FROM SOURCE TO SEA

Interactions between the Orange-Senqu River Basin and the Benguela Current Large Marine Ecosystem

ORANGE - SENQU RIVER COMMISSION
BOTSWANA LESOTHO
ORASECOM
NAMIBIA SOUTH AFRICA
Established 2000

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VIEWED FROM SPACE, THE ORANGE RIVER IN FLOOD CAN BE SEEN SPEWING A PLUME OF SEDIMENT-LADEN FRESHWATER INTO THE ATLANTIC OCEAN. BUT THIS MIGHTY RIVER HAS BEEN TAMED BY DAMS AND SHACKLED BY WATER ABSTRACTION SCHEMES, TO THE EXTENT THAT ITS AVERAGE ANNUAL FLOW HAS BEEN REDUCED BY HALF, WHILE ITS WATERS HAVE BEEN POLLUTED IN PLACES BY URBAN DEVELOPMENT, INDUSTRIAL ACTIVITY AND AGRICULTURAL PRACTICES.

WHAT ARE THE IMPACTS OF THE ORANGE RIVER'S ALTERED QUANTITY AND QUALITY OF FRESHWATER INPUT ON THE MARINE AND COASTAL ENVIRONMENT? A MULTI-DISCIPLINARY TEAM OF SPECIALISTS WAS APPOINTED BY THE ORANGE–SENQU RIVER COMMISSION (ORASECOM) TO FIND OUT.

FOREWORD

The discharge of the Orange–Senqu River into the Atlantic Ocean off south-western Africa forms a natural linkage between the two commissions responsible for promoting the sustainable management of these two important ecosystems: the Orange–Senqu River Commission (ORASECOM) and the Benguela Current Commission (BCC). That the freshwater Orange–Senqu and the marine Benguela Current form an estuary of global significance and recognition – as a Ramsar site – makes the linkage that much more important.

A common understanding of how these freshwater and marine ecosystems interact and influence each other is essential for the respective and joint management of the river basin, marine ecosystem and estuary. Cooperation between two United Nations Development Programme–Global Environment Facility (UNDP–GEF) projects on environmental concerns – the Orange–Senqu Strategic Action Programme supporting ORASECOM and the the Benguela Current Large Marine Ecosystem Strategic Action Programme Implementation Project supporting BCC – has enabled us to explore these interactions.

Of particular interest are the interaction of the estuary with the coastal zone and larger marine ecosystem, and the impact of the altered state of the Orange–Senqu River and its catchment with respect to flow, sediment transport, nutrient loads and other water quality issues.

This initiative has helped to establish working relations and cooperation at three levels:

- between two international commissions on data and information sharing,
- between two UNDP–GEF projects addressing transboundary environmental concerns and
- between the two estuarine states of Namibia and South Africa in the development of coordinated management plans for the Ramsar site.

Based on a more detailed scoping report and workshop, this booklet provides a comprehensive, yet succinct, summary of these interactions that will be useful for managers, while its colourful and attractive design makes it appealing to a much broader audience. Furthermore, it paves the way for future joint action. We invite you to explore this interesting topic as we strive for deeper collaboration and common understanding of pertinent management challenges to the nations sharing the river and the marine ecosystems.

Lenka Thamae
Executive Secretary
ORASECOM Secretariat

Hashali Hamukuaya
Executive Secretary
BCC Secretariat

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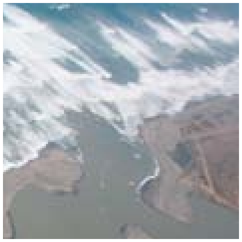
    


ZIMBABWE
MOZAMBIQUE
BOTSWANA
NAMIBIA
SOUTH AFRICA
LESOTHO
SWAZILAND
WINDHOEK
GOBABIS
MARIENTAL
KEETMANSHOOP
GABORONE
MAFIKENG
POLOKWANE
PRETORIA
JOHANNESBURG
NELSPRUIT
MAPUTO
VRYBURG
UPINGTON
KIMBERLEY
BLOEMFONTEIN
MASERU
DURBAN
DE AAR
SENDELINGSDRIFT
ORANJEMUND
VIOOLSDRIFT
SPRINGBOK
CAPE TOWN
PORT ELIZABETH
EAST LONDON
Kgalagadi Transfrontier Park
Limpopo National Park
Kruger National Park
Ai-Ais/Richtersveld Transfrontier Park
Namib Desert
Nossob
Auob
Fish
Molopo
Orange
Vaal
Caledon
Bloemhof Dam
Vaal Dam
Vanderkloof Dam
Gariep Dam
BENGUELA CURRENT
AGULHAS CURRENT
Main Towns or Cities
Main River
Orange-Senqu River Basin
International Boundary

