Initial assessment of vulnerability of humans to the effects of climate change on the Benguela Current Large Marine Ecosystem (BCLME)

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Aim of study

Initial desktop study to assess from available scientific and socio-economic information:

1. How vulnerable the exploited fish resources of the BCLME are to climate change

2. How vulnerable industries, communities and individuals dependent on these resources are to climatically-induced changes in abundance and/or distribution of these resources

Major sources

- Biophysical Report:
  *Biophysical features and trends in the Benguela Current Large Marine Ecosystem (*Hampton, 2011*)*
- Fishing Industry Handbooks
- BCLME State of Stocks Review (Japp *et al.* 2007)
- Economic and sectoral study of the South African fishing industry (Sauer *et al*., 2003a, 2003b)
- Human dimensions of small-scale fisheries in the BCLME region (Sowman *et al.,* 2011).
- Socio-economic contribution of South African fisheries and their current legal, policy and management frameworks. (Hara *et al*., 2009)

Fisheries considered

Angola (BCLME region only)

- Industrial & semi-industrial purse seine fisheries for small pelagic fish (sardinella, horse mackerel, sardine)
- Artisanal fishery for above and many other species
- Trap fishery for deep sea red crab

Namibia

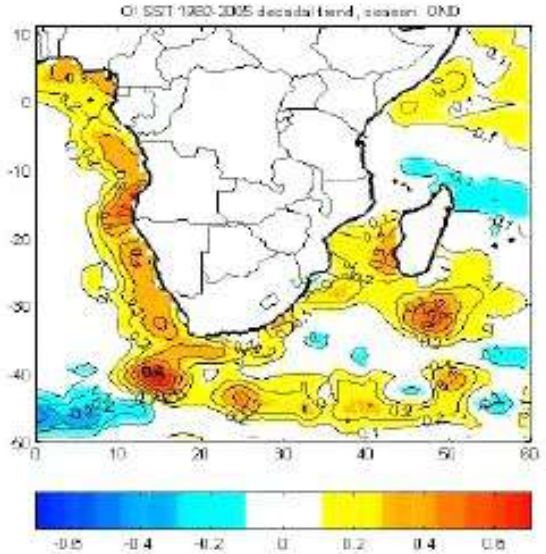
- Trawl fishery for hake and other demersal species
- Purse seine fishery for sardine (predominantly)
- Midwater trawl fishery for adult horse mackerel
- Line fisheries (hake, snoek, large pelagic fish)
- Trap fisheries for rock lobster and deep sea red crab
- Recreational fishery (kob, steenbras, galjoen)

Fisheries (cont)

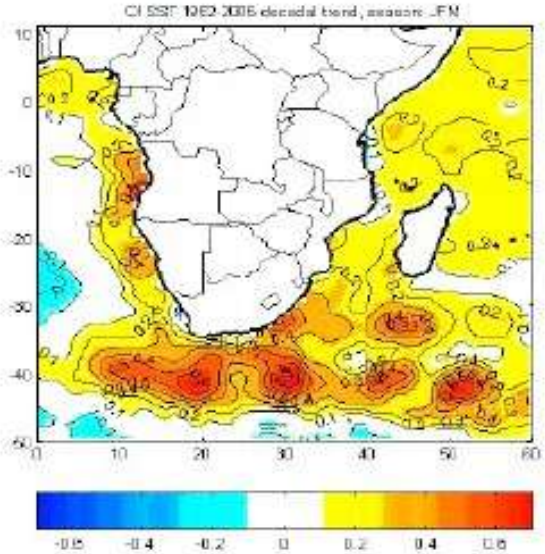
South Africa (BCLME region only)

- Trawl and long-line fishery for hake and other demersal species
- Purse seine fishery (sardine, anchovy, round herring)
- Midwater trawl fishery for adult horse mackerel
- Commercial, recreational and artisanal/subsistence line fisheries (snoek, kob, yellowtail, geelbek etc.)
- Rock lobster fishery (traps, hoop nets, dive)
- Offshore fishery for large pelagic fish (tuna, swordfish etc.)

OND



JFM



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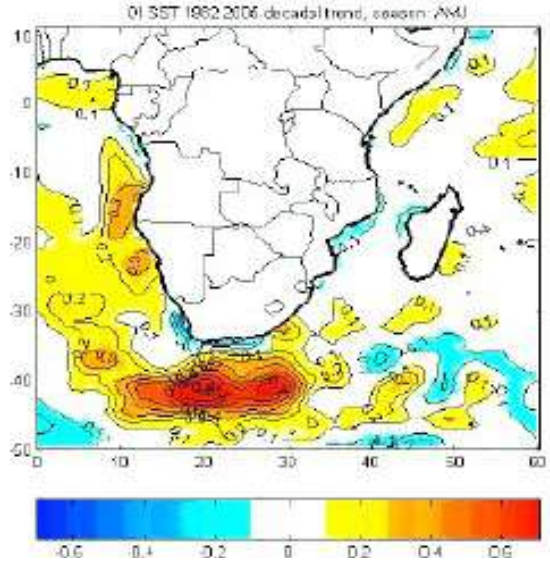
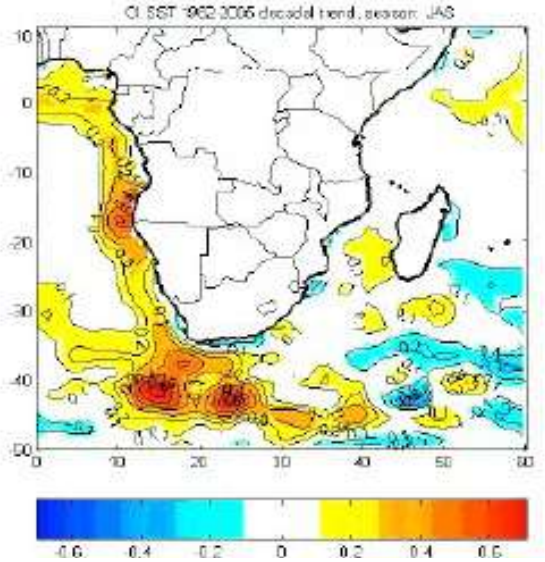
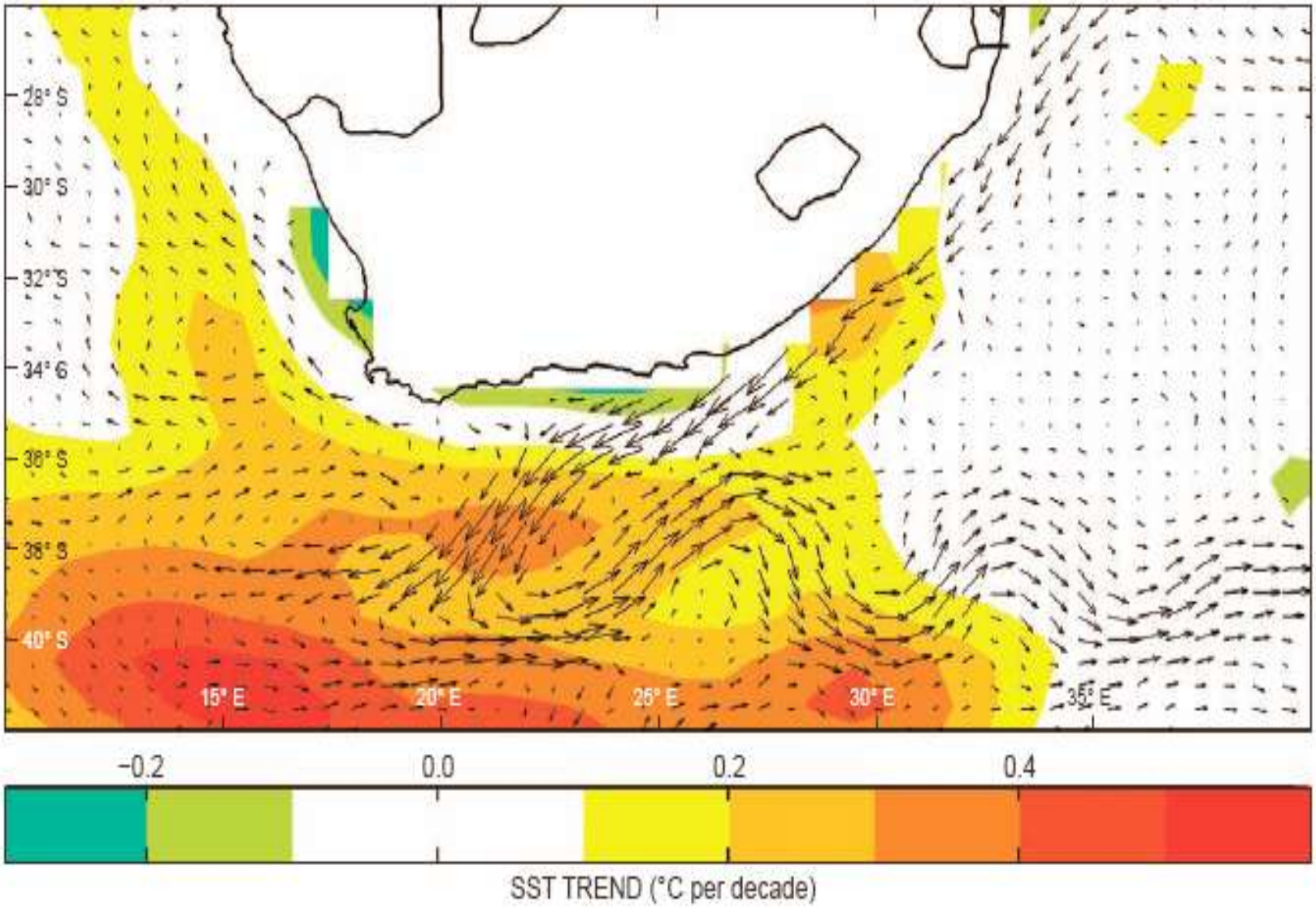


