THE CHANGING STATE OF THE BENGUELA CURRENT LARGE MARINE ECOSYSTEM: EXPERT WORKSHOP ON CLIMATE CHANGE AND VARIABILITY AND IMPACTS THEREOF IN THE BCLME REGION

Dates: 15th - 16th May 2007 (with drafting of output document by a small group on 17 May)
Venue: Kirstenbosch Research Centre, CBC Conference Room, located in the Centre for Biodiversity Conservation.

Background and Rationale:

The Benguela Current Large Marine Ecosystem (BCLME) which borders the coasts of Angola, Namibia and South Africa at the eastern side of the South Atlantic is unique among comparable upwelling systems in that it is bounded on both northern and southern ends by tropical or sub-tropical regimes that have a significant impact on it. The Benguela is a highly productive but complex ecosystem – one that displays considerable environmental variability on several time and space scales, which is mirrored by variability in its living marine resources. Human impact on the BCLME, which includes fishing, pollution, mining and exploration for and extraction of oil and gas, is superimposed on the inherent natural variability of the ecosystem. Moreover, the flora and fauna of the Benguela and adjacent areas may be especially sensitive to long-term climate change as the region is situated at the choke point in the "global ocean climate conveyor belt", where, on time scales of decades to centuries, warm surface waters from the Indo-Pacific pass around Africa into the Atlantic. Indeed, it is thought that the BCLME may well be an early site for the manifestation of global climate change. Climate variability and change have the potential to alter the distribution and abundance of many Benguela species and cause the extinction of sensitive species, with consequential impacts on fisheries and tourism and the livelihoods of the coastal communities, who depend on these industries.

To date much of the focus of BCLME Programme (certainly of the environmental variability component) has been in documenting the *present* state of the ecosystem and short term variability, and undertaking work addressing system predictability. However, in order to ***establish a proper baseline*** against which to measure future variability and changes, it is necessary also to ascertain the extent of and trends in variability and change over the full period of record (50-100 years) . This is seen as an important element of the BCLME Programme – indeed was listed as a key policy action in the Strategic Action Programme which was endorsed by the governments of Angola, Namibia and South Africa, who saw the establishment of a baseline for the BCLME as a high priority regionally, and also important in the global context. Accordingly it is both appropriate and timeous to assess the long-term records within the context of climate change and variability.

Irrespective of one's views about the impact of the increase in greenhouse gasses, such as carbon dioxide, in the atmosphere on the climate of the earth, the fact is that our planet has been warming for many decades, and that since 1955 the oceans' net heat uptake has been 21 times that of the atmosphere. There is now substantial evidence that ocean temperatures have been rising, with the global ocean heat content estimated to have increased by 14.5×10^{22} joules between 1955 and 1998, equivalent to an average warming of the entire ocean by 0.037°C. Global sea level rise over the same period is 1.8 ± 0.3 mm yr^{-1}, with a faster rate measured since 1993 by satellite. The country reports prepared by both Namibia and South Africa as input to the United Nations Framework Convention on Climate Change highlight the vulnerability of the marine environments to climate change, including *inter alia* migration and displacement of marine species, changes in ocean currents and the frequency of upwelling, increases in the occurrence of harmful algal blooms as well as the impact of sea level rise on low-lying coastal towns.

While there is no absolute proof that climate change is directly implicated in the variability and change that has been observed in the BCLME over the past half century, there is a growing body of evidence (refer to Appendix I at end of document) which suggests that a change in state of the ecosystem may have taken place. Some examples:

- Both oceanography and ecosystem studies show that components of the BCLME have been displaced poleward and eastward. For example, the changes in SST over the past 25 years strongly suggest this, as do changes in the abundance and distribution of a number of living marine resource species and marine predators. There has been a southward and eastward displacement in the distributions of key harvested species (sardine, horse mackerel, Cape rock lobster) and dominant predators during the past decade or so.
- There has been an increased frequency of warm events (which include *inter alia Benguela Niños*) in the northern Benguela, decreased upwelling in the north, changes in stratification, increased coastal upwelling on the west and south coasts in the southern Benguela, changes in the retroflection area of the Agulhas Current and significant warming in this region, which may indicate that the Current has intensified or that the retroflection point has shifted. Some of these aforementioned changes are compatible with general circulation, i.e. climate, model outputs.
- A "regime shift" appears to have taken place in the BCLME pelagic ecosystem, which includes the switch in the northern Benguela from a sardine/anchovy dominated system to one where other species of lesser value predominate, in particular jelly fish.
- There is a perception that there has been an increase in the scale of sulphur "eruptions" in the northern Benguela, which has had impacts at both local and ecosystem levels.

- There is a perception that hypoxia in the BCLME increased over the period of record and that this influenced the substantial decline in abundance of rock lobster, which did not respond in the central Benguela to precautionary management as might have been anticipated, the decreased growth rates of lobsters and the failure of the Namibian hake stocks to recover fully from earlier over-exploitation, again in spite of conservative management by the Namibian authorities.

Whether or not the changes are a consequence of climate change or are part of one or more natural cycles, which may be superimposed on a slowly changing climate, remains unanswered. However, the body of evidence that climate change or variability is implicated is growing. What we need to do is to document properly the available long term records and then assess to what extent the observed variability and change in the BCLME can, with more certainty, be ascribed to climate change as opposed to inherent natural climate variability *per se* and the effects of fishing. This is a non-trivial exercise, but the Workshop is a first step in addressing the issue. Please read Appendixes I and II at the end of this document when preparing for this Workshop.

Workshop Theme:

Documentation and assessment of decadal scale variability and changes in the greater BCLME region during the past 100 years – causes, linkages, effects and mitigation strategies to minimize risks in a highly variable system

Workshop Key Questions:

1. Is there evidence of climate change and its impacts in the Benguela, or is the longer term (decadal) variability/change that is evident in the physical environment and biota purely an artifact of cyclical processes or fishing?
2. What are the potential consequences of climate variability and change which pose threats to sustainable management of the BCLME and/or to socio-economic progress in the region?
3. Are there any apparent trends in extreme events in the BCLME?
4. What are the critical processes within the BCLME that are already demonstrating instabilities of concern (cf. whether a possible "tipping point" has been reached)

NOTE**:** ***Question 2 will not be addressed in presentation and discussions on Day 1, but will be covered in Days 2 & 3.***

Objectives:

The objectives of the Workshop are as follows:

1. Document, from all available data and information sources, the decadal and longer period variability/changes in the ocean-atmosphere environment of relevance to the BCLME and document changes/variability in living marine resources, top predators and at the ecosystem level in the BCLME as may be reliably extracted from available records

2. Examine these long-term records, extract from these trends and/or significant variations (e.g. shunts or steps) and assess or re-assess whether there is clear evidence in the record for change on decadal and longer timescales
3. Assess whether there are any apparent trends in the extreme events which have occurred in the BCLME (including ocean and atmosphere) over the period of record
4. Assess whether the decadal and other variations or changes as may be evident from the abiotic data (ocean and atmosphere) can be reliably attributed to climate change (global warming) or otherwise loosely associated with climate fluctuations in the South Atlantic and South Indian Oceans – i.e. examine the records within the context of any possible climate change effects
5. Make the assumption that there is no environmental forcing of the ecosystem, then assess whether the changes/fluctuations that are apparent in the resources, top predators or at the ecosystem level can be ascribed solely to fishing and other anthropogenic (but not greenhouse gas driven) causes
6. Assess whether the changes that have been observed in the biota in the BCLME are associated with any decadal or other longer term fluctuations in the ocean-atmosphere system around South Africa – i.e. consider whether the biological changes can in any way be as a consequence of or in response to climate variability/change over the period of record
7. Assess the potential consequences of climate variability and change which pose threats to sustainable management of the BCLME and/or to socio-economic progress in the region
8. Assess whether there are critical processes within the BCLME that are already demonstrating instabilities of concern (cf. whether a possible "tipping point" has been reached)
9. Document fully all available information relating to decadal and long-term changes/variability in the BCLME and possible causes and consequences thereof which might be of relevance to resource and ecosystem managers in the BCLME region and which may be of relevance to them in developing adaptation strategies or mitigating possible irreversible changes in the ecosystem
10. Identify possible mitigation strategies to minimize risks arising from system/environment variability and/or change
11. Gain consensus on and document and prioritise important (outstanding) issues and gaps in knowledge
12. Document the essential steps which should be taken in respect of putting in place an affordable, implementable and sustainable ocean observing system for the region
13. Lay the foundation for future problem-orientated ocean climate change-related research in the three BCLME countries

