Namib—Benguela interactions

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The region embracing the Namib and Benguela ecosystems provides a special opportunity for examining processes linking the geosphere and biosphere. A recent meeting attempted to identify the more important processes and plan for their future collaborative study.

A specialist workshop on the Namib and Benguela, focusing on interactions between the two very different ecosystems, was held at Gobabeb, Namibia, during November 1988 under the auspices of the South African Special Committee for the International Geosphere-Biosphere Programme (IGBP). Twenty-six invited marine, terrestrial and atmospheric scientists participated.

The idea of a scientific meeting on the Namib-Benguela originated during the preparation of a suite of syntheses on the Benguela ecosystem.[1–5] It was evident that information about the Namib, such as land morphology, vegetation cover, rainfall and winds, and the transport of material during episodic floods could be relevant to local marine science, while, conversely, marine processes such as upwelling, fog generation and sulphur cycling were likely to be important for the functioning of the desert ecosystem. If, as a point of departure, it could be assumed that the two systems are coupled, then it follows that it is principally the atmosphere that provides the connection.

It appeared that those interactive processes which link the two systems, and also the meridional similarities and contrasts between some structural features of the Namib and the Benguela, were worth examining further—hence the concept of a workshop involving scientists from different disciplines and contrasting backgrounds. This concept gained further momentum following the launch of ICSU's International Geosphere-Biosphere Programme (IGBP: A Study of Global Change) and the establishment of the South African Special Committee for the IGBP. The primary goal of the programme is to advance man's ability to predict and plan for elements of anthropogenic global change by means of modelling the global environment. The Namib-Benguela (which spans the region between latitudes 14°S and 32°S) seemed to provide a unique field 'observatory' in Southern Africa for examining some of the small and medium-scale processes linking the geosphere and biosphere, particularly as its climatic regime has been much the same for most of the last five million years or so.

Workshop objectives were as follows:

1) To bring together key scientists who are active in research in the Namib Desert and in the Benguela ecosystem so as to exchange ideas and information and to stimulate future collaboration.

2) To compare variability in the two systems and to explore the potential utility of long-term data series.

3) To examine the role of marine and atmospheric processes in the aridification of the Namib region.

4) To examine the impact of aeolian and riverine input of material into the Benguela on shelf sediments, chemistry and marine life.

5) To examine chemical cycles that may be regionally important.

6) To stimulate active participation in the National Conference on Geosphere-Biosphere Change in South Africa (4 – 8 December 1989) and to provide a useful contribution to the IGBP.

The workshop programme was developed so as to provide for both overview and in-depth discussion, the latter being in five sessions: latitudinal changes and similarities; temporal variability; aridity of the Namib; chemical cycling; and the marine sediment budget. Further details about the programme and the rapporteurs' reports are available in the proceedings.[6]

In the following sections we critically review the workshop, identify highlights and shortcomings, and indicate gaps and research needs.

Dichotomy

The workshop set itself the task of reviewing all appropriate physical, chemical and biological data sets dealing with marine (Benguela) and terrestrial (Namib) interactions via the linking atmosphere. The review revealed the strengths and weaknesses of the available data base, as expected, but more importantly it strongly underlined differences in philosophy, methodology and interpretation between researchers of the marine and terrestrial environments. These are summarized as follows:

1) The marine scientists are visitors to the region, whereas the terrestrial researchers are resident there, and this yields different perspectives.

2) Generally, marine scientists, being largely dependent on ships, sample the environment differently over both time and space. Obvious exceptions are where satellite imagery or fixed or moored instruments are employed.

3) The marine scientists obtain much more synoptic information from satellite imagery than terrestrial workers. The latter tend to be more concerned with individual populations than with systems-based studies.

4) The marine scientists are orientated towards resource utilization (e.g. fisheries and diamond mining), whereas the terrestrial scientists tend to have a more theoretical/academic approach to their studies.

5) The terrestrial scientists are more aware of, and attach greater importance to, the marine input than do the marine scientists to the terrestrial contribution. In this context, the assumption made by the workshop that the Namib and the Benguela comprise one system (depending largely on one another for their properties) may not be true (but see below).

