10

Sustainability of the Benguela: ex Africa semper aliquid novi

L. Vere Shannon and M. J. O'Toole

THE BENGUELA AS A LARGE MARINE ECOSYSTEM

The Benguela Current ecosystem is situated along the coast of south western Africa, stretching from east of the Cape of Good Hope, in the south, northwards into Angola waters and encompassing the full extent of Namibia's marine environment. It is one of the four major coastal upwelling ecosystems of the world which lie at the eastern boundaries of the oceans. Like the Humboldt, California and Canary systems, the Benguela is an important centre of marine biodiversity and marine food production. Its distinctive bathymetry, hydrography, chemistry and trophodynamics combine to make it one of the most productive ocean areas in the world, with a mean annual primary productivity of 1.25 kilograms of carbon per square metre per year—about six times higher than the North Sea ecosystem. This high level of primary productivity of the Benguela supports an important global reservoir of biodiversity and biomass of zooplankton, fish, sea birds and marine mammals, while near-shore and off-shore sediments hold rich deposits of precious minerals (particularly diamonds), as well as oil and gas reserves.

Based on the LME concept and definition proposed by Sherman (1994), subsequently elaborated on, some 64 Large Marine Ecosystems (LMEs) have been delineated. The Benguela, which appears as 29 on the list, fits the definition well, and the Benguela Current Large Marine Ecosystem (BCLME) is an obvious candidate for an LME programme. However, unlike most other LMEs identified for international action which are closed or semi-enclosed "concave" systems, e.g. Black Sea, Bay of Bengal, Baltic Sea, all of which have "hard" natural boundaries, the Benguela is a "convex" system situated at the crossroads between the Atlantic, Indian and Southern Oceans with open boundaries.

The Namib Desert which forms the landward boundary of the greater part of the BCLME is one of the oldest deserts in the world, predating the commencement of persistent upwelling in the Benguela (12 million years before present) by at least 40 million years. With the exception of the Congo River, the main impact of the discharges of rivers flowing into the Benguela tends to be episodic in nature and in terms of transboundary concerns these are limited to extreme flood events. The landward boundary of the greater part of the Benguela can thus be taken as the coast. Much of this coast is pristine and immensely beautiful.

What makes the Benguela upwelling system so unique in the global context is that it is bounded on both northern and southern ends by warm water systems, viz the equatorial eastern Atlantic and the Indian Ocean's Agulhas Current, and its retroflection area. The principal upwelling centre which is situated near Lüderitz in southern Namibia, is the most intense found in any upwelling regime and forms a natural internal divide within the Benguela, with the domains to the north and south of it functioning rather differently. Pronounced fronts exist at the boundaries of the upwelling system, but these display substantial spatial and temporal variability, at times pulsating in phase, and others not. Interaction between the BCLME and the adjacent ocean systems occurs over thousands of kilometers. For example, much of the BCLME, in particular off Namibia and Angola, is naturally hypoxic, even anoxic, at depth. This oxygen depleted water flows southwards at subsurface depths, and the hypoxia is compounded by depletion of oxygen from more localised biological decay processes. There are also teleconnections between the Benguela and processes in the North Atlantic and Indo-Pacific Oceans (e.g. El Niño). Moreover, the southern Benguela lies at a major choke point in the "Global Climate Conveyor Belt." Warm surface waters move from the Indo-Pacific into the Atlantic Ocean mainly in the form of rings shed from the retroflection of the Agulhas. The South Atlantic is the only ocean in which there is a net transport of heat towards the equator!). As a consequence, not only is the Benguela at a critical location in terms of the global climate system, but it is also potentially extremely vulnerable to any future climate change or increasing variability in climate.

So, from an LME perspective, where are the oceanic boundaries of the BCLME? The Benguela Current is generally defined as the integrated equatorward flow in the upper layers of the South-east Atlantic between the coast and the 0^{o}meridian, so this would seem to be a pragmatic western boundary. It encompasses the entire upwelling region, upwelling fronts, and the EEZs of Angola, Namibia and South Africa. In the south, upwelling extends seasonally as far east as Port Elizabeth, and the area is dominated by the Agulhas Current and retroflection area. It would thus be appropriate to take the Agulhas as the Southern boundary and 27ºE longitude (near Port Elizabeth) as the eastern limit.

The selection of a northern boundary is much more problematic. While the Angola-Benguela Front is an apparent natural boundary, the frontal zone is only well defined in the surface layer. Moreover, there is evidence that there is a substantial flux of water (about 6 Sv) into the northern Benguela from the west and north (Lass *et al*. 2000), and it is likely that the Angola Dome, centred around 12ºS, 5ºE, is important in terms of regional (Benguela) ocean dynamics. Moreover, there is a well defined front further north at around 5ºS, viz the Angola Front (Yamagata and Iizuka 1995) which is apparent at sub-surface depths and separates the Benguela part of the South Atlantic from the Gulf of Guinea and equatorial current systems. A northern boundary of the Benguela at 5ºS would encompass the Angola Dome and the area in which the main oxygen minimum in the South Atlantic forms, the dynamics of which are inextricably linked with that off Namibia. The 5ºS parallel is in general agreement with the transition between the BCLME and the Gulf of Guinea LME shown by Sherman (1994) and others. Further, in a geopolitical context, as 5ºS is at the northern boundary of the Cabinda province of Angola, the full Angolan EEZ would fall within the scope of the BCLME, and this would mean that the issues and problems facing Angola's resource managers and which are not dissimilar to those further south, could be addressed within the context of the BCLME.

CHANGING STATE OF THE BENGUELA

The BCLME displays a high degree of variability over a broad spectrum of time and space scales. In the following paragraphs we shall only touch on aspects of small scale and mesoscale variability, highlighting some key characteristics of inter-annual variability, and then focus on decadal change. Papers listed under References address the subject more fully.

Short period and seasonal variability

In the extreme South, upwelling tends to be more seasonal than in the remainder of the Benguela, with the main upwelling season being out of phase with that in the North. This is a consequence of the seasonal shifts in the atmospheric pressure systems and increased influence of westerly winds during the austral winter in the South. Here, during summer, the free passage of easterly moving cyclones south of Africa result in upwelling events pulsed on time scales of about 3 to 10 days. In the central and northern Benguela, upwelling is most pronounced during winter and spring and winds have a distinct diurnal character (land-sea breeze effect). The ecosystem is well adapted to the pulsed nature of upwelling and intra-annual changes in physical forcing, and there is extensive literature on this. What is less well understood are the ecosystem effects of major