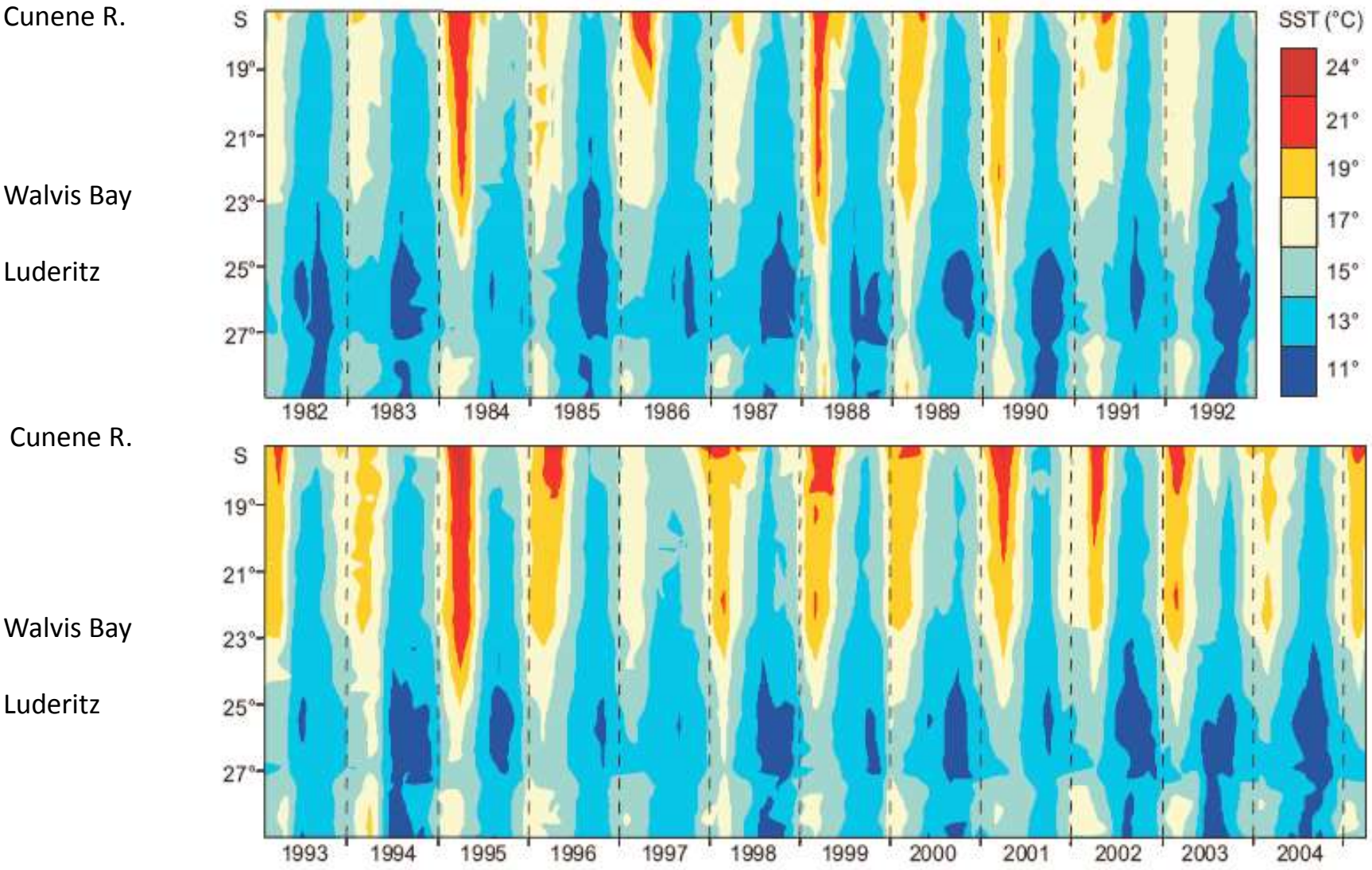
JAS



Trends in sea surface temperature 1982 – 2006, from satellite imagery (Rouault, 2007)



Decadal linear trends in sea surface temperature from satellite imagery (Rouault, 2010)