THE ORANGE–SENQU RIVER: LIFEBLOOD OF THE BASIN

The Orange River rises as the Senqu in the highlands of Lesotho, some 3,300 metres above mean sea level and more than 2,300 kilometres from its destination on the west coast of southern Africa. With a total catchment area of almost a million square kilometres, the Orange–Senqu River Basin is one of the largest in Africa, encompassing the whole of Lesotho and parts of Botswana, Namibia and South Africa. Its many tributaries include the Vaal River in South Africa and the ephemeral Fish River in Namibia.

The basin has a population of 14.3 million people, and the river system plays a vital role in sustaining livelihoods and stimulating economic growth. Water is abstracted for urban, industrial and agricultural use, and harnessed for hydroelectric power via several water transfer schemes and 29 large dams.

The combined effect of abstraction and evaporative losses has been a reduction by more than 50% in the natural runoff of 11,600 million cubic metres per year. Demand for water is predicted to increase with economic growth and development, emphasising the urgency for effective water resource management to ensure sustainability.

The river is also important to regional cooperation, as it crosses national boundaries and – in the case of Namibia and South Africa – forms part of the border between the two countries. Furthermore, each country, by way of national legislation and international conventions, is obliged to account for water allocations to the other riparian countries.

The four countries in the basin are committed to working together to protect their shared water resources, and through an agreement in 2000 established the Orange–Senqu River Commission (ORASECOM) to facilitate this. ORASECOM is founded on the provisions of the Revised SADC Protocol on Shared Watercourses.

REVISED SADC PROTOCOL ON SHARED WATERCOURSES

The Revised Protocol on Shared Watercourses in the Southern African Development Community (referred to as the Revised Protocol) was the first sectoral Protocol among SADC member states after the SADC Treaty was signed in 1992. The original Protocol was named the SADC Protocol on Shared Watercourse Systems and drafted in 1995 in line with the International Law Association's Helsinki Rules. The Protocol was subsequently revised (and renamed) to reflect the 1997 United Nations Convention on the Law of Non-navigational Uses of International Watercourses. The Revised Protocol was signed in 2000 and came into force in 2003.

The Revised Protocol is a regional framework agreement based on the central principles of international water law, namely equitable and reasonable utilisation, the obligation to take all reasonable measures to prevent significant harm and the duty to cooperate. The Revised Protocol encourages SADC states to conclude basin-specific agreements that apply the provisions of the Protocol to the characteristics and uses of specific shared watercourses.

The agreement establishing the Orange–Senqu River Commission (ORASECOM) was the first basin-specific agreement concluded in that context, shortly after the SADC Protocol was signed by the majority of SADC Member States in 2000. Several provisions of the ORASECOM Agreement explicitly state that they need to be interpreted as determined by the Revised Protocol.

From the highlands of Lesotho to its lowest reaches, the Orange–Senqu River system is an essential water resource, supporting over 14 million people and a variety of industries and livelihoods.

Clockwise from top left: The Ace Apparel clothing factory in the industrial zone of Maputsoe in Lesotho; irrigated vineyards of export table grapes in arid southern Namibia also support a large informal raisin industry; diamond mining close to Oranjemund; service delivery lags behind in Bekkersdal, South Africa; melon farming in the Northern Cape, South Africa.

A HOLISTIC AND HARMONISED APPROACH

ORASECOM provides a forum for consultation and coordination between its member states – Botswana, Lesotho, Namibia and South Africa – to promote integrated water resources management (IWRM) within the Orange–Senqu River Basin. The IWRM approach helps to manage and develop water resources in a sustainable and balanced way, taking into account social, economic and environmental interests. A primary mechanism of achieving IWRM in the Orange–Senqu River Basin is the development of a basin-wide IWRM plan, which will provide the cooperative framework for the management and development of water and related resources.