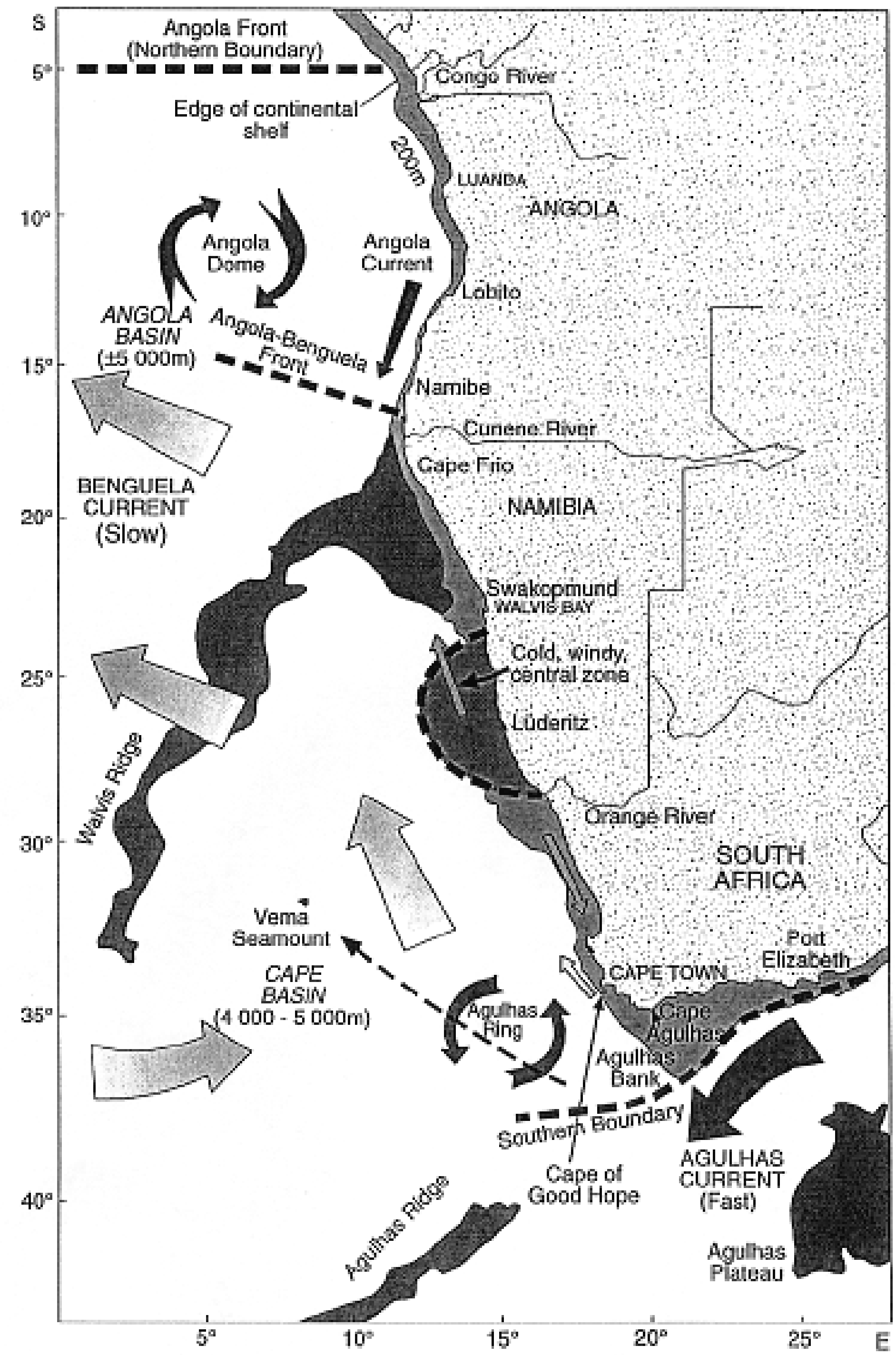

Figure 10-1. External and internal boundaries of the Benguela Current Large Marine Ecosystem, bathymetric features and surface (upper layer) currents.

storm events such as the 50 year storm which occurred in May 1984. Although short-lived, it is not inconceivable that events such as these might trigger a change of state of the ecosystem.

Inter-annual variability

In contrast with Pacific upwelling systems which have small seasonal and large inter-annual signals, the inter-annual variability in the Benguela is relatively small, and major events are less frequent. Perhaps more important, however, Benguela variability appears to be less predictable. Moreover, the occasional extreme sustained events in the Benguela do result in major perturbations of the ecosystem and mass mortalities of marine fauna have impacted on fisheries. The major variability and changes in the Benguela physical environment have manifested themselves in the following forms:

- Sustained intrusions of anomalously warm, nutrient poor equatorial/tropical water across the northern and southern boundaries of the ecosystem, viz Benguela Niños and Agulhas intrusions,
- Large scale changes in the windfield (intensity, direction and frequency) resulting in changes in the intensity and spatial distribution of upwelling, the position of the upwelling/oceanic fronts, warming or cooling of large areas of the system, altered stratification and changes in advection,
- Changes in the composition and advection of subsurface waters, particularly in changes in the concentrations of dissolved oxygen in the poleward undercurrent.

The term "Benguela Niño" was coined by Shannon *et al.* (1986) and refers to large scale episodic warm events that occur along the coast of southern Angola and Namibia every ten years on average, and which have a character not unlike the El Niño in the Pacific Ocean. Every few years the tropical eastern Atlantic becomes anomalously warm as a consequence of relaxation in the trade winds and the deepening of the thermocline and reduced loss of heat from the ocean to the atmosphere. Occasionally, every ten years on average, this warming is even more extreme, evidently as a consequence of a sudden relaxation of the winds off Brazil, and when this happens the warm water anomaly in the tropical Atlantic travels eastwards and southwards, trapped (guided) by the coast of Africa. The result is a large southward displacement of the Angola-Benguela front, and a flooding of the Namibian shelf by warm tropical water, sometimes very saline (1984), at other times low surface salinity (1995), depending on the orientation of the flow and the amount of fresh water from the Congo River present. Benguela Niños are accompanied by increased oxygenation of subsurface and bottom shelf waters either as a consequence of reduced deep flow of water southwards from Angola, or (more likely) reduced primary production and decay on the Namibian shelf. Benguela Niños occurred in 1934, 1949, 1963, 1984, 1995 and probably around 1910, in the mid-1920s and in 1972-1974. The most recent event and its biological impact has been well documented by Gammelsrød *et al.* (1998). Benguela Niños are not necessarily in phase with Pacific El Niños, but there is increasing evidence that they are a regional response to changes in the global atmosphere-ocean system.

Just as Benguela Niños are characterized by extreme disturbance of the Angola-Benguela front, extreme disturbances in the retroflection (turning back) of the Agulhas Current at the southern boundary of the Benguela can be manifest as a major incursion of Agulhas water moving into the Benguela system around the Cape of Good Hope. These intrusions may be in the form of shallow surface filaments of warm water (the more usual case) but, on occasions, warm rings shed from the Agulhas Current can take a more northerly path than usual and impact on subsurface and deeper currents along the edge of the continental shelf, as was the case in 1989. A well-documented Agulhas intrusion occurred in 1986 (Shannon *et al.* 1990). Previous large-scale intrusions may have occurred in 1957 and 1964. The most recent event took place during the post austral summer 1997-1998.

Whereas Agulhas intrusions result in the input of anomalously warm water into the Benguela, incursions of cold sub-Antarctic water do occur, and occasionally the effect of these can be felt as far north as 33ºS (north of Cape Town), as was the case early in 1987. It seems that these rather unusual events are associated with the shedding of rings at the Agulhas retroflection, and they have an appearance of a compensatory northward flow from the Subtropical Convergence following the formation of a ring. Their biological consequences in the Benguela are unknown.

During some years, the most recent being 1993-1994, the oxygen depletion of shelf waters in the Benguela is unusually severe, and this results in widespread anoxia and hypoxia in the system. Although most pronounced in the northern Benguela, episodic depletion of oxygen does occur in the southern Benguela (e.g. in autumn of 1994). These large scale hypoxic and anoxic conditions appear to coincide with quiescent conditions which follow periods of sustained and enhanced upwelling, as a consequence of increased primary production and subsequent decay of phytoplankton blooms (e.g. red tides). It also appears likely that changes in the composition and flow of subsurface waters, in particular the concentrations of dissolved oxygen in the southward moving undercurrent along the west coast, may be contributing factors, and this suggests that processes taking place off Angola may exert an important influence on the entire upwelling domain via advection. Large scale hypoxia and anoxia result in massive mortalities of marine organisms and changes in distribution and abundance of fish such as hakes (e.g. Hamakuaya *et al.* 1998).]

Decadal changes and regime shifts

There is a growing body of evidence which suggests that marine ecosystems undergo decadal-scale fluctuations driven by variability in climate. This is most apparent at the higher trophic levels (fish). For example, in the Humboldt Current system decadal period switches in dominance between sardine and anchoveta have occurred this century, and it is also apparent from the sediment record (from analysis of fish scale deposits) that species alternations have occurred during past centuries, i.e. prior to the advent of fishing and other anthropogenic impacts. Moreover, it has been demonstrated that populations of sardine in different parts of the Pacific (off Chile/Peru, California/Mexico and Japan) have undergone synchronous fluctuations this century. In the Benguela ecosystem there have been corresponding fluctuations in sardine abundance, although these appear to be out of phase with those in the Pacific. Also, there is evidence in the southern Benguela, at least, of species alternations, regime shifts, between anchovy and sardine, and in the northern Benguela the sediment record suggests that both species undergo decadal-scale fluctuations, at times alternating species dominating, at others the two species fluctuating synchronously (e.g. Shackleton 1986). What is also apparent from the sediment record is that there can be long periods (several decades) where both species are absent or only present at a low biomass.

There are few long-term data series of environmental parameters for the Benguela region. The available indices do (see Figure 10-2), nevertheless, show that changes and fluctuations on decadal or longer time scales have occurred in the Benguela this century and, superimposed on this variability, a progressive warming of surface waters of about 0.7^{o} C from 1920 is apparent throughout the Benguela and South-east Atlantic.