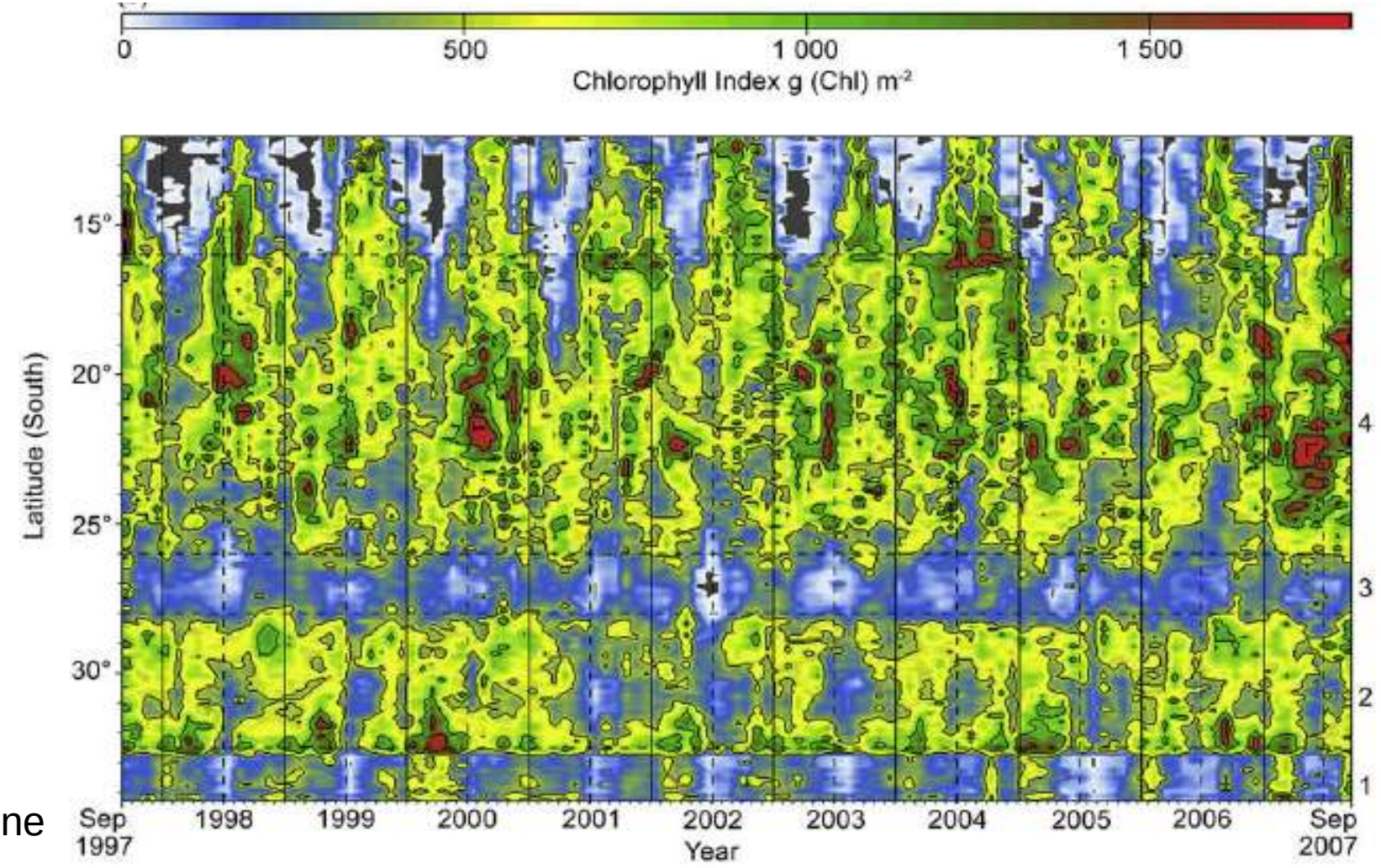


Monthly satellite-derived SST off Namibia, 1982 – 2004, averaged over 60 km wide strips (Bartholomae and van der Plas, 2007)