In a nutshell then, bullets 1-3 address what has changed, by how much and at what rate; bullets 4-6 address issues relating to the drivers of change; bullets 7-10 address the consequences of change and mitigation strategies; bullets 11-13 provide a foundation for future actions.

Outputs and Deliverables:

The products of the workshop will be as follows:

1. A CD ROM which comprises (a) the invited overview papers (b) summaries of the envisaged specialist (parallel) sessions (c) a synthesis of the identified gaps, issues and uncertainties which are of relevance to both management and science (d) consensus on issues relating to climate change/variability and its impacts in the BCLME, and recommendations for work that is needed to provide answers and generate useful results within the next five years to help guide managers, funders and researchers
2. A Workshop Report i.e. quality reader-friendly product suitable for publication as a BCLME Programme report and on the BCLME website

Workshop Structure:

In a nutshell:

Day 1 (15th May): Overview presentations and discussions thereon – in plenary (i.e. mainly what we know or think we know!)
Day 2 (16th May): Specialist Sessions (in parallel and/or in sequence) – i.e. mainly what we don't know, got wrong, issues, gaps, priority actions needed etc – followed by report backs in plenary
Day 3 (17th May): Drafting of Workshop Report

PROGRAMME

Day 1 (15th May) : 08:15 - 17:30
Venue: Centre for Biodiversity Conservation

After each presentation there is a 5 minute period for discussion.

08:15 - 08:45	Registration and tea/coffee
08:45 - 08:50	Welcome: Michael O'Toole
Session 1	**Chairman:** Vere Shannon
08:50 - 09:15	Global warming and upwelling systems (George Philander)*
09:20 - 09:45	Trends in southern African climate – observations and findings of the IPCC (Bruce Hewitson)*
09:50 - 10:05	Climate change and variability in Southern Africa – a perspective from the SA Weather Service (Deon Terblanche, William Landman and Warren Tenant)
10:10 - 10:25	Modelling capacity in the South African Weather Service and how weather systems over the Benguela are affected by climate variability and how they may be in a future climate regime (Warren Tennant)
10:30 - 11:00	Tea/coffee
Session 2	**Chairman:** George Philander
11:00 - 11:25	Variability and change in the BCLME on decadal timescales – an overview (Larry Hutchings)*
11:30 - 11:45	Climate variability in the South Atlantic and South Indian Oceans of relevance to the Benguela region (Chris Reason)
11:50 - 12:05	Observed trends in the oceans and atmosphere around southern Africa over the past 50 years (Mathieu Rouault)
12:10 - 12:25	Hypoxia variability in the Benguela: are there long-term trends? (Pedro Monteiro, Anja van der Plas, Pierre Florenchie, Jean Luc Melice and Warren Joubert,)
12:30 - 12:45	The Namibian record. Part 1 - Environment (Chris Bartholomae, Anja van der Plas and Kathy Noli-Peard)
12:50 - 13:50	Lunch
Session 3	**Chairman:** Neville Sweijd
13:50 - 14:05	The Namibian record. Part 2 – Resources (Anja Kreiner and J-P Roux.)
14:10 - 14:25	The Angolan record (Quilanda Fidel)
14:30 - 14:45	Decadal changes in distribution and species composition of plankton in the BCLME (Hans Verheye and Grant Pitcher)
14:50 - 15:05	Patterns of variability in pelagic resources in the southern Benguela (Carl van der Lingen and Janet Coetzee)
15:10 - 15:25	Changes in the distribution and productivity of the west coast rocklobster over the period of record (Andy Cockcroft)
15:30 - 16:00	Tea/Coffee