Figure 10-2 shows an increasing trend in equatorward windstress in the off-shore northern Benguela from the late 1940s until the 1990s. This trend, which is also confirmed by a much sanitized COADS (Comprehensive Ocean Atmosphere Data Set) data set, appears to be real. The analysis of Taunton-Clark and Shannon (1988) showed that the 1920s and 1930s were cool years in the region and that a change to warmer conditions took place during the 1940s, followed by a gradual strengthening of the south-easterly trade winds over the next few decades. A system-wide change occurred in the late 1960s, to be followed by an extended warm period. The warming trend accelerated during the 1980s and this decade was the warmest this century in the South-east Atlantic. Longshore wind stress in the Benguela increased sharply after 1974 and the shelf waters along the west coast of South Africa and Namibia were abnormally cold in the early 1980s. In the extreme southern Benguela (at least), the wind record displays a sharp change in 1982/1983, with significantly lighter winds blowing for the remainder of the

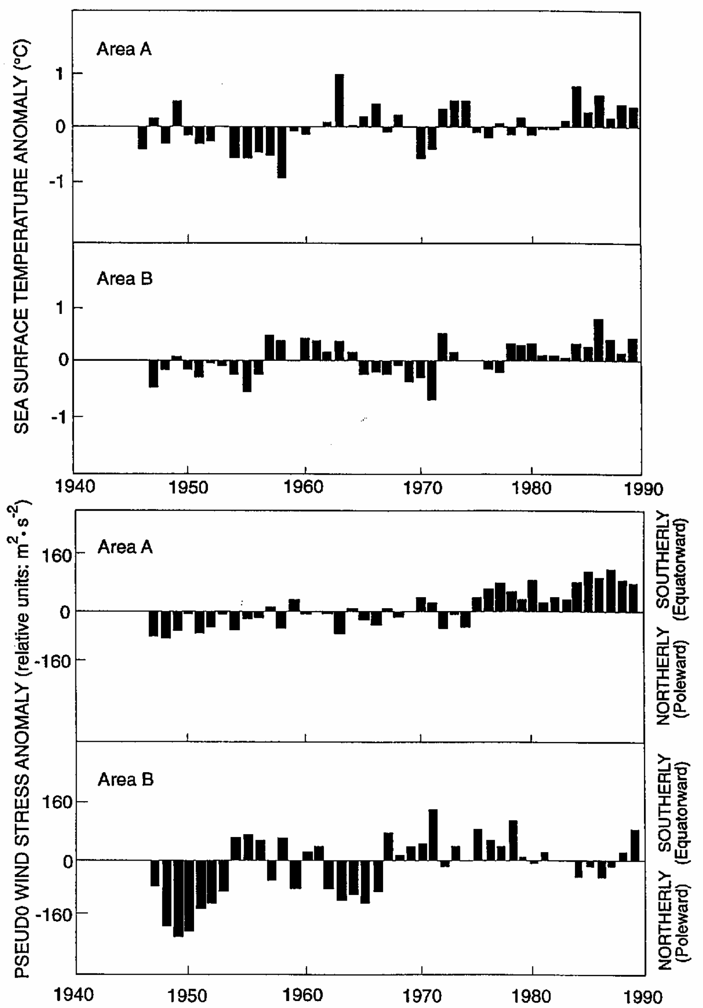

Figure 10-2. Sea surface temperature (°C) and pseudo windstress ($m^2 s^{-2}$) anomalies in the offshore northern Benguela (area A: 10° - 15°S, 0°- 5°E) and southern Benguela (area B: 30° - 35°S, 10° - 15°E) modified from Shannon *et al.* (1992).

decade there (Shannon *et al.* 1992). It is perhaps significant that there is substantial decadal-scale variability evident in the post 1960 winds off Brazil (Carton and Huang 1994). The Gulf of Guinea temperature records also suggest an apparent periodicity between large sustained warm events of about 10 years.

While decadal-scale changes are evident from some of the physical parameters, these are not so apparent in the chemistry and plankton because of the fragmented nature of the available records. The available information does, however, point to the likelihood that comparable changes in the plankton have

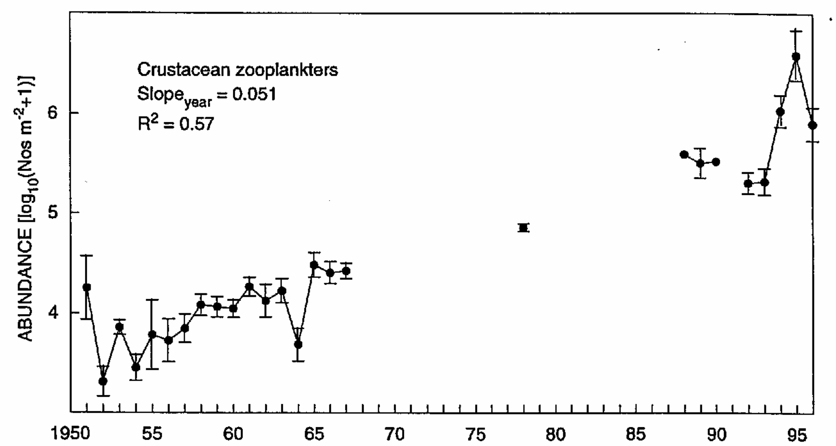

Figure 10-3. Change in crustacean zooplankton abundance, St. Helena Bay area (southern Benguela), March-June, 1951-1995 from Verheye *et al.* 1998.

taken place, and by extrapolation from the biology and physics, that changes in nutrient supply have also occurred. Brown *et al.* (1991) analyzed chlorophyll *a* (a proxy for phytoplankton biomass) data available for the southern Benguela between 1971 and 1989. Although there appears to be a decreasing trend during the two decades from about 3.5mg/m^3 to 2.0mg/m^3, the trend is not statistically significant because the data are highly patchy. In what is perhaps the most important paper on zooplankton in the Benguela during recent years, Verheye and Richardson (1998) found that the abundance of animals in all main taxonomic groups in the St. Helena Bay area increased by at least tenfold between 1951 and 1996. (These measurements applied to the main pelagic fish recruitment season, viz March-June). This is illustrated in Figure 10-3. Total zooplankton abundance expressed in numbers of animals increased by more than one hundredfold. The increase was accompanied by a significant shift in the community structure of near shore zooplankton, with a trend towards smaller size organisms. Whether the observed change is a consequence of reduced predation pressure by anchovy and sardine ("top down control") or climatologically induced, viz upwelling,

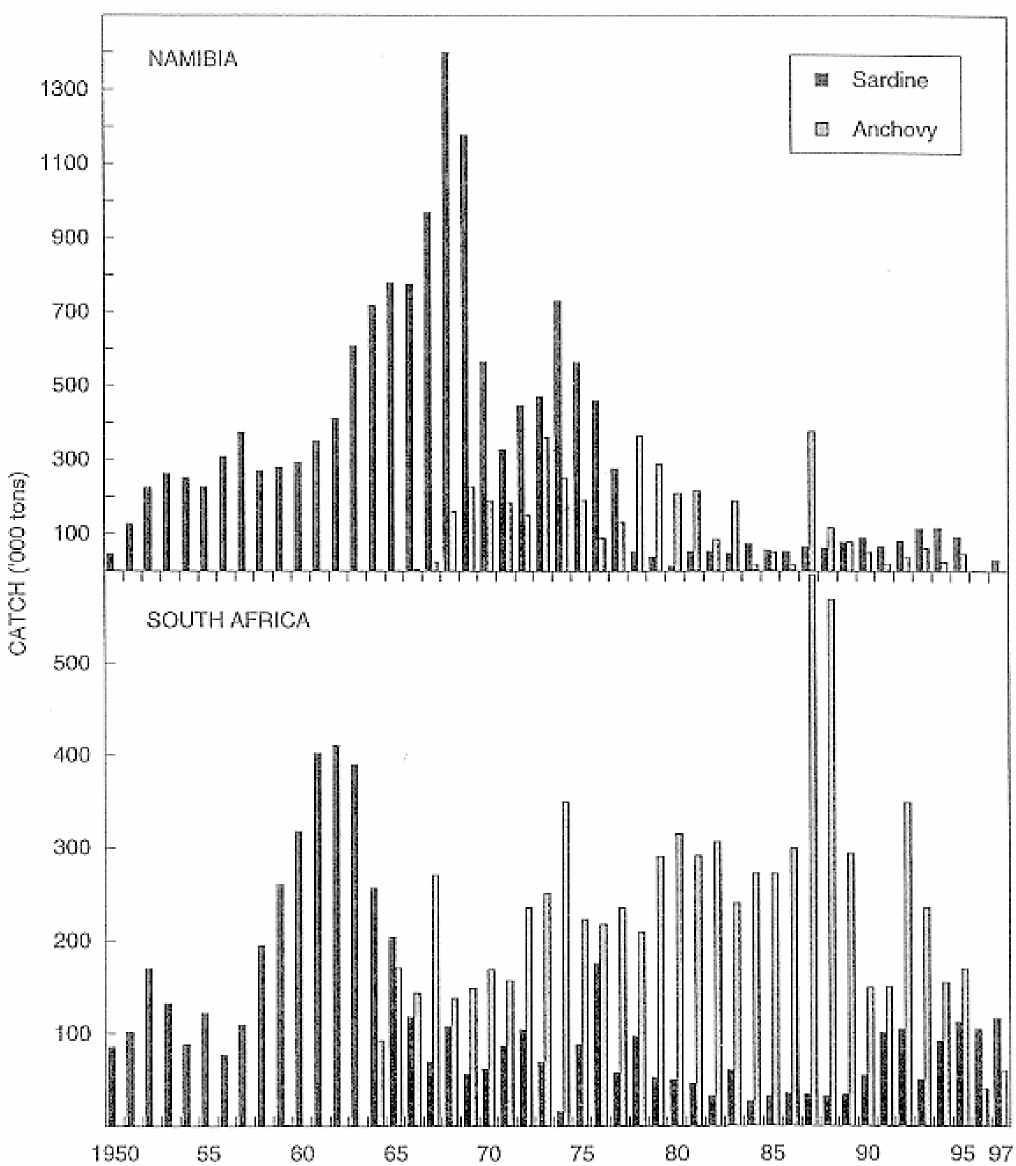

Figure 10-4. Sardine and anchovy catches off Namibia and South Africa, 1950-1997, modified from Crawford (1999)