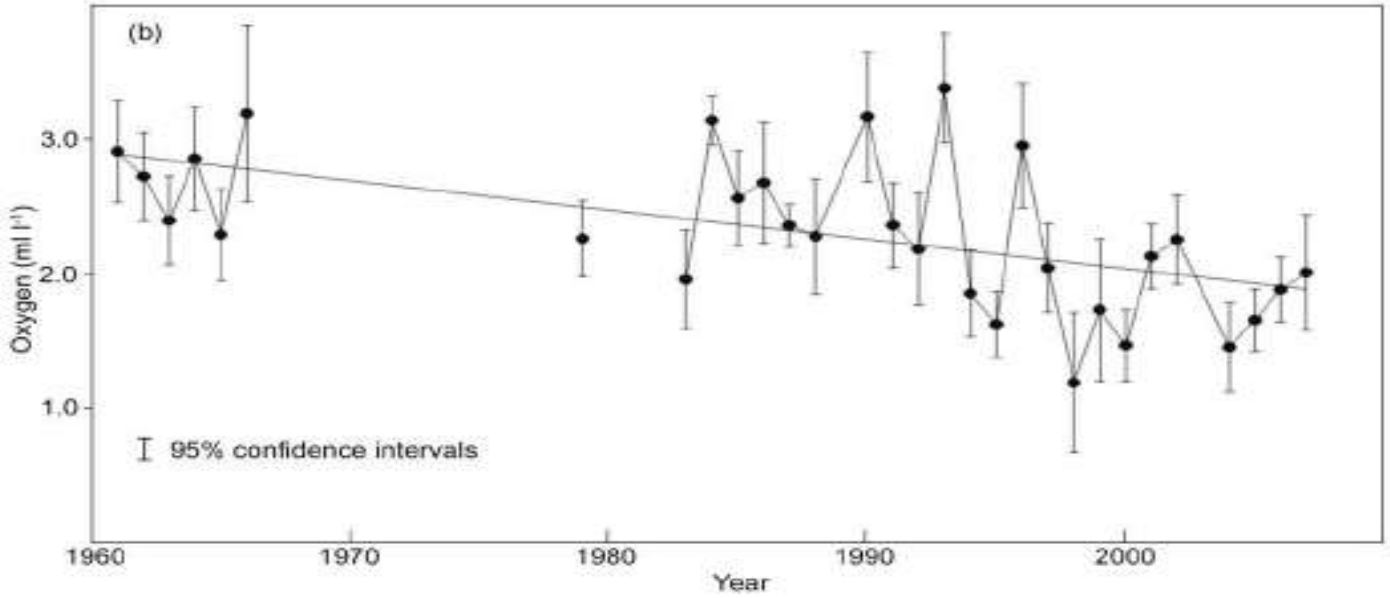
C. Frio

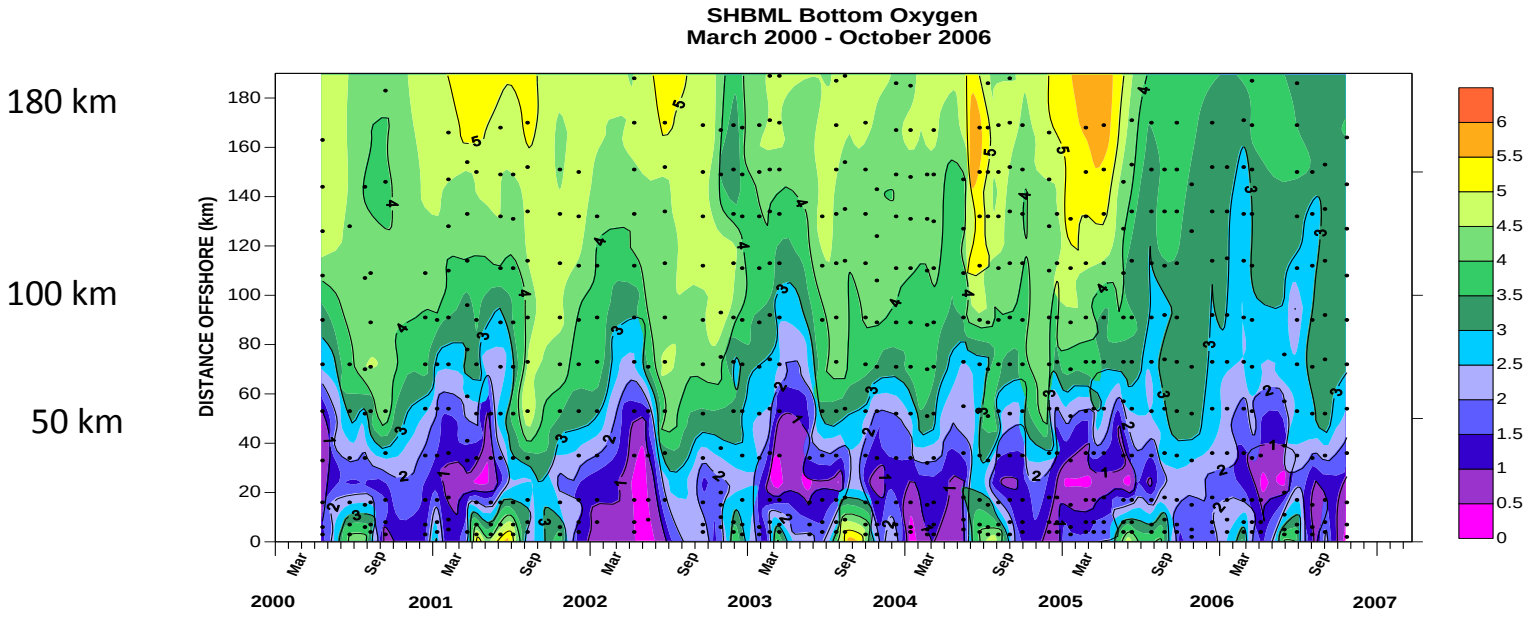
Luderitz

C. Columbine

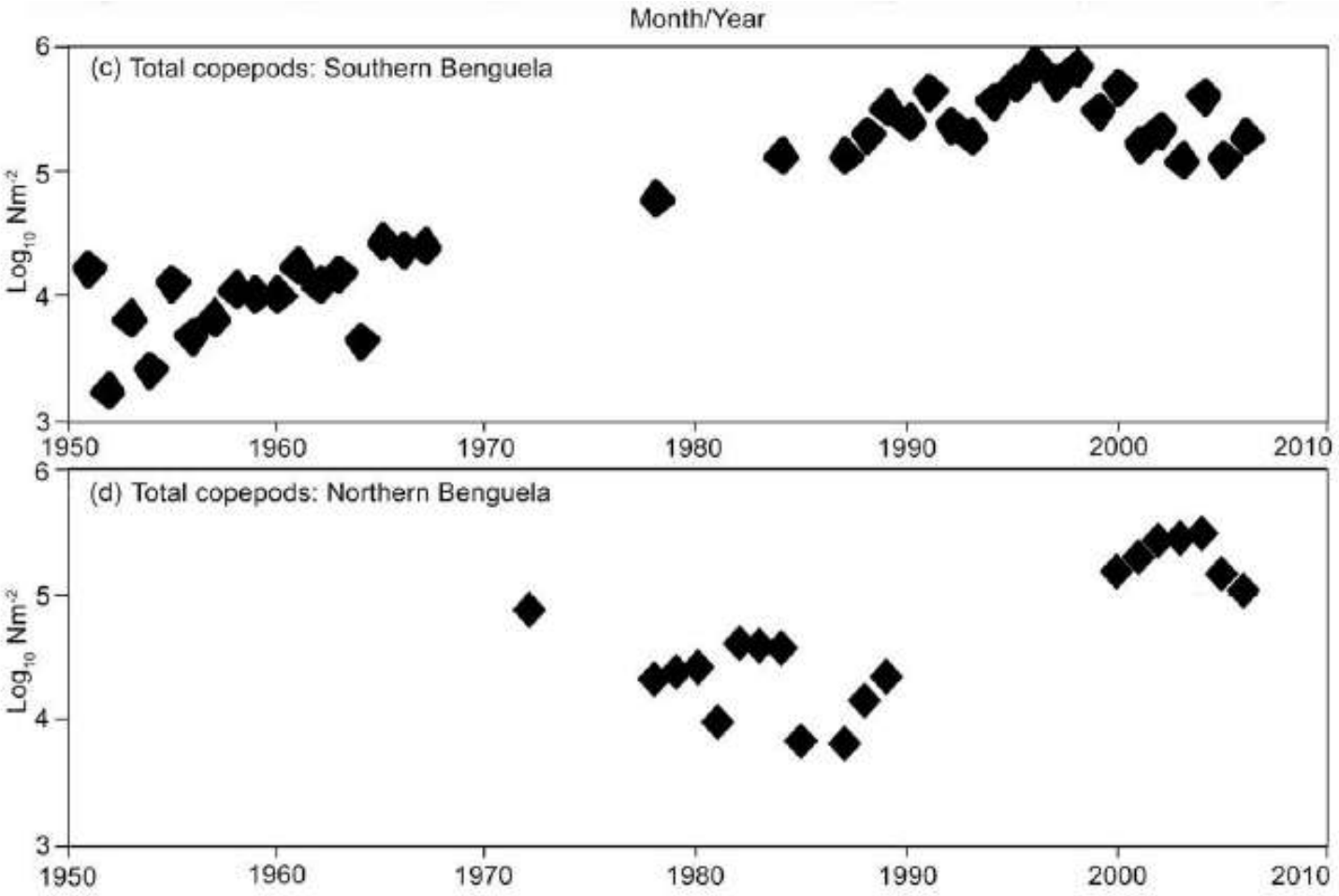


Mean chlorophyll *a* concentration from ocean colour (SeaWiFS) satellite data, 1997-2007 (in Hutchings *et al*., 2009)

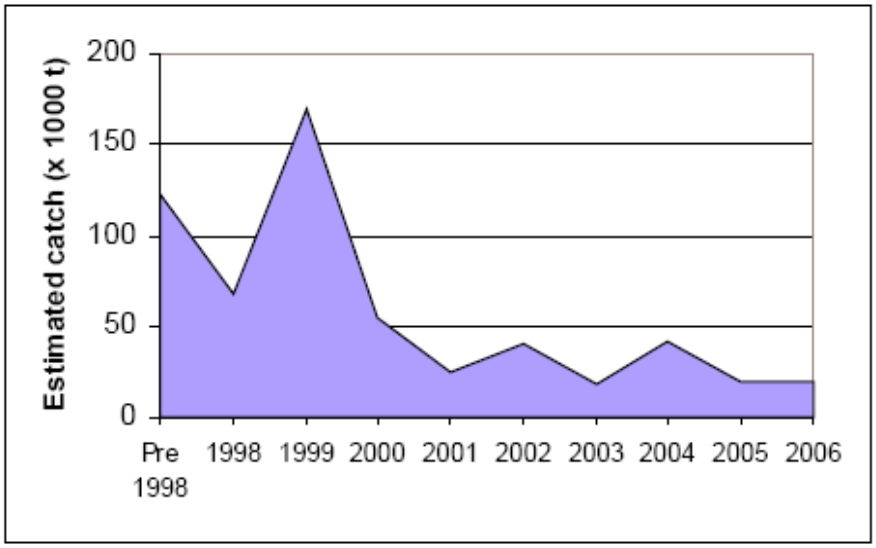


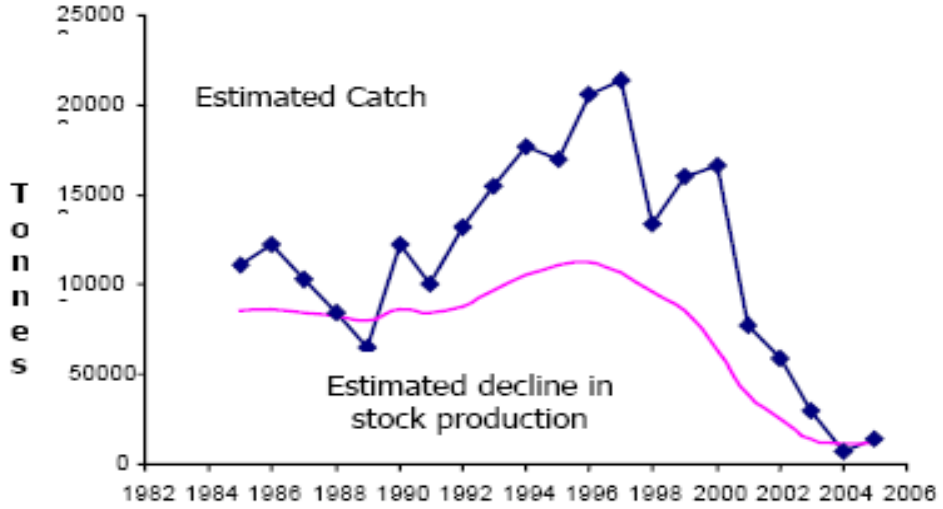


Trends in oxygen concentration below thermocline (upper) and on bottom (lower) on St Helena Bay monitoring line (Hutchings *et al*., 2009)