Contributing to the development of this plan is the Orange–Senqu Strategic Action Programme, funded by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP). This UNDP–GEF project aims to ensure that the quality and quantity of water throughout the basin meets the needs of its dependent ecosystems, communities and economies. Without ignoring national concerns and priorities, its interventions will focus on transboundary problems, although some actions may arise from shorter term or more narrowly focused studies. Also explored are the interactions between the river's freshwater flows and the nearshore marine environment. Through an expert workshop conducted in 2010, it was concluded that the river's impact on the offshore environment is probably restricted to sediment deposition on the continental shelf, and the associated influence on some commercially important fish species.

ORANGE–SENQU RIVER COMMISSION

The Orange–Senqu River Commission – ORASECOM – was established by the governments of Botswana, Lesotho, Namibia and South Africa to promote equitable and sustainable development and management of the resources of the Orange–Senqu River. This joint commitment was sealed through an Agreement on the Establishment of the Orange–Senqu River Commission signed in November 2000 in Windhoek, which conforms with best international practices regarding the joint management of shared rivers.

The highest body of ORASECOM is the Council, consisting of delegations from each country, supported by various 'Task Teams' that manage projects, and a Secretariat. The Council serves as technical advisor to the member states on matters related to development, utilisation and conservation of water resources of the Orange–Senqu River system. The Secretariat, established by agreement with South Africa in 2006 and hosted there, coordinates ORASECOM activities, implements ORASECOM decisions and is the focal point of the institution.

The Orange River estuary is an important stopover for migrating wetland birds, such as these flamingoes. This internationally recognised Ramsar site provides food and shelter for thousands of waders every year.

A GLOBAL PERSPECTIVE

Internationally, there has been a growing realisation that freshwater flows can have a significant effect on marine ecosystems. Along the east coast of southern Africa, for example, the Catchment2Coast Project in Mozambique revealed the linkages between river flow, salinity, mangrove production and shrimp grow-out to explain local knowledge of a two-month lag between good rains and high shrimp catches in Maputo Bay. Likewise, in South Africa's KwaZulu–Natal Province, a long-term monitoring programme has shown a strong positive correlation between river flow and fish egg abundance, implying increased spawning intensity during years of high freshwater flows to the marine environment.

In many parts of the world, human activities in the catchment cause nutrient enrichment of coastal waters by elevating nitrogen and phosphorus levels in river discharge, leading to more frequent algal blooms with associated oxygen depletion and fish kills. Reductions in freshwater flow compound these problems because rivers are a significant source of silica, which originates from the weathering of rocks on the continents.

Silica is used by diatoms to make their hard cell walls, called frustules, so silica input from rivers creates favourable conditions for diatom production. Any changes in the ratios of silica (Si), nitrogen (N) and phosphorus (P) in coastal waters can disrupt plankton communities. In temperate regions, a decrease in Si:N and Si:P ratios has caused a shift in community composition from diatoms to flagellates, cyanobacteria and other non-siliceous phytoplankton, many of which cause harmful algal blooms. Furthermore, since diatoms form the base of the 'classic' pelagic food web, their decline may have a ripple effect throughout the coastal marine ecosystem.