primary production and entrainment ("bottom up control"), is not clear at this stage. Other changes in zooplankton include the decrease in abundance on the west coast of the copepod *Calanus agulhensis* between 1988 and 1991 and the relative scarcity of the euphausiid *Nyctiphanes capensis* now in comparison with the 1950s (*Euphausia lucens* is currently dominant).

Major changes in the principal harvested species of finfish and crustaceans have occurred this century. While there is little doubt that the declines in stocks of hake, sardine and rock lobster during the 1960s and 1970s were consequences of over-fishing, changes in the environment have been contributory factors. In the following paragraphs we summarize the main changes in key harvested species and their predators which have taken place, and comment on possible environmental links.

Sardine and anchovy

Sardine *Sardinops sagax* and anchovy *Engraulis japonicus* mainly occur off Namibia and South Africa, and to a lesser extent off southern Angola. From the sediment record these species have historically (i.e. prior to fishing) displayed large fluctuations. In the more recent past the biomass of the sardine resource declined sharply off Namibia following the 1963 Benguela Niño during a period when the sardine was available close to Walvis Bay and fishing mortality was high (Stander and De Decker 1969). A second collapse occurred there after 1974, again following a protracted, but less intense, Benguela Niño. The resource showed a slow recovery subsequently, but this was retarded (Figure 10-4) by the most recent 1995 Benguela Niño. Anchovy was abundant off Namibia in the 1970s but has been less significant in the catches there during the past decade. In the southern Benguela, the sardine stock declined in the late 1960s and again after 1976, only recovering as a result of successive good year classes in the late 1980s-1990s (Figure 10-4). In the South, the anchovy which was the dominant species during the 1970s and 1980s appears to have been partly replaced by the increasing biomass of sardine. This evident species switching is reflected quite well in the catch record for South Africa, but less so in Namibia (Figure 10-4).

Apart from the system wide changes in the abundance of species such as anchovy and sardine, the Benguela exhibits equatorward and poleward shifts associated with meridional shifts in the major wind belts which appear to be in synchrony with shifts in the Canary Current System. In addition, species switching and regime shifts occur in the Benguela which appear to be out of phase with those in Pacific stocks, displaying a characteristic periodicity of about 50 years. In the case of the sardine *Sardinops sagax,* the species is most abundant in the Pacific when it is least abundant in the Benguela and vice versa.

Sardinellas

The most important commercial pelagic species off Angola are the sardinellas, *Sardinella aurita* in the south and S. *maderensis* north of 10ºS. The main spawning area is in the area between Pointe Noire and the Congo River, with peak spawning in March-April. Longshore migration of both species occurs seasonally, with an equatorward shift during the first part of the year (to spawning grounds) with a return migration of adults occurring later in the year. There is some evidence that a southward shift in the distribution of sardinellas occurred in the mid-1960s which was followed by an equatorward displacement during the early 1980s, congruent with the changes in the distributions of sardines and hakes in the Benguela proper. These displacements of stocks which occur across national boundaries have important implications for resource management.

Hakes

Three species of hakes occur in the Benguela viz *Merluccius capensis*, *M. paradoxus* and *M. polli.* Relatively little is known about their behavior and responses to environmental variability and change. Adult hakes are good swimmers, undergo diurnal vertical migrations and can tolerate a range of temperatures. Being relatively opportunistic feeders, long lived, and fished over a variety of age classes, hakes would be robust to all but major environmental perturbations. There is some published evidence (Shannon *et al.* 1988) which suggests that hakes do better when SSTs (sea surface temperatures) are low, or at least the recruits seem to be more available and at higher densities during cool periods, e.g. in 1992 in the case of *M. capensis* off Namibia and in 1987 in the southern Benguela (*M. paradoxus*). There is, from catch results, an indication that longshore shifts in hake stocks in the Benguela might occur. Although hake can evidently tolerate low oxygen levels, down to 0.25 $ml \cdot l^{-1}$, they would avoid areas with extremely low concentrations of dissolved oxygen. Thus it is likely that the system wide low oxygen event in 1993-4 which was followed by the 1995 Benguela Niño did retard the expected recovery of the hake resources off Namibia (e.g. Woodhead *et al.* 1998). Nevertheless, on a time scale of decades, the main impact on hakes appears to be due to fishing mortality (Figure 10-5) rather than to changes in the environment.

Rock Lobster

The Benguela spiny lobster, *Jasus ialandii,* has been fished for centuries, and there is evidence that the overall biomass decline started in the early 1900s and then accelerated after 1950. Toward the end of the 1980s there was a sharp decline in

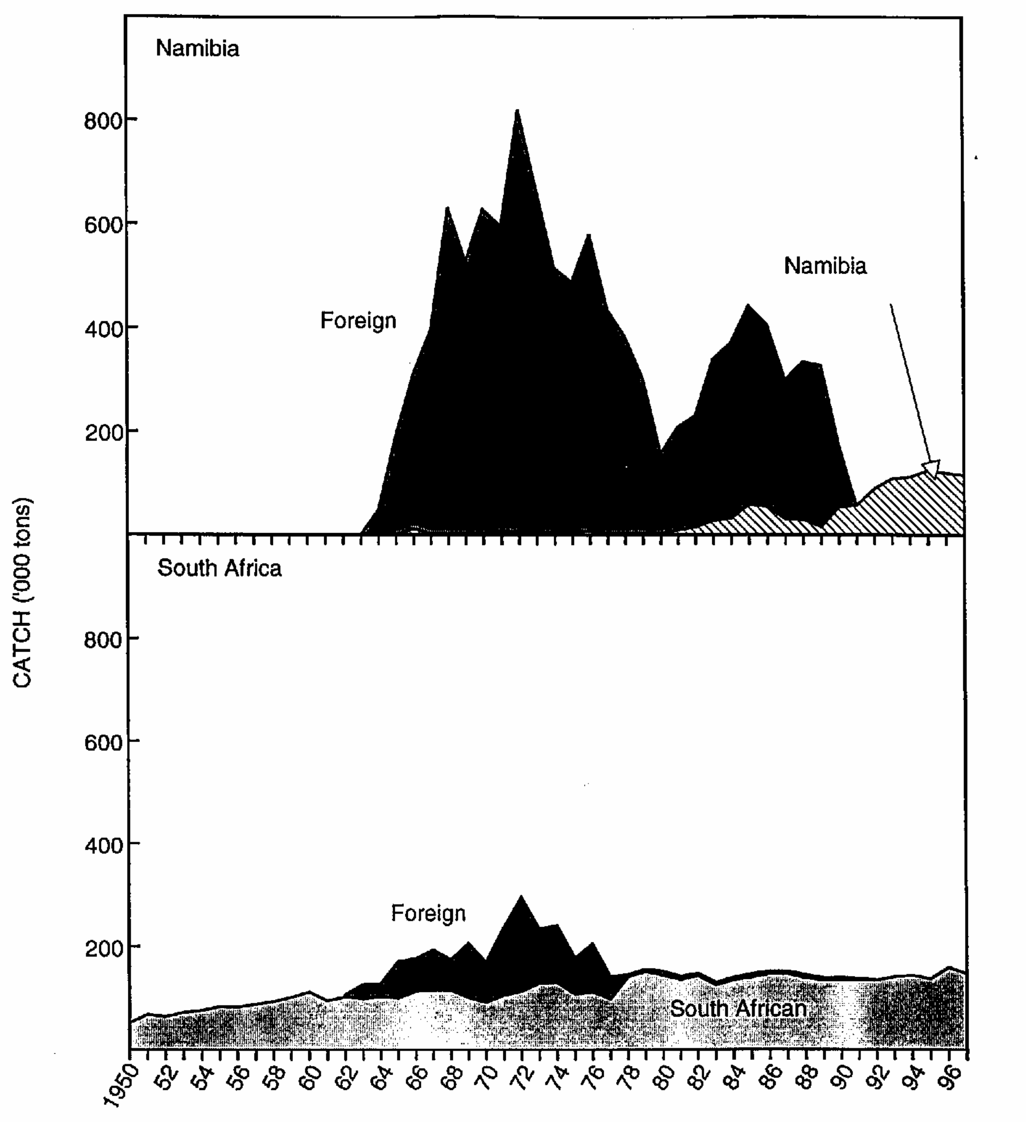

Figure 10-5. Catches of hakes off Namibia and South Africa from 1950 (Data kindly provided by Mr. Michael Stuttaford, author of Fishing Industry Handbook, South Africa,