Session 3 continued	**Chairman:** Michael O'Toole
16:00 - 16:15	Predators tell their own story! (Robert Crawford, S Kirkman, LG Underhill, JP Roux, WH Oosthuizen and J Kemper)
16:20 - 16:35	The Benguela Ecosystem prior to and after the onset of large scale commercial fishing (Kate Watermeyer)
16:40 - 16:55	Is there evidence of climate driven change/variability in the BCLME at the ecosystem level? (Astrid Jarre)
17:00 - 17:15	The importance of an appropriate observing system (John Field)
17:20 - 17:30	**CLOSING** (Michael O' Toole)

* Presentations are from the 3 Keynote invited guests

Day 2 (16th May): Specialist Sessions : 09:00 - 17:00
Venue: Session 1 - Centre for Biodiversity Conservation
Session 2 - Freylina Meeting Room in CBC Centre

Note: Detailed approach and plans, questions to be addressed, key participants, presentations, actions etc to be provided by the relevant Session Leaders

Specialist Session 1: Climate variability and change in the oceans around southern Africa: Are there any definite trends, including in extremes? (Discussion Leaders: Frank Shillington and George Philander)
Specialist Session 2: Decadal changes and trends in resources, predators and at the ecosystem level (Discussion Leaders: John Field and Robert Crawford)

Plenary Report-backs, Integration and Discussion Session: To what extent has climate variability and/or change impacted on the BCLME, and what needs to be done (cf. mitigation strategies)? What are the potential consequences of climate variability and/or change which pose threats to sustainable management of the BCLME and/or socio-economic progress in the region: Is the system becoming unstable; has a tipping point been reached? (Discussion Leaders/Panel: Pedro Monteiro, Michael O'Toole, Larry Hutchings, Astrid Jarre and Vere Shannon)

10:30 - 11:00	Tea/coffee
13:00 - 14:00	Lunch
15:30 - 16:00	Tea/coffee

Day 3 (17th May): Synthesis and Way Ahead : 09:00 - 17:00
Venue: Golden Mole Meeting Room in CBC Centre

This will be undertaken jointly by a small group who will synthesize the findings of the Workshop and prepare the Workshop Report. (Note that the Report will be circulated to all Workshop participants.)

10:30 - 11:00	Tea/coffee
13:00 - 14:00	Lunch
15:30 - 16:00	Tea/coffee

Workshop Administration and Direction

Administration and organization: EVAC (Director: Ms Lesley Staegemann)
Workshop Leaders: Larry Hutchings, Vere Shannon and Pedro Monteiro
Publications: Claire Attwood

Appendix I: Variability and Change in the Benguela during the Past Half-Century *(extracted from a recent article drafted by* ***Vere Shannon, Rob Crawford and Larry Hutchings****)*

The following are some examples of variability and changes that have occurred in the Benguela environment, its living marine resources and the ecosystem, as well as the socio-economic impacts thereof, during the past half century or so:

Variability and Change in the Physical Environment

There was a rise in sea surface temperature (SST) in the coastal and offshore areas of the BCLME of, on average, approximately 1°C between 1920 and 1990. Close examination of high resolution SST records from 1982 to present reveals some interesting features: an increase of 0.13°C for the South Atlantic as a whole, of 0.8-1.0°C in the northern Benguela in the vicinity of the Angola-Benguela Front (near the Angola-Namibia geopolitical border), of approximately 1.0°C in the Agulhas retroflection area near the southern boundary of the BCLME, and a SST *decrease* of 0.2-0.3°C near the coast in the southern Benguela. In the Southern Ocean there has been substantial warming in the upper 400m near 40°S, mid-water temperatures have increased, and Antarctic Intermediate Water has freshened (become less saline).