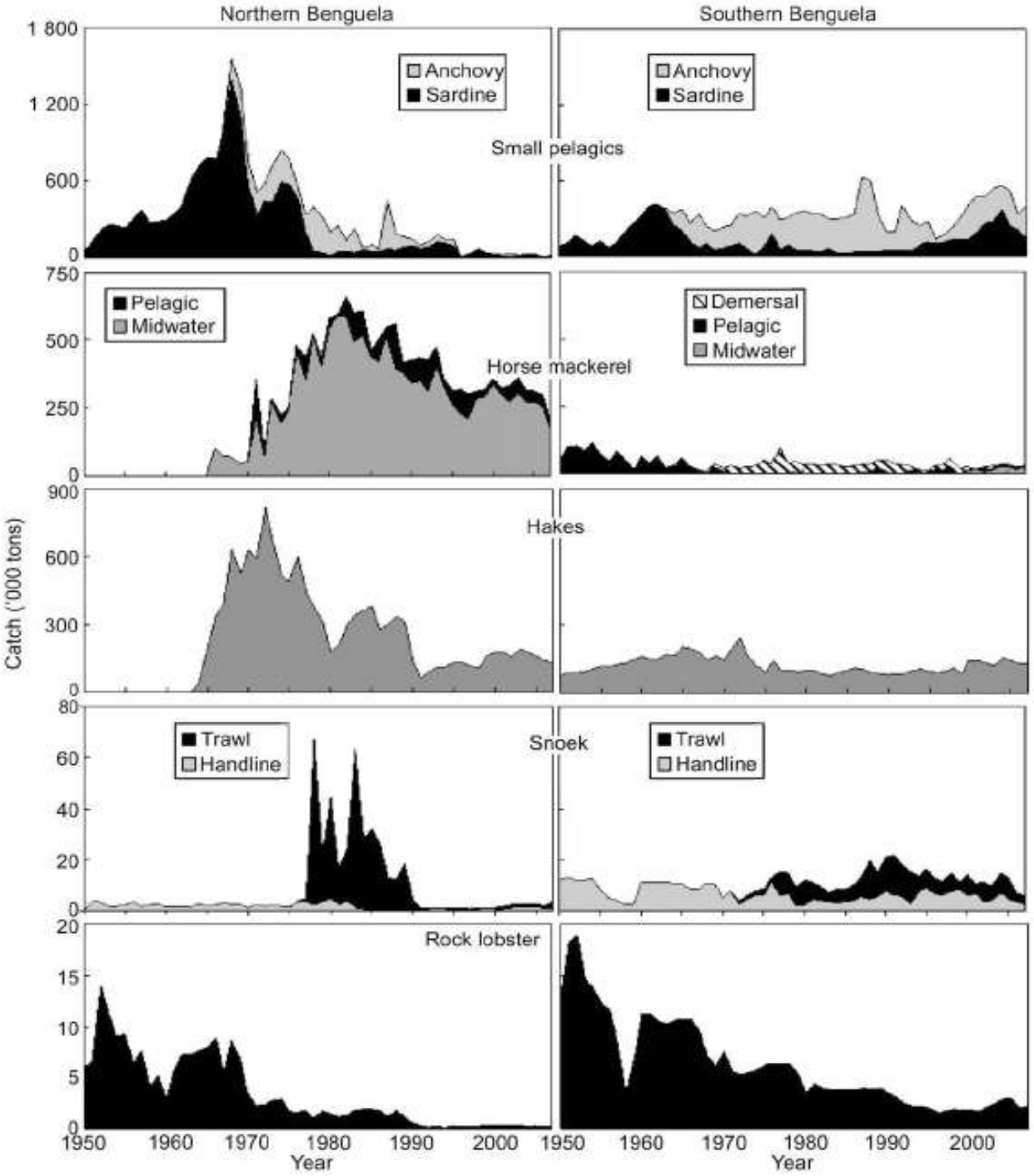


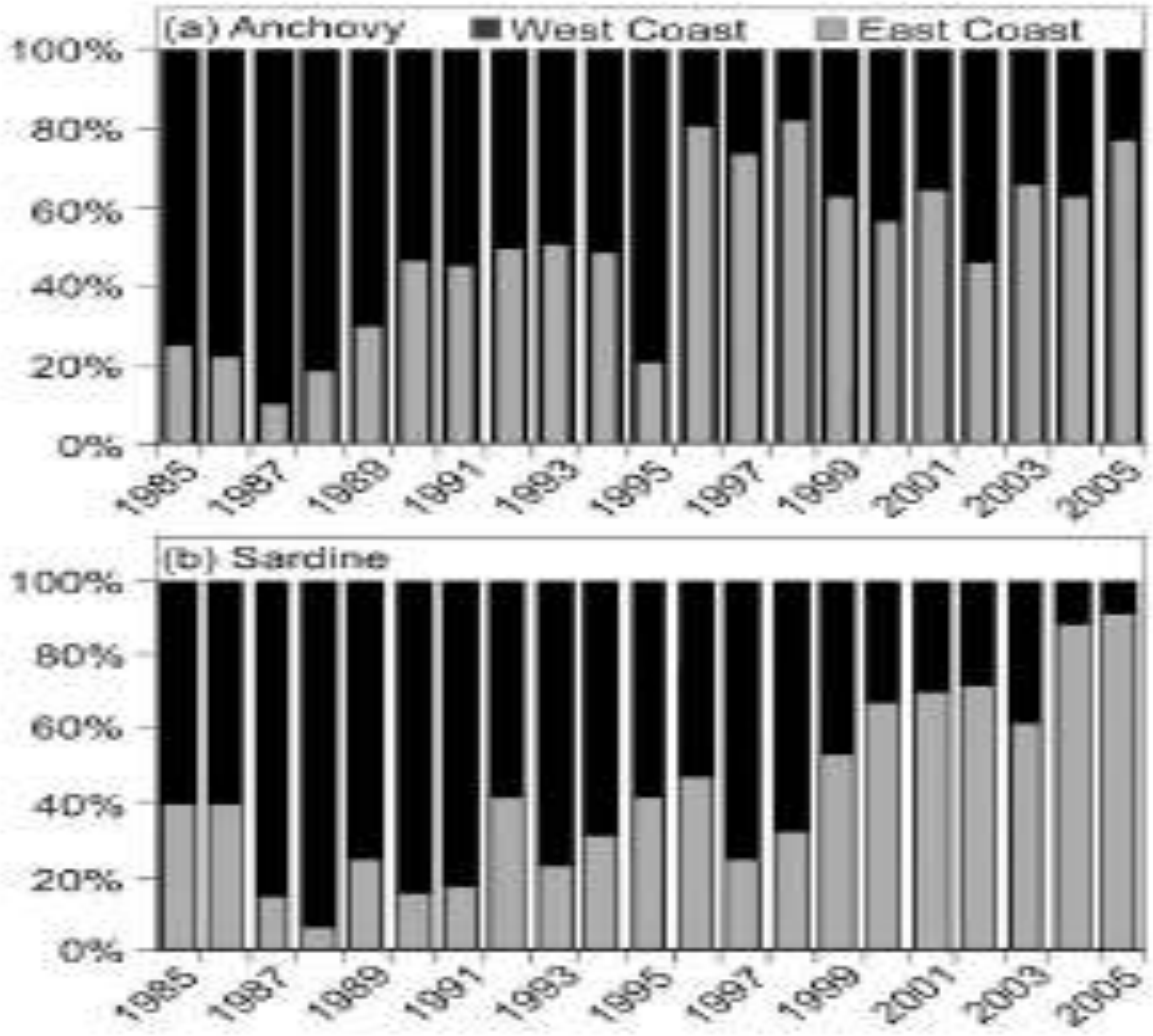
Trends in copepod abundance, Southern (top) and Northern (bottom) Benguela, 1950 – 2004 (Verheye *et al.,* 1998, Hutchings *et al.,* 2009)