6) The terrestrial scientists focus strongly on the central Namib, with relatively little work having been done in Namaqualand to the south and southern Angola in the north. In contrast, the marine scientists' studies have been more widely spread from St Helena Bay (biogeographically, the Namib's southern limit is at the mouth of the Berg river) to Porto Alexandre in Angola.

7) The terrestrial and marine geologists tend to be moving along different pathways, with little interaction, in elucidating the palaeo-history of the two systems. The relationship of apparently aeolian deposits on the continental shelf with past sea levels may provide a solution to some of the biogeographical problems attending present-day dune organisms in the Namib.

8) Perceived differences in scaling contributed significantly to members of the workshop 'talking past each other' more often than not. This phenomenon manifested itself even between members of seemingly homogeneous groups. For instance, some terrestrial ecologists failed to appreciate that rainfall in 'average' years in the Namib normally occurs as 40 – 50-km-wide storm cells, and not over broader fronts. Consequently, rainfall events are extremely patchy in their dispersion both in space and time. The implications of this for the survival of the biota are profound (e.g. storage of plant seeds in refugia). A possibly related example concerns avian nomadism. The relatively high incidence of nomadic species in the avifaunas of the area and semi-arid areas of Southern Africa

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might be vested in the patchily dispersed nature of much of the region's rainfall.

Omissions

These differences were bridged, to some extent, by the few climatologists and systems ecologists who attended the workshop. The climatologists, in particular, displayed a sound grasp of the macro- and meso-scale wind patterns, and it was regrettable that they were under-represented as wind is obviously of paramount importance in shaping the two environments and their components and interactions. The atmosphere, as the link between the marine and terrestrial environments, merited more attention. Atmospheric chemistry was not represented and, consequently, little was said about the constituents of fog, their potential importance to plants and their role in the formation of gypsum. Even the formation of fog was shrouded by ignorance and clouded by speculation. Other notable under-representations and omissions included reviews of intertidal systems and the marine littoral. Here, for example, one thinks of the biotic input from the sea to the desert ecosystem, which might be important locally and in the vicinity of seal colonies and in sheltered bays.

These factors compounded to create the impression that the Namib and the Benguela are separate systems. Indeed, the workshop did far more to focus on differences and on apparent paucity of vital interactions between the two environments than it did on commonalities and links between them, which was at variance with the themes of the workshop sessions devised by the conveners.

Criticism was expressed at the meeting that the workshop, in spite of having been organized under the auspices of the South African IGBP, gave scant attention to the following 'greenhouse' forces which might promote large changes in the Benguela and Namib ecosystems in the foreseeable future: change in sea level; ambient temperature increase; ultraviolet (especially UV-B) increase; increase in atmospheric carbon dioxide; and change in episodic events, such as fogs, 'berg' winds and floods. Perhaps it was expecting too much of the workshop to describe likely impacts of these factors, particularly as discussion of greenhouse forcing was not an objective of the meeting. It might have been interesting, however, to have examined potential change in the flood regime of the Orange river, in terms of its discharge of sediment and ultimate contribution of sand to coastal dune fields. No attempt was made to grapple with the problem of scaling down predictions of General Circulation Models (GCMs), which typically operate on 500 × 500 km grid squares, to local climate domains. (This remains a central problem within the IGBP.) Interestingly, however, the workshop produced some evidence for the same factors determining macro-, meso- and micro-scale happenings on land as well as in the sea, with wind being regarded as pre-eminent. It was disappointing to note that very few participants in the workshop made special attempts to place their presentations and remarks within the framework of the IGBP. Indeed, there is a lesson here for those who would learn from it: the IGBP, and particularly the South African contribution, needs more publicity among the scientific community.

Highlights

Thus far we have been rather critical—perhaps harshly so. There were, however, many aspects of the workshop that were positive, and which led to constructive exchange of information and ideas among the participants, to the development of hypotheses, and to the identification of important gaps in knowledge and understanding—which is probably what a workshop is all about. Measured against these criteria, we believe that the workshop was successful.