Namibia and Moçambique, published by Marine Information CC and updated). Note the extent of foreign exploitation of Namibia's resources prior to independence in 1990.

production of rock lobster throughout the Benguela system. In the southern Benguela, the decreased production resulted from reduced growth rates. Off Namibia, it has been attributed to over-exploitation and changes in availability related to fluctuations in the levels of oxygen depletion of bottom waters. There is relatively little meridional migration of rock lobster, and it seems improbable that fishing would have impacted all fishing zones of the species at the same time, unless what happened was a consequence of fishing out of larger animals and reduced predation on smaller lobsters with resultant increased competition for food. It seems likely that the resource responded to some large-scale change in the environment. In the south, the reduced rates of growth may have been caused by a reduced biomass of ribbed mussels. Alternatively the changes may have been linked with changes in primary production and a regime shift in the benthic food web. Whatever the cause, the west coast rock lobster growth rate appears to be responding in a manner analogous to that of a depressed population trapped in a predator pit.

Impact on predators

Crawford *et al.* (1992), Crawford (1999), and others, have highlighted the relationship between changes in abundance of certain resources in the Benguela ecosystem and changes in the diets of predators such as seabirds and seals. In the southern Benguela numbers of Cape cormorants that breed in any years are closely related to the biomass of anchovy. Breeding of swift terns and Cape gannets also reflects changes in anchovy biomass. Similarly, the distribution and breeding of the African penguin is related to the abundances of anchovy and sardine. Following the collapse of the sardine stocks in the 1960s, penguin colonies in southern Namibia and near Cape Town crashed to low levels and the centre of their distribution shifted southwards and eastwards with increasing reliance on anchovy. The trend was reversed in the mid-1980s when the sardine stocks began to recover. Not only do the changes in diet of top predators provide information on possible regime shifts, but trends in abundances of distribution of the predators provide proxy information on the performance of some harvested resources. For example, with the demise in the sardine in the northern Benguela in the late 1960s and 1970s, there was an evident increasing reliance on pelagic gobies. In another example the severity of the 1993/1994 black tide/low oxygen event and its system-wide impact was highlighted by the response of the seal population north in the northern and central Benguela, where the high mortality rates of pups (and adults) from starvation caused the seal stock to decline.

FRAGMENTED MANAGEMENT: A LEGACY OF THE PAST

Following the establishment of European settlements at strategic coastal locations where victuals and water could be procured to supply fleets trading with the East Indies, the potential wealth of the African continent became apparent. This resulted in the great rush for territories and the colonization of the continent, mostly during the nineteenth century. Boundaries between colonies were hastily established, often arbitrary and generally with little regard for indigenous inhabitants and natural habitats. Colonial land boundaries in the Benguela region were established at rivers (Cunene, Orange). Not only were the languages and cultures of the foreign occupiers different (Portuguese, German, English, Dutch) but so were the management systems and laws which evolved in the three now independent and democratic countries of the region—Angola, Namibia and South Africa. Moreover, not only were the governance frameworks very different, but a further consequence of European influence was the relative absence of inter-agency (or inter-ministerial) frameworks for management of the marine environment and its resources and scant regard for sustainability. To this day, mining concessions, oil/gas exploration, fishing rights and coastal development have taken place with inadequate proper integration and scant regard for other users. For example, exploratory wells have been sunk in established fishing grounds and the well-heads (which stand above the sea bed) subsequently abandoned. Likewise the impact of habitat alterations due to mining activities and ecosystem alteration (including biodiversity impacts) due to fishing have not been properly assessed.

Prior to the coming into being of the United Nations Law of the Sea Convention and declaration and respecting of sovereign rights within individual countries' Exclusive Economic (or Fishing) Zones, there was an explosion of foreign fleets fishing off Angola, Namibia and South Africa during the 1960s and 1970s, an effective imperialism and colonization by mainly First World countries of the Benguela and the rape of its resources. (This is highlighted quite dramatically in Figure 10-5). This period also coincided with liberation struggles in all three countries, and associated civil unrest. In the case of Namibia, over whom the mandate by South Africa was not internationally recognized, there was an added problem in that, prior to independence in 1990, an EEZ could not be proclaimed. Although an attempt was made to control the foreign exploitation of Namibia's fish resources through the establishment of the International Commission for the South-east Atlantic Fisheries (ICSEAF), this proved to be relatively ineffectual at husbanding the fish stocks. Until fairly recently, environmental issues and sustainable management were low priorities on the political agenda in South

Africa. Another consequence of the civil wars has been the population migration to the coast and localized pressure on marine and coastal resources (e.g. destruction of coastal forests and mangroves) and severe pollution of some embayments.

While mineral exploration and extraction and developments in the coastal zones obviously occur within the geographic boundaries of the three countries, i.e. within the EEZs, and can to a large degree be independently managed by each of the countries, mobile living marine resources do not respect the arbitrary geographic borders. This has obvious implications for the sustainable use of these resources, particularly so in the case of straddling and shared fish stocks.

Thus, the legacy of the colonial and political past is that the management of resources in the greater Benguela area has not been integrated within countries or within the region. The real challenge of an LME project in the Benguela is to develop a viable joint and integrative mechanism for the sustainable environmental management of the region as a whole, i.e. at the ecosystem level.

REGIONAL CO-OPERATION: THE KEY TO SUCCESS

Nearly all of the problems in the BCLME which require scientific investigation and management action are common to all three countries, Angola, Namibia and South Africa. For example most of the regions' important harvested resources are shared between countries or move across national EEZ boundaries at times. Environmental variability and change impact on the ecosystem as a whole and there is poor predictability of its consequences. Mining impacts and pollution, while seemingly localized, are really generic issues. So are harmful algal blooms and the loss of biodiversity. Perhaps the greatest problem, however, is the lack of appropriate capacity in the region (both human and infrastructure) and the enormous capacity gradient from south to north. Putting this together with the existing fragmented management suggests that, if ever there were a case for collaboration between countries and concerted action to address problems collectively, then this was so in the Benguela region, with the enablement of the international community.

Namibia made the first move in 1995 when its Ministry of Fisheries and Marine Resources hosted an International Workshop/Seminar on "Fisheries Resource Dynamics in the Benguela Current Ecosystem" in partnership with the German Organisation for Technical Co-operation (GTZ), the Norwegian Agency for Development Co-operation (NORAD) and the Intergovernmental Oceanographic

Commission (IOC) of UNESCO. This meeting proved to be a milestone in regional co-operation, for out of it evolved two major Benguela initiatives. The first, BENEFIT (BENguela-Environment-Fisheries-Interaction-Training) was launched in April 1997 jointly by Angola, Namibia and South Africa with foreign partners, "To develop the enhanced science capacity required for the sustainable utilization of living resources of the Benguela ecosystem by (a) improving knowledge and understanding of the dynamics of important commercial stocks, their environment and linkages between environmental processes and stock dynamics, and (b) building appropriate human and material capacity for marine science and technology in the countries bordering the Benguela ecosystem." The BENEFIT Programme which is driven by the region for the region has been a catalyst for stimulating further collaboration within the BCLME. Several joint ocean surveys have been undertaken generating a number of publications and reports and improved understanding of, for example, the Angola-Benguela Front. Training courses have been held, and fifteen joint projects have been funded. In the first half of 1999 alone, some 50 persons from Southern African Development Community (SADC) countries have been trained at sea on the BENEFIT cruises. Strong links have been built between BENEFIT and other parallel but distinctly different programmes, viz South Africa's established and internationally acclaimed Benguela Ecology Programme (BEP), ENVIFISH (a three year European Union funded project between seven EU states and Angola, Namibia and South Africa which focuses primarily on the application of satellite data in environment-fisheries research and management, and which commenced in October 1998) and VIBES (a bilateral French-South African initiative which focuses on the variability of pelagic fish resources in the Benguela and the environment and spatial aspects of the system, which also commenced in 1998).