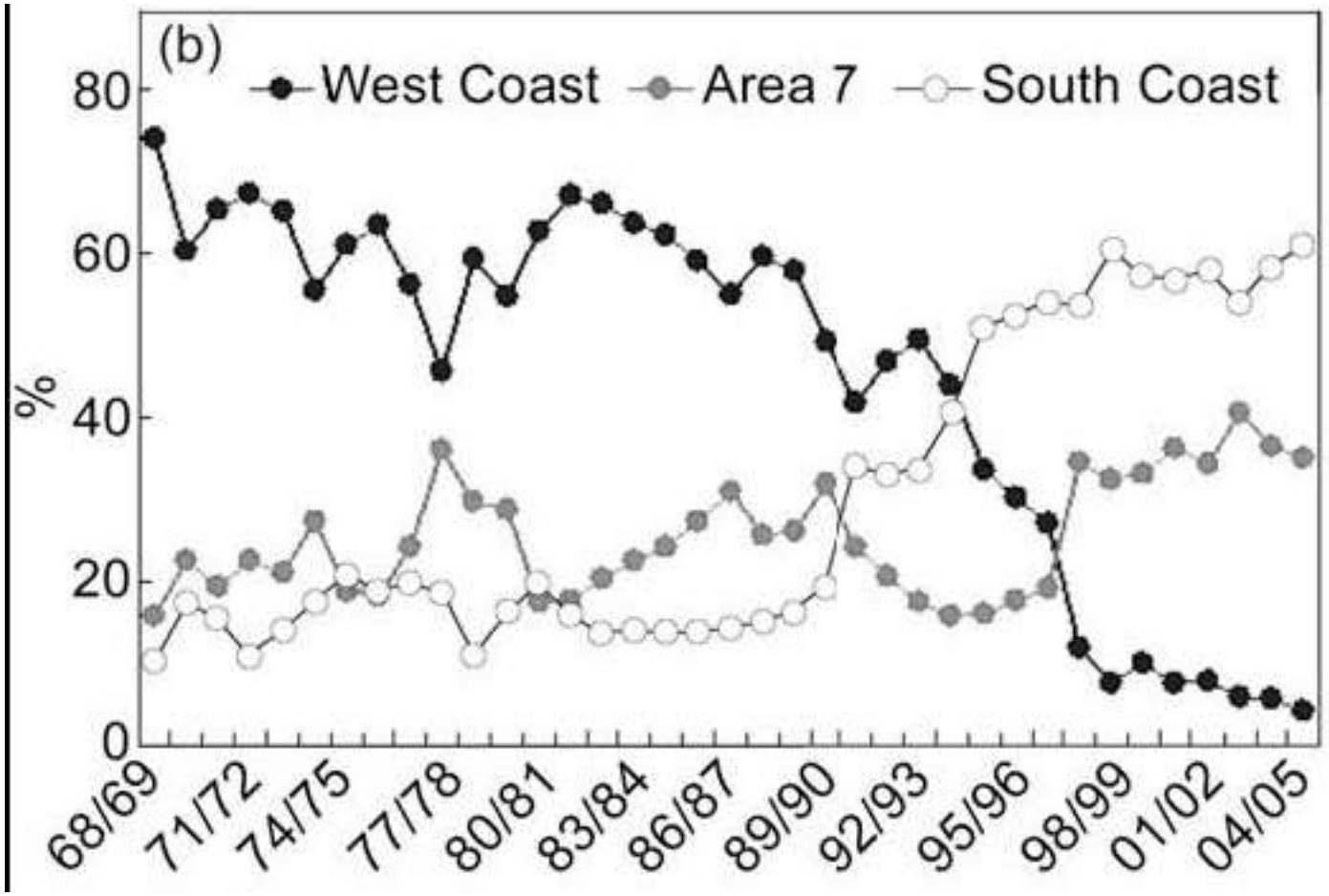


Angolan catches of sardinella 1998- 2006 (top) and horse mackerel 1982 – 2005 (bottom). From Japp *et al.,* 2007