Benguela Niño events (major episodic, but protracted, southward intrusions into the Namibian part of the BCLME of warm tropical water, which are generally preceded by sudden relaxation of zonal winds along the equator) occurred on average every 10 years during the 20th century. Well-documented *Benguela Niños* were those of 1934, 1963, 1984 and 1995. The counterpart of *Benguela Niños, Benguela Niñas*, are cold events, of which those in the early 1980s (which preceded the 1984 *Benguela Niño*) and 1997 were perhaps the most intense. In the southern Benguela, several warm and cold events have been documented, e.g. the warm event of 1983 (which was linked to the major ENSO of that period), the intrusions of warm Agulhas Current water which occurred in 1992, in 1997/1998 and early in the 21st century, the influx of Sub-Antarctic water into the BCLME in 1986/87 and cooling in 1987. .

Sea level as measured by tide gauges around the coast of southern Africa shows an increase of 1.2mm per year over a three-decade period, a figure not that dissimilar to the global average. This suggests that the projections of the International Panel on Climate Change (IPCC) for sea level rise in the 21st century can be used with some degree of confidence in the BCLME. So, unless there is some catastrophic event which results in a sudden elevation, sea level rise is not likely to be a significant factor in the BCLME in the short to medium term.

Concentrations of dissolved oxygen in the water column vary spatially and temporally, with oxygen deficiency or depletion being characteristic of bottom and mid-waters over the shelf in the northern Benguela and, seasonally (late summer – autumn), in the St Helena Bay area in the southern Benguela. A major hypoxic (low oxygen) event occurred in the northern Benguela during 1993 and 1994. This was implicated in the recruitment failure of Namibian hake in the early 1990s, which effectively negated careful management efforts to rebuild the hake stocks in the northern Benguela. Frequent "eruptions" of hydrogen sulphide have occurred along the coast of Namibia, which further deplete the oxygen content of shelf waters, are toxic and result in mass mortalities of fish.

Variability in the Biological Environment

High variability over the time scale of days to weeks, at small and medium spatial scales, makes it difficult to examine long-term changes in plankton in South African waters. However, more higher trophic level resources (fish and top predators) are adapted to the high short-term variability through longevity, seasonal migration and opportunistic behaviour, i.e. flexibility in response to forcing functions. Inter-annual variability is apparently much less than short-term variability, as annual measures as wind forcing, heating or mean current strength rarely depart from 10-20% of the long-term mean.

Seasonal cycles in the surface expression of phytoplankton biomass are apparent from satellite imagery. These are superimposed on the event-scale perturbations in the coastal upwelling and south coast shelf areas. Interannual trends are weakly apparent, e.g. winter of 2001 on the Namaqua shelf area which lies to the south of the Namibia – South Africa border. Decadal changes on the west coast from sparse data from shipboard surveys indicate an increase in phytoplankton abundance over the period 1980-2000, but these could be artefacts of the sampling locations and frequencies due to poor coverage.

The abundance of copepods (crustacean zooplankton) during April-June in St Helena Bay indicates a 100-fold increase from 1950 to 1995, followed by a subsequent sharp decrease. This change is most marked for the large copepods and may be related to the changes in pelagic fish abundance and species composition. In addition the seasonal cycle of zooplankton biomass has altered from 1977/78 to 2000/04. Zooplankton has increased by about an order of magnitude in summer from 1 to 10 ˚C m^{-2} with a 5-10 fold seasonal variation recently, compared with a two-fold variation in 1977/78. Little is known about long-term changes for other areas along the Benguela coast, although preliminary indications are that copepods are more abundant off Namibia than they were two decades ago.

Frequent blooms of harmful algae (HABs) "red tides" occur in the BCLME. It is not clear whether these HAB events are increasing in frequency, or whether they are associated with climate change in the Benguela at this stage. Their consequences have, however, been very negative.