The second regional initiative for which the seed was sown at the 1995 Workshop/Seminar was the development of a programme to enhance the sustainable integrated management of the Benguela. Inspired by the success of BENEFIT, the tangible fruits of regional collaboration, and progress being made on sustainable management of other LMEs, Angola, Namibia and South Africa in partnership requested support from the Global Environment Facility (GEF), a fund established in 1991 under the management of The World Bank. Following the award of a grant from the GEF in 1998, a comprehensive project proposal has been developed in the region, which hopefully will attract incremental international funding and assistance in developing a proper framework for the sustainable integrated management of the BCLME. This will be very different from BENEFIT (which focuses on science capacity for fisheries) in that it aims to develop enabling management mechanisms to address a broad spectrum of environmental issues, including diamond mining, offshore oil and gas exploration and extraction, coastal development and modification, environmental variability and ecosystem change, habitat loss and degradation, pollution, loss of biodiversity etc. in addition to fisheries. Socio-economic factors and the need for sustainability will play an overarching role. The full implementation phase of the BCLME was approved by the GEF Council in late 2001, and the programme commenced in March 2002.

What has emerged so clearly from BENEFIT and related activities and the embryonic BCLME Management Programme is that there is a strong desire in Angola, Namibia and South Africa to work together to solve common problems in the Benguela region, to share expertise, to build capacity and to develop a collective approach to ensure the sustainability of the Benguela ecosystem.

TRANSBOUNDARY CONSIDERATIONS

In developing an enabling management mechanism for an LME, priority has to be given to addressing the principal common or transboundary issues (transboundary here refers to cross internal geopolitical, not the external boundaries of the ecosystem). These include inter alia:

- Regional/national issues with transboundary causes/sources
- Transboundary issues with national causes/sources
- National issues that are common to at least two of the countries and that require a common strategy and collective action to address
- Issues that have transboundary elements or implications (e.g. fishery practices on biodiversity/ecosystem resilience).

The first step in the process is therefore to identify the key transboundary issues and the associated problems. The second is to identify the root causes of these problems, and the third step is to specify the affordable and implementable remedial action which is needed. This requires broad inter-country consultation involving all stakeholders. Within the context of the developing BCLME Management Programme (GEF), there has been wide stakeholder participation in the process, and regional planning workshops involving a large number of local and international experts were held in 1998 and 1999. From this broad consultative process a consensus view has emerged that there are three main transboundary issues in the Benguela which need to be addressed to ensure sustainable integrated management viz (a) utilization of resources, (b) environmental variability and (c) ecosystem health and pollution. Within the context of these, many problems requiring solution were identified, of which seven were seen as major problems common to all three countries. These seven perceived problems and their transboundary characteristics are as follows:

Problem (i): Decline in BCLME commercial fish stocks and non-optimal harvesting of living resources
Transboundary Characteristics: Country boundaries do not coincide with ecosystem boundaries; most of the regions' important harvested resources are shared between countries, or move across national boundaries at times. Over-harvesting of a species in one country can therefore lead to depletion of that species in another, and in changes to the ecosystem as a whole. Moreover, many resource management difficulties are common to all the countries.

Problem (ii): Uncertainty regarding ecosystem status and yields in a highly variable environment
Transboundary Characteristics: The Benguela environment is highly variable and the ecosystem is naturally adapted to this. However, sustained environmental events such as Benguela Niños, Agulhas intrusions and changes in winds, impact on the system as a whole, compounding the negative effects of fishing, while the poor predictive ability limits the capacity to manage effectively system wide. In addition, the BCLME is believed to play a significant role in global ocean and climate processes and may be an important site for the early detection of global climate change.

Problem (iii): Deterioration in water quality – chronic and catastrophic
Transboundary Characteristics: Although most impacts of chronic deterioration in water quality are localized (national issues), they are common to all of the countries and require collective action to address. Moreover, chronic pollution can favour the development of less desirable species, and result in species migration. Catastrophic events (major oil spills, maritime accidents) can impact across country boundaries, requiring co-operative management and sharing of clean-up equipment and manpower.

Problem (iv): Habitat destruction and alteration, including inter alia modification of seabed and coastal zone and degradation of coastscapes
Transboundary Characteristics: Although most impacts may appear localized, habitat alteration or loss due to fishing and mining can cause migration of fauna and system-wide ecosystem change. Uncertainties exist about the regional cumulative impact on benthos resulting from mining and associated sediment re-mobilisation. Inadequately planned coastal developments result in degradation of coastscapes and reduce the regional value of tourism.

Problem (v): Loss of biotic integrity (changes in community composition, species and diversity, introduction of alien species, etc.) and threat to biodiversity/endangered and vulnerable species
Transboundary Characteristics: Past over-exploitation of targeted fish species has altered the ecosystem, impacting at all levels, including on top predators and reducing the gene pool. Some species, e.g. African penguin, are threatened or endangered. Exotic species have been introduced into the Benguela. (This is recognized as a global transboundary problem).

Problem (vi): Inadequate capacity to monitor/assess ecosystem (resources and environment, and variability thereof)
Transboundary Characteristics: There is inadequate capacity, expertise and ability, in the region to monitor and assess adequately the shared living resources and to monitor environmental variability. Moreover, there is unequal distribution of this capacity between the three countries.

Problem (vii): Harmful algal blooms (HABs)
Transboundary Characteristics: HABs occur in all three countries, who face similar problems in terms of impacts and management, and which require collective regional action to address.

A host of root causes of the common problems in the BCLME listed above have been identified, and these can be grouped into seven broad generic categories, viz:

- Complexity of ecosystem and high degree of variability (resources and environment)
- Inadequate capacity development (human and infrastructure) and training
- Poor legal framework at the regional and national levels
- Inadequate implementation of available regulatory instruments
- Inadequate planning at all levels
- Insufficient public involvement
- Inadequate financial mechanisms and support

The above problems and generic root causes are illustrated schematically in Figure 10-6.

The next step in the process is the specification of agreed collective actions which must be taken within the BCLME. These must be affordable, implementable and sustainable.

TOWARDS A SUSTAINABLE FUTURE

Correcting decades of over-exploitation of resources in the Benguela ecosystem and fragmented management actions (the consequence of the colonial/political past and greed) will require a substantial coordinated effort in the years ahead, to be followed by sustained action on a permanent basis. A task of this magnitude will require careful planning, not only by the government agencies in the three countries bordering on the Benguela but also by all the other stakeholders, including the international community. There already exists the willingness on