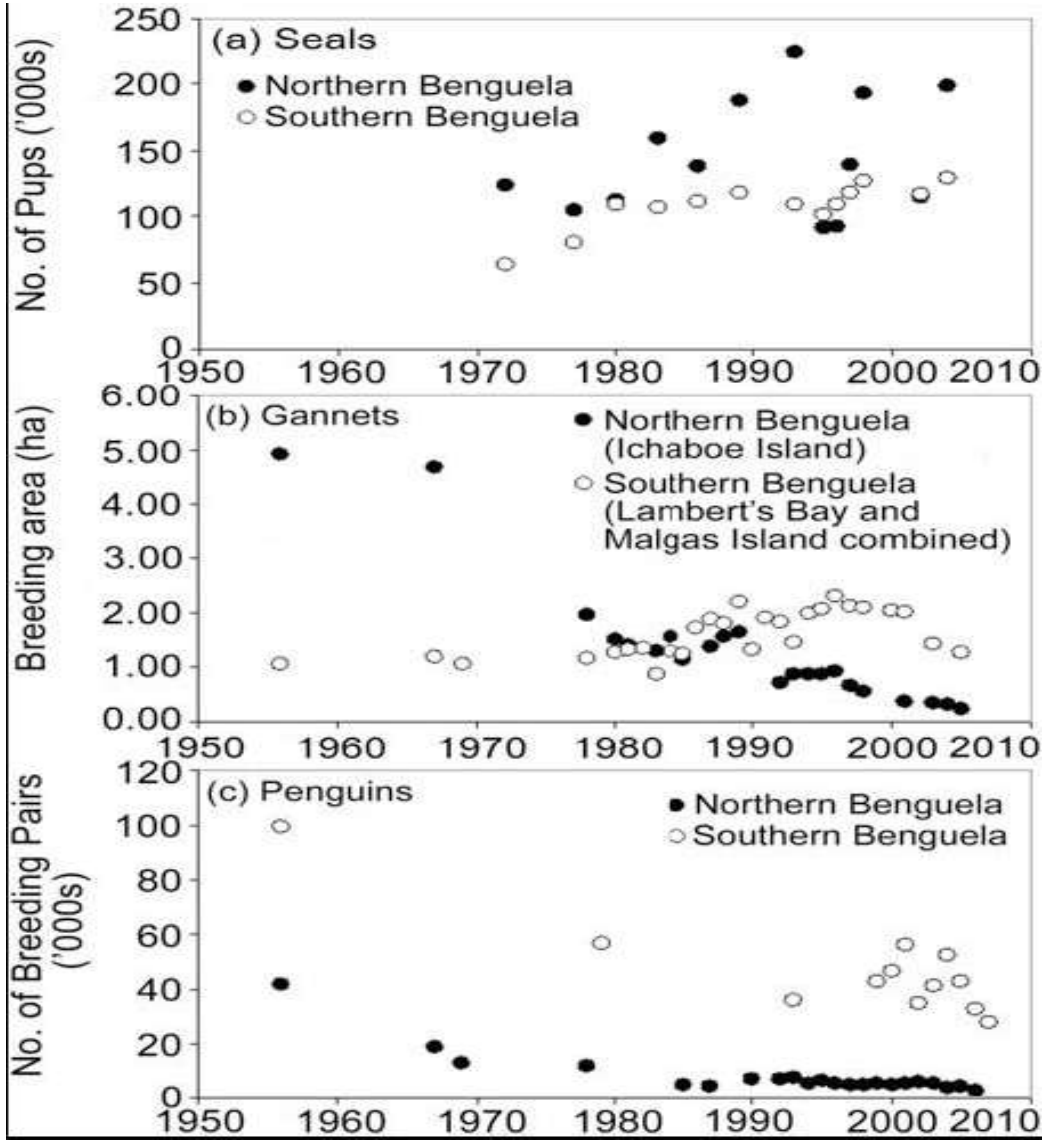

Northern Benguela
Southern Benguela
Anchovy
Sardine
Small pelagics
Pelagic
Midwater
Horse mackerel
Demersal
Hakes
Trawl
Handline
Snoek
Rock lobster
Catch ('000 tons)
Year
1 800
1 200
600
0
750
500
250
900
300
80
60
40
20
15
10
5
1950
1960
1970
1980
1990
2000



Shifts in anchovy (top) and sardine (bottom) biomass from west to east of Cape Agulhas between 1985 and 2005 (Coetzee *et al*., 2008)



Eastward shift in West Coast rock lobster catches, 1968 – 2005 (Cockcroft *et al*., 2008). Area 7 is centred on Dassen Island.



Changes in indices of top predator abundance in N. and S. Benguela, 1950 – 2010 (van der Lingen *et al.,* 2006, Hutchings *et al*., 2009)

Summary: long term trends

1. Most dramatic long-term change is major decline in exploited resources , primarily due to over-fishing, not environment.

2. Removal of sardine and anchovy from N. Benguela has led to possibly irreversible shift to less efficient, less resilient and commercially less productive regime. Eastward shift in distribution of sardine and anchovy in S. Benguela in past decade apparently now reversing – not a regime shift. S. Benguela more resilient than N. Benguela?

3. Widespread warming of surface water at both boundaries in past few decades and cooling inshore on W. and S. coasts of South Africa over same period → intensification of cross-shelf SST gradients in S. Benguela.

4. Intrusions of warm, low salinity and low oxygen water from north (e.g. *Benguela Niños*) most important perturbations in N. Benguela. Frequency increasing?

Trends (cont.)

5. General increase in upwelling-favourable winds in summer over past 3 decades, but very variable. N. Benguela currently in low phase. However, little evidence of large-scale changes in primary production in response to changing wind fields.

6. General decline in oxygen below the thermocline in St Helena Bay (primary monitoring site) over last 30 years. Symptomatic of S. Benguela?

7. Copepod abundance has increased 10 – 100 fold in both N. and S. Benguela in last 40 years, accompanied by substantial changes in size composition. Controlled from bottom up (environment) or from top down (predation) ?

8. Mean sea level rise of order of global average (1.8 mm per year). Not a threat (except to Walvis Bay ?), but

Prediction

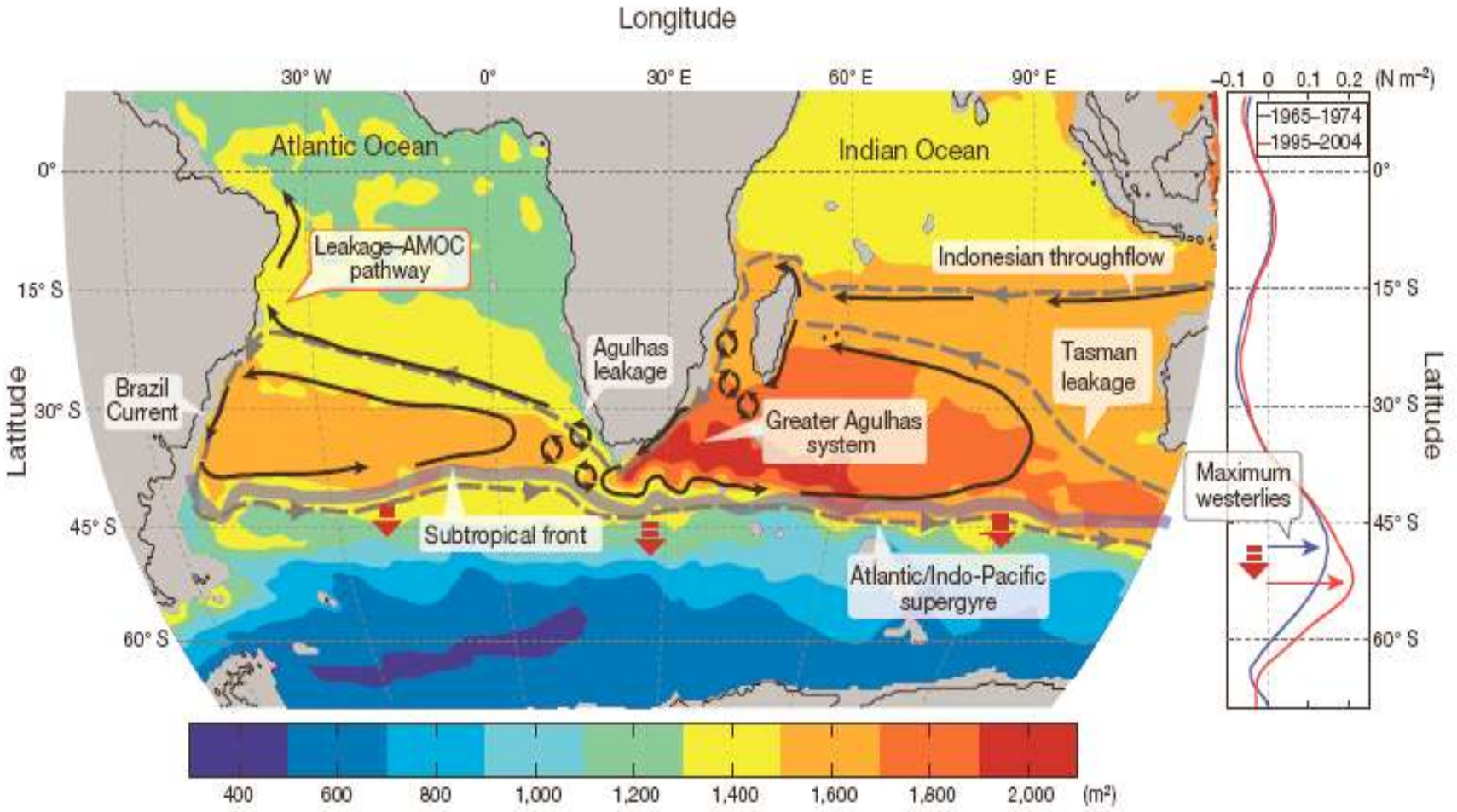
1. Because of wide-ranging natural variability, very difficult to detect long-term trends due to global climate change. Exception – long term warming at both extremes of system and cooling inshore on west and south coasts of SA (increased upwelling).

2. Despite decades of work, understanding of system responses to remote forcing is generally inadequate for prediction. Exception: intrusions of warm, low oxygen water from Angola into northern Benguela (e.g. *Benguela Niños)* may be predictable up to 2 months ahead. Connection to ENSO **(***El Niño/La Niña*) events in south-east Pacific now better understood.