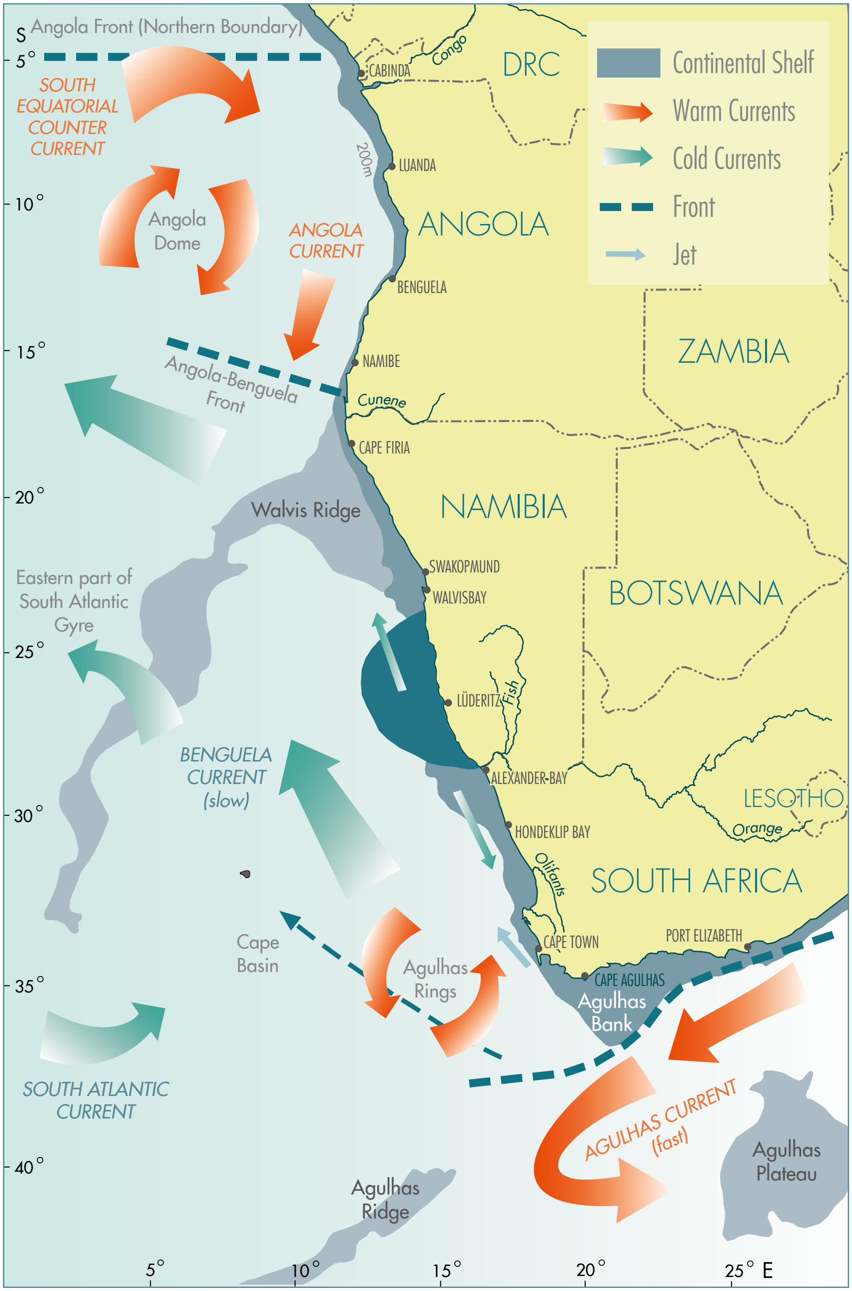
Similarly, limited occurrence of the trace metal iron, which is necessary for photosynthesis and growth, may negatively affect primary production by phytoplankton. River discharge of suspended sediments is the major source of iron in many parts of the world's oceans, and supports the development of phytoplankton blooms.

In addition, sediment supply from rivers is in itself vital for maintaining coastal sediment budgets. In some regions, a reduction in sediment discharge to the sea through damming of rivers has caused erosion problems on adjacent coastlines, requiring costly mitigation measures such as breakwater construction and beach nourishment programmes.

Far left: Mass mortalities in some coastal regions are attributed to or indirectly caused by pollution.

Top right: Rivers play an important role in coastal sediment budgets, helping to prevent beach erosion.

Bottom right: Harmful algal blooms, such as this 'red tide', may discolour the water .



The Benguela Current – one of the most productive in the world – supports a diverse fauna and an important fishing industry.

WHERE RIVER AND OCEAN WATERS MEET

The Orange–Senqu River discharges into the Atlantic Ocean on the west coast of southern Africa. Offshore, the Benguela Current – the eastern boundary current of the oceanic circulation known as the South Atlantic Subtropical Gyre – moves slowly up the subcontinent's margin, while wind-driven coastal upwelling closer inshore injects cold, nutrient-rich waters into surface waters. As a result, the Benguela is one of the four most productive marine ecosystems in the world.