Changes in Living Marine Resources and the Ecosystem

Off Angola, catches of horse mackerel shifted southwards in warm years preceding 1976, then northwards during a cool period ending in 1983. From 1984, the abundance of horse mackerel over the Angolan shelf increased during warm events. The distribution, and hence availability to fisheries, of two species of *Sardinella*, important contributors to the purse-seine catch, also is influenced by warm water intrusions, as well as the Congo River plume.

There has been a large decrease in epipelagic fish resources in Namibia. In the 1960s, the Namibian purse-seine fishery for sardine was one of the most productive fisheries in the world. Catches totalled 7.5 million tons in this decade, but fell to 3.9 million tons in the 1970s, 0.6 million tons in the 1980s and 0.7 million tons in the 1990s. Following the collapse of the sardine in Namibia, there was only limited growth of the anchovy there. Most of the production appears to have been transferred to the mid-water, with likely large increases in horse mackerel and pelagic gobies. There was also a probable increase in abundance of jellyfish. The loss of epipelagic fish resources had severe impacts on seabirds in Namibia, including species endemic to southern Africa. Two seabirds that feed mainly on sardine and anchovy underwent massive decreases. The Namibian populations of African penguins and Cape gannets fell by 85% and 95%, respectively, between 1956 and 2005. Conversely, despite harvesting, there was a large increase in numbers of Cape fur seals in Namibia. New mainland colonies were formed and grew rapidly. Seals are able to forage much deeper in the water column than are penguins and gannets.

Similarly to Namibia, there was a decrease in the South African sardine stock (Figure 2) in the 1960s. However, unlike the situation in Namibia, there was a recovery of sardine in the 1980s and 1990s. Unlike the situation in Namibia, anchovy replaced sardine in the catches of the South African purse-seine fleet in the 1970s and 1980s and remained abundant in the 1990s. In South Africa, the population of Cape gannets remained stable following the collapse of sardine in the 1960s. Gannets switched their diet from sardine to anchovy. However, the South African population of African penguins decreased. When breeding, gannets have a much greater foraging range than penguins. African penguins attempted to adjust to a reduced year-round availability of food on the west coast through emigration of first-time breeders to colonies in the south. As a resurgence of sardine in South Africa was initiated in the mid 1980s, three new colonies of African penguins were formed in the west and grew rapidly. Later, the increases in penguins spread to other western colonies. In the new century there was a marked eastward shift in the distribution of sardine in South Africa. This was followed by a recent decrease in numbers of penguins and gannets breeding off South Africa's west coast. However, numbers of gannets breeding in South Africa's Eastern Cape increased rapidly.

These changes in stocks of epipelagic fish in the Benguela system are encapsulated in a progressive southern and eastern shift in the distribution of Cape gannets. Namibia supported 81% of the Cape gannet population in 1956; just 7% in 2005. South Africa's Western Cape had 12% of the population in 1956, which increased to 45% in 1998 but fell to 26% in 2005. The Eastern Cape had 7% in 1956 and 67% in 2005. Recently there have been eastward shifts in the distributions of other species off South Africa. Up until the 1970s, breeding by the endemic crowned cormorant was restricted to localities to the west of Cape Agulhas, Africa's southernmost point. In 2003, crowned cormorants were breeding in Tsiksikamma National Park, 355 km farther east. Similarly, the endemic Hartlaub's gull, until 1990 known only to breed west of Cape Agulhas, in mid 1990s bred farther east and in the early 21st century established two colonies in the vicinity of Port Elizabeth, 550 km farther east than in the 1990s. Since the early 1980s there has also been a large increase in the number of kelp gulls breeding in the Eastern Cape.