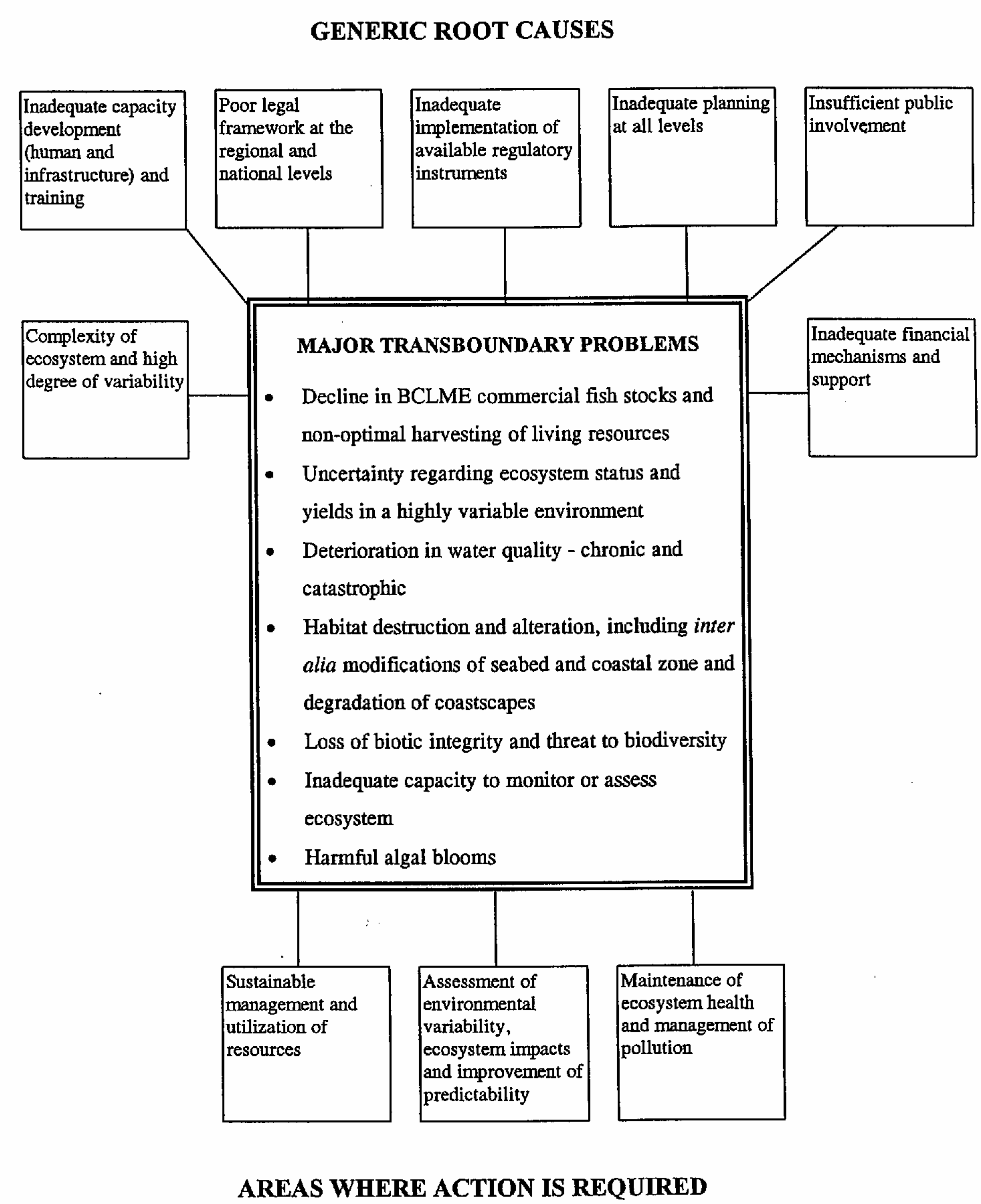

Figure 10-6. Major transboundary problems, generic root causes and areas requiring action.

the part of the key players to collaborate to achieve this objective, but the real challenge will be to develop systems that take cognizance of the naturally highly variable and potentially fragile nature of the BCLME and its coastal environments within the context of a changing society and world.

In order to address the main transboundary problems and their root causes (see previous section), the stakeholders have identified three broad areas where immediate action is necessary, viz improving management and utilization of resources, assessing impacts and improving predictability of environmental variability, and maintaining ecosystem health and reducing pollution (see Figure 10-6). In all of these areas capacity development and training is seen as a high priority activity. Policy development and harmonization and regional networking and collaboration in surveys, monitoring, assessment etc. are likewise seen as very important. However, the success of any management action will clearly be dependent on the proper understanding of the underlying ecosystem processes and the linkages between the Benguela and the larger ocean-atmosphere environment. This will require a concentrated research effort in partnership with the international science community, building on existing local and regional activities such as the BEP and the fisheries-based BENEFIT programmes, and international programmes such as Climate Variability and Prediction Program (CLIVAR), Global Ocean Ecosystem Dynamics (GLOBEC) and Global Ocean Observing system (GOOS). The question is, can this be best done through an LME-type approach? Furthermore, is the present LME definition adequate or even appropriate for an ecosystem such as the Benguela?

From an LME research and management perspective, system boundaries cannot ignore regional political and economic realities, and the interdependence of countries. In the case of the Benguela, it would make little sense to regard the relatively shallow Angola-Benguela Front as the northern extent of the ecosystem for reasons previously given. Moreover, it is our contention that the present LME definition is applicable to closed or semi-closed systems with "concave" fixed boundaries, but perhaps less so to open "convex" systems such as the Benguela. At first appearance the Benguela upwelling area does have distinct boundaries in the form of shallow fronts which demarcate various epi-pelagic domains. However, the sources of much of the significant variability and change in the Benguela ecosystem lie outside the system. Regional human impact on the ecosystem (fishing, mining, coastal development, etc.) thus takes place within the context of substantial externally forced variability—mainly natural, but there is also increasing evidence of anthropogenic climate change superimposed thereon. Unlike concave fixed boundary ecosystems such as the Black Sea, where corrective management can largely ignore external forcing, in an open ecosystem such as the Benguela, sustainable integrated management has to take the external forcing into account, and that means looking beyond the narrow confines of the various fronts. The approach to a highly variable LME like the Benguela will necessarily be very different to that for closed or semi-closed systems. What must therefore clearly be recognized is that the Benguela does not function in isolation, but rather as part of the global ocean system.

Sustainable integrated management of the Benguela requires a collective and proactive approach by Angola, Namibia and South Africa, not a reactive "knee-jerk" response to problems. Apart from the joint actions which the three countries are committed to, visionary thinking and innovative management on the part of the governments will be required. Within the next decade it is likely that the first signs of global environmental change will become apparent, and governments which choose to ignore this probability do so at their peril. Management cannot proceed in the absence of good advice based on good science, and accordingly the regional research structures will need to be strengthened, not undermined. Access to international expertise and collaboration with other players in the Atlantic is essential, particularly in terms of modeling and improving predictability. Moreover, links will need to be established between the BCLME and the Gulf of Guinea LME and activities in the LMEs of our neighbors the other side of the Atlantic (Patagonian Shelf, Brazil Current, North Brazil Shelf) and the proposed Agulhas Current LME. In this respect the establishment of operational networking between the various LMEs would perhaps go a long way towards giving effect to the UNCED declaration. If this is done, then certainly the LME approach will stand a good chance of success.

Returning to the title of the paper, "The Benguela: Ex Africa semper aliquid novi," so what then is new? Simply put, it is the determination of three countries which have been subjected to centuries of oppression and exploitation to take joint action to correct the wrongs of the past and demonstrate to the rest of the world how a fragile and variable marine ecosystem can be managed sustainably.

ACKNOWLEDGEMENTS

The paper, "The Benguela: Ex Africa semper aliquid novi," is largely based on material contained in the BENEFIT Science Plan (Anon 1997) and in documents prepared for GEF/UNDP as inputs for approval by the GEF of the BCLME Programme. Financial support from the BCLME PDF/B grant via UNDP is gratefully acknowledged.

REFERENCES

Andrews, W.R.H. and L. Hutchings. 1980. Upwelling in the southern Benguela Current. Prog. Oceanogr. 9:81 p

Anon. 1997. BENEFIT Science Plan, BENEFIT Secretariat, Windhoek, Namibia 90p

Bailey, G.W. and J. Rogers. 1997. Chemical oceanography and marine geoscience off southern Africa: Past discoveries in the post-Gilchrist era, and future prospects. Trans. Roy. Soc. S. Afr. 52(1): 51-79

Brown, P.C., S.J Painting and K.L. Cochrane. 1991. Estimates of phytoplankton and bacterial biomass and production in the northern and southern Benguela ecosystems. S. Afr. J. mar. Sci. 11: 537-564

Carton, J.A. and B. Huang. 1994. Warm events in the tropical Atlantic. J. Phys. Oceanogr. 24: 888-903

Chapman, P. and L.V. Shannon. 1985. The Benguela ecosystem. 2. Chemistry and related processes. In: Barnes, M., ed. Oceanography and Marine Biology: An annual review. Aberdeen Univ. Press. 23: 183-251

Crawford, R.J.M. 1999. Seabird responses to long-term changes in prey resources off southern Africa. In: Proceedings of 22nd International Ornithological Congress, Durban. Adams, N. and R. Slotow, eds. Birdlife South Africa; Johannesburg. 688-705

Crawford, R.J.M., Underhill, L.G., Raubenheimer, C.M., Dyer, B.M. and J. Martin. 1992. Top predators in the Benguela ecosystem—implications of their trophic position. In: Payne, A.I.L., Brink, K.J., Mann, K.J. and R. Hilborn, eds. Benguela Trophic Functioning. S. Afr. J. mar. Sci. 12: 95-99

Croll, P. 1998. Benguela Current Large Marine Ecosystem (BCLME) First Regional Workshop UNDP, 22-24 July 1998, Cape Town, South Africa (Moderator's report on Workshop). 73 p

De Decker, A.H.B. 1970. Notes on an oxygen-depleted subsurface current off the west coast of South Africa. Investl. Rep. Div. Sea Fish. S. Afr. 84:24p

Dubnov, V.A. 1972. Structure and characteristics of the oxygen minimum layer in the Southeastern Atlantic. Oceanology 12(2): 193-201