The Benguela Current Large Marine Ecosystem (BCLME) extends from the Angola Front in the far north to the retroflection area of the warm Agulhas Current in the south-east, encompassing the area from Angola's Cabinda Province to Port Elizabeth in South Africa. As one of the world's most productive ocean areas, the Benguela supports a number of commercially important fisheries, while its marine mammals, seabirds and scenic landscapes offer considerable tourism opportunities.

At the BCLME's northern extreme, the Congo River discharges the second highest volume of freshwater into the oceans after the Amazon. Given that freshwater is less dense than seawater, this intensifies the thermal stratification of Angolan waters. Such stratification suppresses vertical mixing, allowing phytoplankton to remain in surface waters where light levels are optimal and nutrient concentrations may be higher due to river inputs. Zooplankton accumulations associated with phytoplankton blooms provide a concentrated food source for fish, which in turn attract mammals and birds.

While the Orange–Senqu River is only a fraction of the size of the Congo River, it is by far the largest river discharging into the BCLME. A joint workshop was therefore convened by ORASECOM and the Benguela Current Commission (BCC) in August 2010 to explore the interactions between the Orange–Senqu River Basin and the BCLME. A scoping report, based on specialist input made at the workshop and a review of relevant scientific literature and data, was subsequently compiled.

BENGUELA CURRENT COMMISSION

Benguela CURRENT COMMISSION

The Benguela Current Commission (BCC) was established in 2008 to promote the integrated management, sustainable development and protection of the Benguela Current Large Marine Ecosystem (BCLME). Its key focus is the management of shared fish stocks; protection of biodiversity and ecosystem health; environmental monitoring; and pollution prevention and mitigation.

The Commission has its origins in the BCLME Programme, a joint initiative by the governments of Angola, Namibia and South Africa, supported by the Global Environment Facility (GEF) and other donors. Its objective is to improve the structures and capacities of the three countries to deal with environmental problems that occur across national boundaries, to ensure that the BCLME can be managed in a coordinated and integrated way.

Originally conceived in 1995, the BCLME Programme was developed over the next five years in partnership with GEF and the United Nations Development Programme (UNDP), and guided by the preparation of a transboundary diagnostic analysis and strategic action programme. Its implementation between 2002 and 2008 made it the first large marine ecosystem programme to address an open-ocean ecosystem, rather than being limited to coastal ecosystems.

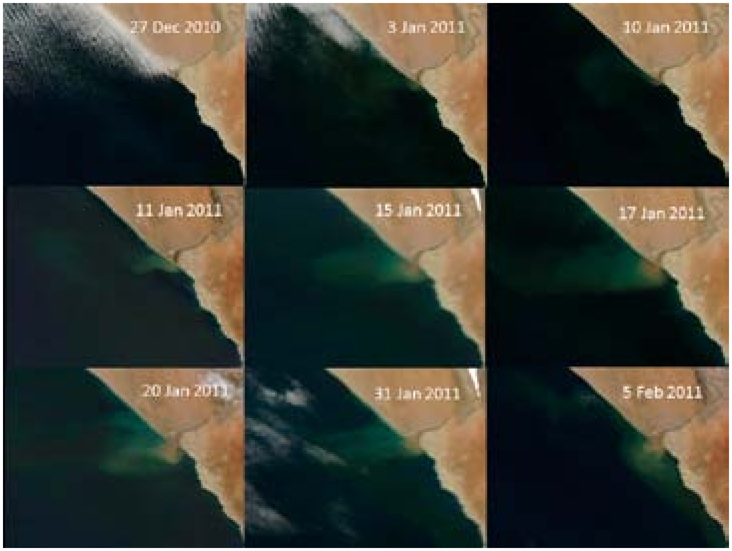
FRESHWATER FLOWS

Under normal circumstances, flow from the Orange–Senqu River is too small to have any impact on the Benguela Current offshore, nor does it influence coastal circulation other than in a localised area near the mouth. The river's outflow typically forms a plume of buoyant, nutrient-rich freshwater, but this nutrient input is insignificant compared to that of wind-driven coastal upwelling.