Landings of Cape (west coast) rock lobster in both Namibia and South Africa declined in the 1960s and again in the 1970s and 1980s, mainly as a consequence unsustainable levels of exploitation and inappropriate management. From the late 1980s, there was reduced rate of somatic growth of Cape rock lobsters off western South Africa, and in the 1990s an increased frequency of low-oxygen induced rock lobster walkouts. From the mid 1990s, there was a very dramatic southern and eastern shift in the distribution of Cape rock lobsters along the South African coast, which apparently cannot be attributed to fishing or management actions, and suggests that there has been a major change in the ecosystem.

Unregulated fishing, often by foreign fleets, caused a large decrease in the abundance of hakes off southern Africa by the end of the 1980s. South Africa (in 1977) and Namibia (in 1990) declared 200-nautical-mile fishing zones and implemented policy to rebuild hake stocks through setting conservative catch limits. However, the biomass of hake off Namibia decreased in the mid 1990s, probably as a result of severely anoxic conditions in 1993 and 1994 having a negative influence on recruitment. In South Africa, poor recruitment in the 21st century also reduced biomass. As in Namibia, this poor recruitment may have resulted from environmental factors. However, it may also have resulted from the establishment of line fisheries for hake from the mid 1990s onwards. These caused increased pressure, which was partly market driven, on the larger, more fecund females by both trawl and line fisheries, with possible adverse consequences for recruitment.

In addition to the long-term changes in resources, episodic climate perturbations have caused major shorter-term fluctuations in resources. They may also have influenced the longer term trends. Of especial importance have been the *Benguela Niños* (discussed above) which have affected resources over a wide area, from as far north as the Gulf of Guinea to the southern tip of Africa. These events have influenced year-class strength of fish resources and the short-term distributions of fish stocks. In so doing, they have resulted in local shortages of food that have led to abandonment of breeding or high mortality of predators such as seabirds and seals, notably off Namibia.

Socio-economic Impacts of Variability and Change

The following is a summary of some of the socio-economic consequences of the changes that have occurred in the Benguela region during the past half century:

- There has been substantial changes in the distribution of horse mackerel and *Sardinella* species off Angola.
- The rock lobster fishery in the central Benguela collapsed in the 1970s and impacted coastal communities in Lüderitz and Port Nolloth in particular.
- There was a massive decline in the Namibian sardine in the late 1960s and 1970s and anchovy in the 1980s, with no subsequent recovery of these stocks.

- This decimated the Walvis Bay canning industry, and led to losses of a large number of jobs.
- Harm was done to the hake resource in Namibia by hypoxia in the early 1990s and stocks there have failed to recover subsequently to expected levels under conditions of conservative management. This has been a serious setback for the Namibian economy and for employment in Walvis Bay.
- The decline of the South African west coast rock lobster fishery and its displacement eastwards inshore along the south coast, as well as the apparent unsustainable nature of the *offshore* south coast rock lobster fishery, have had serious socio-economic impacts on coastal communities.
- In addition mass mortalities of rock lobsters during the past two decades in the St Helena Bay area as a consequence of hypoxia and harmful algal blooms have had negative financial and ecosystem impacts.
- The eastward shift of epipelagic fish species in South Africa over past decade has had major implications for fishing vessel deployment, catching and processing of fish, employment, and use and development of infrastructure. There are difficulties associated with catching epipelagic fish in warm water and delivering fish, which spoil easily, in good condition to canning plants.
- For central-place foragers, such as African penguins, the shift of epipelagic fish stocks to a region with few islands available for breeding has led to a 50% decrease in the breeding population in the 21st century, exacerbating the already precarious conservation status of this endemic species, Africa's only penguin.
- There has been a decline in other top predators, which has impacted on tourism in some localities. Cape gannets stopped breeding at Lambert's Bay in 2005. Tour buses no longer visit this town.
- Major storms accompanied by abnormally large swells a few years back in Cape Town resulted in damage to maritime operations and coastal infrastructure and financial loss in the shipping and other maritime industries.
- Problems associated with harmful algal blooms have had a negative impact on the developing mariculture industry.
- All the above have impacted on jobs, demographics and development.