from an effective regional co-ordination. Improvement in the overlap of surveys across the national boundaries during resource surveys will improve the detection of distributional shifts and aid comparability of data.

• A better balance of line function monitoring is required, with equal weight for resources, biodiversity and environmental monitoring.

• Consequences of changes in survey design/gear need to be determined for all components, not just the target organisms.

• As immediate improvements in implementation of the existing surveys, acoustics should be run on demersal surveys, and environmental sampling should be conducted at every biological/trawl station, at the very least aligning CTD and trawl stations.
Some benefits of the NansClim project

• The NansClim project provided the framework for a region-wide discussion on ecosystem dynamics which projects examining the individual subsystems did not provide.

• The success of the project is also due to the way it was conducted, both in terms of integrating oceanographic, pelagic and demersal observations & research across all three countries.

• And in providing breathing space for stretched scientists through focussed workshops for analysis and writing.

• Regional competence building on ecosystem effects of climate change.

• The project has added considerably to our understanding of the relative influence of human versus environmental drivers.

• The present synthesis provides qualitative answers to questions raised regarding effects of climate variability in addition to identifying a number of knowledge gaps, which if resolved will contribute to reducing the uncertainty associated with predicting ecosystem effects of climate change.
Oceanography knowledge gaps

- Consistent hydrographic observations off Angola
- Understanding of impact of Congo river outflow on coastal ecosystem
- Monitoring of boundary zones in the Benguela
- Hydrographic observations on the south coast of South Africa.
- Continued analysis of wind/temperature observations given the continued discrepancy between major data sets, both satellite-based and in situ
- Large scale indices of circulation in the ocean basins surrounding southern Africa, e.g. shift of the large-scale drivers of climate, (Hadley Cell, S Atlantic High)
- Analyses on possible seasonality changes (in the long term), along the lines of “cold season got shorter off Angola” and “no change of seasonality in SHB”
- Retrospective analysis of ROMS model outputs forced by realistic winds
- Modeling transport of eggs and larvae under climate change scenarios

Pelagic subsystem knowledge gaps

- Horse mackerel spawning areas in Angola – comprehensive ichthyoplankton studies
- Implication of possibly changed seasonality on plankton phenology – has seasonality changed in from the zooplankton samples (complementing signals from oceanography data sets)? This will also need further analysis of existing zooplankton data
- Vertical exchange processes between pelagic and demersal habitats and communities
- Continued monitoring/analyses of life history characteristics of commercially important species, all subsystems
- Ecological understanding of mesopelagic fish and invertebrates

Demersal subsystem knowledge gaps

- Early life history of key demersal species
- Size-based analyses of range shifts, linked to resolving life history changes
- Biodiversity monitoring surveys, offshore and inshore, aimed at understanding climate change effects on demersal communities
- Studies further disentangling climate and fishing as drivers of biodiversity

Cross cutting

- Modelling studies with plausible future climate scenarios to be carefully designed and implemented. End-to-end modelling approaches to integrate bottom-up and food-web processes, evaluate effects of human pressures


Yemane, D., Kirkman, S., Kathena, J., Nsiangango, S.E., Axelsen, B. and Samaai, T. Assessing changes in the distribution and range size of demersal fish populations in the Benguela Current Large Marine Ecosystem. *Reviews in Fish Biology and Fisheries*. In review

Axelsen, B. and Johnsen, E. Review of the sampling methodology of the demersal trawl surveys in the BCLME region in the period 1985-2010.


Mhlongo, N., Yemane, D., Hendricks, M., van der Lingen, C.D. Have the spawning habitat preferences of anchovy (Engraulis encrasicolus) and sardine (Sardinops sagax) in the southern Benguela changed in recent years?


Wilhelm, M.R., Jarre, A. and Moloney, C.L. Spawning and nursery areas and longitudinal and cross-shelf migrations of the Merluccius capensis stock in the northern Benguela.
Acknowledgements

• All NansClim project members
• The Norwegian Agency for Development Cooperation is thanked for supporting/funding the NANSCLIM project
• South Africa’s Department of Agriculture Forestry and Fisheries, Namibia’s Ministry of Fisheries and Marine Resources and Angola’s Instituto Nacional de Investigação Pesqueira for data