3. Empirical evidence from previous responses of resources to above such events in Namibia could be useful in management.

4. Responses to future unprecedented environmental changes

An elephant in the room



Increased leakage of Agulhas Current water into south Atlantic in response to global warming (Beal *et al., Nature* 472, April 2011)

What is meant by “Vulnerability” ?

Following IPCC guidelines, it is a combination of:

1. Sensitivity - the degree to which the resource is likely to be affected by the indicated change.

2. Impact- the importance of the resource to humans in terms of:
   - Commercial value
   - Employment
   - Food security
   - Societal values

3. Adaptability - the degree to which industries and people dependent on the resource can adapt to changes in resource abundance and/or availability

Vulnerability assessment method

Sensitivity Index (SI): $1 \rightarrow 3$ (mild $\rightarrow$ severe)

Considered magnitude of environmental effect(s) on resource and likelihood of occurrence. Based on Biophysical Report.

Impact Index (II) Commercial value + employment + food security + societal importance. Each rated 0, ½ or 1.

e.g. Small scale line fishery in SA = 0 + 1 + ½ + 1 = 2.5

Adaptability Index (AI): $1 \rightarrow 4$ (highly adaptable $\rightarrow$ almost totally unable to adapt)

Vulnerability Index: = SI x II x AI

Fishery	Sensitivity		Impact					Adaptability	Vulnerability
	Environmental factors	SI	Value	Employment	Food security	Societal importance	II	AI	VI
Industrial pelagic	Movement of ABF *Benguela Niños* ENSO events Other factors ?	3	1	0.5	0.5	0	2	2	12
Semi-industrial pelagic	Movement of ABF *Benguela Niños* ENSO events Other factors ?	3	0.5	1	1	(0.5)	3	3	27
Demersal trawl	?	(2)	1	0.5	0.5	(0.5)	3	2	12
Crustaceans	?	(2)	1	0.5	0	0	1.5	2	6
Artisanal	Movement of ABF *Benguela Niños* ENSO events Other factors?	3	0	1	1	1	3	4	36

Vulnerability analysis, Angolan fisheries. SI = Sensitivity Index, II =Impact Index, AI = Adaptability Index, VI = Vulnerability Index.

Fishery	Sensitivity		Impact					Adaptability	Vulnerability
	Environmental factors	SI	Value	Employment	Food security	Societal importance	II	AI	VI
Demersal trawl	Warm water intrusions from north Increase in low oxygen water on shelf	2	1	1	0	0.5	2.5	2	10
Small pelagic	*Benguela Niños* ENSO events	3	0.5	0.5	0	0.5	1.5	2	9
Midwater trawl	Warm water intrusions from north Increase in low oxygen water on shelf	1	0.5	0	0	0	0.5	1	0.5
Line fishery	Increase in low oxygen water inshore	1	0.5	0.5	0.5	0.5	1.5	3	4.5
Rock lobster	Increase in low oxygen water inshore	1	0.5	1	0	1	2.5	4	10
Crab	Increase in low oxygen water on shelf	2	0	0	0	0	0	3	0
Recreational	Increase in low oxygen water inshore	1	0.5	0.5	0	0	1	1	1
Artisanal/subsistence	Increase in low oxygen water inshore	1	0	0	1	0	1	4	4

Vulnerability analysis, Namibian fisheries. SI = Sensitivity Index, II =Impact Index, AI = Adaptability Index, VI = Vulnerability Index.

Fishery	Sensitivity		Impact					Adaptability	Vulnerability
	Environmental factors	SI	Value	Employment	Food security	Societal importance	II	AI	VI
Hake (including long-line) and other trawled species	Increase in low oxygen water on shelf	1	1	1	0	0	2	2	4
Small pelagic	Increase in upwelling-favourable winds Increase in cross-shelf temperature gradient Increased influence of Agulhas current?	2	1	1	0.5	0.5	3	3	18
Large pelagic	Increased influence of Agulhas current?	(2)	0.5	0	0	0	0.5	2	2
Midwater trawl	Increased influence of Agulhas current?	(1)	0.5	0	0	0	0.5	2	1
Linefish (excluding hake long-line)	Increased influence of Agulhas current?	(1)	0	1	0.5	1	2.5	3	7.5
Rock lobster	Increase in low oxygen water inshore Environmental factors causing shift to South Coast ?	3	0.5	1	0	1	2.5	3	22.5
Recreational	Increase in low oxygen water inshore Increased influence of Agulhas current?	(1)	0.5	0.5	0	0	1	1	1
Artisanal/subsistence	Increase in low oxygen water inshore	(1)	0	1	1	1	3	4	12

Vulnerability analysis, South African fisheries. SI = Sensitivity Index, II =Impact Index, AI = Adaptability Index, VI = Vulnerability Index.

ANGOLA		NAMIBIA		SOUTH AFRICA	
Fishery	**VI**	**Fishery**	**VI**	**Fishery**	**VI**
Demersal trawl	M	Demersal trawl	H	Hake (including long-line) and other trawled species	L
Industrial pelagic	M	Small pelagic	H	Small pelagic	H
Semi-industrial pelagic	H	Midwater trawl	L	Midwater trawl	L
Crustaceans	L	Line fishery	M	Line fish (excluding hake long-line)	M
Artisanal	H	Rock lobster	H	Rock lobster	H
		Crab	L	Large pelagic	L
		Recreational	L	Recreational	L
		Artisanal/subsistence	M	Artisanal/subsistence	M

Qualitative Vulnerability Indices: Angola, Namibia and South Africa

NB: Compare within, but not between countries

Summary (Vulnerability)

- All indices subjective (especially SIs), but do give broad picture within countries
- Most vulnerable fisheries are those with a large number of people living in communities heavily dependent on fish for food, with almost no ability to adapt:
  - Artisanal and semi-industrial fisheries in Angola
  - Rock lobster fishery in South Africa and (less so) Namibia
  - Small-scale line fishery in South Africa
- Valuable hake fishery in South Africa not particularly vulnerable. Namibia's equally valuable hake fishery somewhat more vulnerable
- South African small pelagic fishery particularly vulnerable due to high value, low profit margins and sensitivity to environment

Adaptability

Some ways of adapting to reduced adundance or availability:

- Change target species
- Move fleet and/or personnel
- Improve catching, processing and distribution efficiency
- Improve product value
- Improve stability and skills of labour force
- Sell or move vessels or plant
- Import fish to preserve local markets
- Invest elsewhere
- Leave fishing

Large, highly-organised and capital intensive industries generally most adaptable.

Mitigation strategies

- More **research** aimed at better prediction of environmental changes and responses to them
- New **management** measures taking more account of environmental factors and uncertainty in them
- More **socio-economic studies** to improve understanding of human dimension and find new ways of mitigating negative effects
- New **economic measures** for mitigating effect of lower catches
- New **legislative and compliance** measures to ensure new management measures effectively implemented

Take-home messages

1. **BCLME very complex and naturally highly variable. Difficult to detect and predict responses to climate change at present. Situation unlikely to change soon.**

2. **Largest changes in system due to over-fishing, rather than environment. Therefore concentrate on managing fisheries better.**

3. **Low economic value, labour-intensive fisheries where fishers and dependent communities have little ability to adapt are the most vulnerable to climate change**

Recommendations

1. Refine and update Reports. (More information on Angola and Namibia).

2. Socio-economic study on Namibian and Angolan fisheries similar to sector study by Rhodes University (Sauer *et al*., 2003) on South African fisheries.

3. Aim medium-term research at detecting rather than predicting effects of environmental change. Combine with new ways of incorporating information rapidly into management strategies.

4. For small-scale fisheries, concentrate on finding socio-economic solutions rather than attempting to understand the environmental causes.