Gammelsrød, T., O'Toole, M.J., Bartholomae, C.J., Boyer, D. and V.L. Filipe. 1998. Intrusion of warm surface water layers at the Southwest African coast in February-March 1995: The Benguela Niño '95: S. Afr. J. mar. Sci. 19. 99 41-56

Gordon, A.L. and K.T. Bosley. 1991. Cyclonic gyre in the tropical South Atlantic. Deep-Sea Res. 38 (Suppl. 1A) S323-S343

Hampton, I., Boyer, D.C., Penney, A.J., Pereira, A.F. and M. Sardinha. 1999. Integrated overview of fisheries of the Benguela Current region. BCLME Thematic Report 1, UNDP, Windhoek, 89 p

Hamukuaya, H., O'Toole, M.J., and P.M.J. Woodhead. 1998. Observations of severe hypoxia and offshore displacement of Cape hake over the Namibian shelf in 1994. S. Afr. J. mar. Sci.19

Hart, T.J. and R.I. Currie. 1960. The Benguela Current. Discovery Rep. 31: 123-297

Hutchings, L. and J.G. Field. 1997. Biological oceanography in South Africa, 1896-1996: Observations, mechanisms, monitoring and modeling. Trans. Roy. Soc. S. Afr. 52(1): 81-120

Hutchings, L., Pitcher, G.C., Probyn, T.A. and G.W. Bailey. 1995. The chemical and biological consequences of coastal upwelling. In: Summerchanges, C.P., Emeis, K-C., Angel, M.V., Smith, R.L. and B. Zeitzschel,eds. Upwelling in the Ocean: Modern Processes and Ancient Records. John Wiley & Sons Ltd: 65-81

Lass, H.U., M. Schmidt, V. Mohrholz and G. Nausch. 2000. Hydrographic and current measurements in the area of the Angola-Benguela front. J. Phys. Oceanogr., 30(2000), S. 2589-2609

Monteiro, P.M.S. 1996. The oceanography, the biogeochemistry and the fluxes of carbon dioxide in the Benguela upwelling system. Ph.D thesis, Univ. Cape Town, S. Afr.: 354p

Moroshkin, K.V., Bubnov, V.A. and R.P. Bulatov. 1970. Water circulation in the eastern South Atlantic Ocean. Oceanology 10(1): 27-34

Nelson, G. 1980. Poleward motion in the Benguela area. In: Neshyba, S.J., Moers, C.N.K., Smith, R.L. and Barber, R.T., eds. Poleward Flows along Eastern Ocean Boundaries. Springer, New York: 110-130 (Coastal and Estuarine Studies 34)

Nelson, G. and L. Hutchings. 1983. The Benguela upwelling area. Prog. Oceanogr. 12(3): 333-356.

Payne, A.I.L., Gulland, J.A. and K.J. Brink (Eds.). 1987. The Benguela and Comparable Ecosystems. S. Afr. J. mar Sci, 5: 957 p

Parrish, R.H., Bakun, A., Husby, D.M. and C.S. Nelson. 1983. Comparative climatology of selected environmental processes in relation to eastern boundary current pelagic fish reproduction. In: Sharp, G.D. and J. Csirke eds. Proceedings of the Expert Consultation to Examine changes in Abundance and Species Composition of Neritic Fish Resources, San Jose, Costa Rica, April 1983. F.A.O. Fish. Rep. 291(3): 731-777

Pillar, S.C., Moloney, C.L., Payne, A.I.L. and F.A. Shillington, eds. 1998. Benguela Dynamics: Impacts of Variability on Shelf-Sea Environments and their Living Resources. S. Afr. J. mar. Sci. 12:1108p

Shackleton, L.Y. 1986. An assessment of the reliability of fossil pilchard and anchovy scales as fish population indicators off Namibia. MSc. Thesis, Univ. Cape Town, S. Afr. 141p

Shannon, L.V. 1985. The Benguela ecosystem. 1. Evolution of the Benguela, physical features and processes. In: Oceanography and Marine Biology. An Annual Review 23

Shannon, L.V., Agenbag, J.J. and M.E.L. Buys. 1987. Large and mesoscale features of the Angola-Benguela front. In: Payne, A.I.L., Gulland, J.A. and K.H. Brink, eds. The Benguela and Comparable Ecosystems, S. Afr. J. mar. Sci. 5: 11-34

Shannon, L.V., Agenbag, JJ., Walker, N.D. and J.R.E. Lutjeharms. 1990. A major perturbation in the Agulhas retroflection area in 1986. Deep Sea Res. 37(3): 493-512

Shannon, L.V. and thirteen co-authors. 1992. The 1980s—A decade of change in the Benguela ecosystem. In: Payne, A.I.L., Brink, K..H., and R. Hilborn, eds. Benguela Trophic Functioning, . S. Afr. J. mar. Sci 12:271-296

Shannon, L.V., Boyd, A.J., Brundrit, G.B. and J. Taunton-Clark. 1986. On the existence of an El Niño-type of phenomenon in the Benguela system. J. Mar. Res. 44(3): 495-520

Shannon, L.V., Crawford, J.R.M., Brundrit, G.B. and L.G. Underhill. 1988. Responses of fish populations in the Benguela ecosystem to environmental change. J. Cons. Perm. Int. Explor. Mer. 45(1): 5-12

Shannon, L.V. and G. Nelson. 1996. The Benguela: Large scale features and processes and system variability. In: Wefer, G. and G. Siedler, eds. South Atlantic Circulation: Past and Present. Springer Verlag. 163-210

Shannon, L.V. and J.J. O'Toole. 1998. Proceedings of the International Symposium on Environmental Variability in the South-east Atlantic, Swakopmund., Namibia, March 1998

Shannon, L.V. and J.J. O'Toole. 1999. Integrated overview of the oceanography and environmental variability of the Benguela Current region. BCLME Thematic Report 2, UNDP, Windhoek, 57p

Shannon, L.V. and S.C. Pillar 1986. The Benguela ecosystem. 3. Plankton. In: Barnes, M., ed. Oceanography and Marine Biology. An Annual Review. 24: 65-170. Aberdeen; University Press

Sherman, K. 1994. Sustainability, biomass, yields, and health of coastal ecosystems: an ecological perspective. Mar. Ecol. Prog. Ser. 112: 277-301

Shillington, R.P. 1998. The Benguela upwelling system off Southwestern Africa, Coastal segment (16, E). In: Robinson, A.R. and K.H. Brink, eds. The Sea Vol.II, 583-604

Stander, G.H. 1964. The Benguela Current off South West Africa. Investl. Rep. Mar. Res. Lab SW Afr. 12: 43pp. plus 77 pages figures

Stander, G.H. and A.H.B. De Decker. 1969. Some physical and biological aspects of an oceanographic anomaly off South West Africa in 1963. Investl. Rep. Div. Sea Fish. S. Afr. 81, 46 p

Stuttaford, M. (Ed). 1996. Fishing Industry Handbook South Africa, Namibia & Moçambique. Marine Information C.C., Stellenbosch. 434p

Taunton-Clark, J. and L.V. Shannon. 1988. Annual and interannual variability in the South-east Atlantic during the 20th century. S. Afr. J. mar. Sci. 6:97-106

Verheye, H.M., Hutchings, L., Richardson, A.J., Marska, G. and D. Gianakouras. 1998. Long-term trends in the abundance and community structure of zooplankton during anchovy and sardine recruitment on the west coast of South Africa (1951 to present). S. Afr. J. mar. Sci. 19:317-332

Verheye, H.M. and A.J. Richardson. 1998. Long-term increases in crustacean zooplankton abundance in the southern Benguela upwelling region (1951-1996): bottom-up or top-down control? ICES Journal of Marine Science. 55: 803-807

Voituriez, B. and A. Herbland. 1982. Comparison des systemes producitfs de l'Atlantique Tropical Est.: domes thermiques, upwellings côtiers et upwelling equatorial. Rapp P.V. Reun Con. Int. Explor. Mer. 180: 114-130

Wattenberg, H. 1938. Die Verteilung des Sauerstoffs im Atlantischen Ozean. Wiss. Ergeb. Dt. Atlant. Exped. "Meteor" 1925-1927, 9: 132 p

Woodhead, P.M.J., Hamukuaya, H., O'Toole, M.J., Strømme, T. and S.S. Kristmannsson. Submitted. Recruit mortalities of Cape hake, following exclusion from shelf habitat by persistent hypoxia in the northern Benguela Current. 1998 ICES Recruit Dynamics Symposium Proceedings. ICES J. mar.sci.

Yamagata, T. and S. Iizuka. 1995. Simulation of tropical thermal domes in the Atlantic : a seasonal cycle. J. Phys. Oceanogr. 25(9): 2129-2140