Perhaps the most important contribution the workshop made was bridging the gap between the marine and terrestrial scientists. Both groups tend to be insular in their outlooks, traditionally regarding the coastline as an impenetrable system boundary. Apart from the national conference held jointly between marine and freshwater scientists in Port Elizabeth in 1976,[7] some meetings on limnology and the atmosphere, and occasional symposia dealing with the sea shore,[8] until the inception of the South African IGBP there has been almost no interaction between the oceanographers and terrestrial scientists. The long-term data series meeting[9] paved the way for cooperation, and we believe that the Namib-Benguela workshop has taken this a stage further. Much of the interaction took place outside of the formal meeting. A number of professional friendships have been established and joint marine-terrestrial-atmosphere research projects are beginning to emerge. In this respect the workshop achieved its first objective, and the collaborative work in the pipeline bodes well for the future of the South African IGBP. Environmental science, which is the cornerstone of the IGBP, is necessarily multi- and interdisciplinary.

What came across strongly throughout the workshop was the dominant role which the wind plays in both the Namib and the Benguela. The workshop facilitated the comparison of information and ideas on wind stress and wind maxima over both land and sea in a manner not previously achieved. Whereas the oceanographic data show the principal wind maxima in the region to be situated at, or slightly to the north of, Lüderitz, there was convincing geological evidence—based on an analysis of sand movements and the size and position of yardangs cut in dolomite—that the strongest winds occur south of Lüderitz. Some interesting ideas were expressed about the role of thermal enhancement of longshore winds due to effects of upwelling (providing positive feedback) and topography. The winds along the Namibian coast can be divided into two, with the trade winds predominating in the north and the synoptic weather systems associated with the South Atlantic Anticyclone (high pressure cell), and its ridging, in the south. This concept, which was not previously appreciated by most of those present at the workshop, explains the existence of the 'slack' area in the central Namib.

Of considerable interest was the indication from the geological record that the Lüderitz 'nerve centre' is very old, having persisted through periods of differing climate. If correct, then this has major implications for the South African IGBP. A conceptual model of inter- and intradiurnal wind flow in the central Namib has emerged from case studies undertaken by the University of the Witwatersrand. While the model may be generally applicable throughout the Namib, the substantial meridional variation in the equatorward winds (which is well known to oceanographers) seems to indicate that a number of additional experiments in other parts of the system and preferably extending out over the sea are prerequisites for a more general model. This work, together with the preliminary results which show that sea-surface temperature in several areas of the south-east Atlantic and rainfall and fog over the Namib are positively correlated, could result in some exciting advances in understanding the weather and climate of the Namib-Benguela during the IGBP. Ignorance of the physics and chemistry of Namib fog is, however, a cause for concern and will need to be addressed.

The massive impact of man on changing the input of sediment into the sea was highlighted at the meeting. During the Neogene, the Orange river discharged an average of about 0.5×10^6 tons of sediment each year. By the 1930s the figure had risen, reaching a maximum of 119×10^6 tons due to agricultural malpractices, and then subsequently declined with the construction of dams and the reduced availability of material (topsoil having gone and hardpan calcrete having been exposed). Sediment transport during the major 1988 flood was 81×10^6 tons. Thus human activity has resulted in increased sand supply to the Namib this century. The implications of possible reduced availability of material in the future should, however, be considered.

A preliminary silicon budget was presented at the workshop. Although there is some imbalance, the input of the new and regenerated silicon was shown to account adequately for the loss to sediments. Recycling plays a major role, and Dr D.E. Pollock argued convincingly that the subterranean supply of silicon to shelf waters via desert rivers may be very important for marine processes. The presentation which showed the correspondence between the relative abundance of the diatom *Delphineis karstenii* in shelf sediments and the positions of the main rivers was certainly one of the highlights of the meeting.

Research needs

We have identified a number of gaps in knowledge and research needs. The following list, which is neither exhaustive nor necessarily in order of priority—like the rest of this report—reflects the opinions of the authors.

1) A proper understanding of the wind systems over the Namib and the Benguela is a high priority. This will require both measurement and modelling. Existing data on land and at sea are spatially and temporally extremely patchy. For example, the extent of influence of the land-sea breeze over the sea is unknown as is the influence of berg winds. More case studies of air flow, in particular zonal flow, along the lines of the recent work by Professor P.D. Tyson's group in the central Namib, but extended seawards and at other latitudes, will be necessary to allow for a proper description. (The Lüderitz zone would be a good first choice.)

2) Research on fog formation, movement and chemistry in the Namib-Benguela is necessary in view of the important role which fog plays in the system. Even at a very basic level, the contribution that upwelling makes in fog generation and in the maintenance of the aridity of the Namib needs to be established. A cooperative pilot project involving a cloud physicist, an atmospheric chemist, an oceanographer and terrestrial biologists seems to be indicated. Viewed more broadly, it is essential that a more viable atmospheric chemistry capability should be established in South Africa if any useful input to IGBP is to be made.

3) An attempt should be made to use General Circulation Models to develop climate scenarios for the Namib-Benguela. While the problem of scaling down GCMs to local climate domains will obviously have to be addressed, it is our view that potentially useful work—both predictive and in retrospect—could be done using existing models. The Namib-Benguela could be a climate modeller's paradise!

4) All available rainfall records need to be analysed with a view to determining the scales of the events (i.e. their spatial patchiness and duration) and ascertaining what weather system(s) caused them. This is a prerequisite for planning a monitoring scheme for the Namib.

5) The terrestrial sand budget needs to be quantified and the implications of present surplus and *possible* future limitations of sand supply to the system, due to the impact of humans on the Orange river catchment system, investigated.

6) It would be useful to know whether berg winds are important as source of silicon and iron (which are possibly limiting nutrients for primary production) for offshore waters in the Benguela. Chemical analysis of atmospheric dust coupled with improved estimates of dust flux to sea via the atmosphere would answer this question. The work may be important for the IGBP in addressing the global CO_2 problem if Fe is, as has been suggested, a limiting factor in primary production offshore.

7) There is a belief that strong winds limit the growth of relatively fragile succulents in the Namib. Comparative studies of terrestrial biota in areas of high and low wind speeds in the region may provide the answer.

8) The role of fog and its chemical constituents in the formation of gypsum deposits should be addressed. Is the availability of suitable substrata perhaps the limiting factor?

9) The remarkable correlation between areas of high abundance of the marine diatom *Delphineis karstenii* (an important food organism for the pilchard) and the positions of desert river beds requires further attention. If, as Dr Pollock suggests, the rivers might be an important underground source of silicon supply to the Benguela system and if *D. karstenii* is largely limited by silicon, then the importance of subterranean flow of water via these rivers assumes considerable importance for the Benguela ecosystem.

In conclusion

However interdependent the Namib and the Benguela environments may be, the two systems are linked by the atmosphere. Wind transports water and inorganic and organic matter both ways between the land and the sea, affecting energy flows and nutrient cycling in both systems. Wind, above all else, shapes the physical environment and also elements of the biota, at sea and on land. For example, wind drives longshore sediment transport which influences major coastal features such as at Conception, Sandvis and Walvis Bay and Bahia dos Tigres. In contrast to the world's other major eastern-boundary currents abutting on desert systems (e.g. the Humboldt-Atacama), pelicans are not a striking feature of the otherwise comparable Benguela-Namib region. It seems probable that the winds of the Benguela coast, apart from at a very few sheltered sites such as Walvis Bay, are simply too strong for these birds' aerial manoeuvres. The Namib's vascular plants tend to be grasses and xerophytic shrubs, the latter characteristically having small and narrow leaves. Many rely on fog and groundwater for survival during rain-free periods. Succulent shrubs, with relatively large swollen leaves and stems in which water is stored, are unusual in exposed sites, compared with parts of the Karoo which are more arid than the Namib. Perhaps the evolution of relatively fragile succulent growth forms has been limited by strong wind in the Namib. The physical effects of wind are most pronounced where the continental shelf and the distance from the coast to the escarpment are narrowest, that is, where the linear conveyor belts (see below) are squeezed together laterally.

If wind is the agent linking the land and the sea, this is not necessarily evidence for the interdependency of the two systems. This point has been made before, but it is worth repeating. Indeed, one could view the Benguela and the Namib as two largely separate conveyor belts, moving parallel to each other in a northerly direction with some lateral connections between them as they shed air, water, nutrients and sand at their interface. The physical properties as well as the features of the biotas of these two systems are consequences of their position on the western side of a continent, at a latitude where they are exposed to winds driven by the South Atlantic Anticyclone. This is an exceptionally powerful engine, so linear flow of energy through both systems and between the southern temperate and northern tropical regions could be fast.

Received 31 March 1989.

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