During severe floods, however, the river does exert some control over coastal circulation. In the 1988 flood – the largest in recent times – the river's warm, freshwater discharge formed an eddy 40 kilometres in diameter off the mouth. It subsequently moved southward along the coast as a 15-kilometre-wide plume for some 120 kilometres, causing mass mortalities of intertidal organisms. Lower than usual salinities were measured as far south as Hondeklip Bay, about 200 kilometres from the Orange River mouth. This southward flow direction is compatible with the very light winds experienced at the time. A week later, after the south-easterly wind intensified, the plume responded by flowing to the north.

Satellite images of the January 2011 flood reveal the changing shape and extent of the plume with discharge volume and prevailing wind direction, reaching at least 100 kilometres offshore on 17 January.

Over the past half-century, however, the frequency and magnitude of floods have been significantly reduced by dam development in the Orange–Senqu River Basin. Large floods now only occur when there is spillage from the Vaal and Bloemhof dams on the Vaal River, and the Gariep and Vanderkloof dams on the Orange River. Maximum discharges and flood durations are also much less than in the past.



Facing page, clockwise from top: A flooded road after a severe storm in Christiana, North West Province, South Africa; the Orange River in full flood thundering over the Augrabies Falls after exceptional rains in the basin in 2011; thousands of cubic metres of water spill from the Vanderkloof Dam per second.

Left: A series of satellite images showing the discharge of the river's sediment-laden waters into the Atlantic Ocean at the beginning of 2011, after exceptional rains inland.


MARIENTAL
Nossob
Auob
NAMIBIA
KEETMANSHOOP
Fish
Orange
Buffels
Northern Cape
SPRINGBOK
SOUTH AFRICA
Olifants
Berg
Western Cape
CAPE TOWN
Mud Belt
Main River
International Boundary
Provincial Boundary

MUDDY WATERS

While the freshwater flow of the Orange River generally has no discernible effect on the offshore marine environment, sediments discharged by the river do have an influence.

The Orange River is the most turbid river in Africa, and is the principal source of sediment to the continent's western margin. The deposition of sediment over millions of years is reflected in the width of the continental shelf, more than 200 kilometres wide at the river mouth. It is estimated that during the past 11,500 years (the Holocene epoch) the river has contributed an average flux of 5.1 million metric tonnes of sediment per year.

Much of this sediment originated from the naturally erodible soils in the high-rainfall areas of the Lesotho highlands. In the first half of the last century, however, this shifted to the intensely cultivated lands of the eastern catchment and grazing areas of the southern catchment, when soil erosion resulting from poor farming practices caused a tenfold increase in sediment flux. The construction of large impoundments in the 1970s has meant that much of this sediment is now trapped behind dam walls within the Orange–Senqu River Basin, although this is offset to some extent by increased erosion in the lower catchment areas, below the dams.

Soils eroded by heavy rainfall from as far upstream as the highlands of Lesotho are carried along the system of waterways and purged into the Atlantic Ocean.

Top left: Eroded watercourse of one of the many streamlets flowing into the Senqu River in Lesotho.

Middle: Silt-laden Senqu River, near Quthing in Lesotho.

Bottom: After exceptional rains in 1988, the Orange River flooded through the sand barrier at the mouth, muddying the ocean.

With normal outflow, the sediment load of the river is sorted into size fractions and dispersed by winds, waves and currents once it is discharged into the sea. The coarser gravels accumulate along the shoreline over a distance of 300 kilometres northwards of the mouth, while sands are transported at least 700 kilometres northward by longshore drift and southerly winds to the Namib Desert. The finer sand and clay fractions are carried further out and then southward by an inshore undercurrent, settling out to form a narrow mud-belt extending 500 kilometres south to St Helena Bay. The mud-belt lies at depths of 40 to 140 metres, but some sediment is also transported off the shelf onto the continental slope.

During floods most of the suspended load is deposited on the estuarine delta outside the mouth, after which it takes several years to be redistributed. In the 1988 flood, an estimated 80 million tonnes of sediment was discharged by the river, nearly all of which was derived from bank erosion and riverbed scour downstream of the major dams.

The high sedimentation rates in the delta area, and hence the risk of smothering and constant burial, inhibit the development of invertebrate communities on the sea floor. The resulting absence of burrowing activity means that the sediment layers provide a relatively undisturbed record of historical flood events, in much the same way that rings on a stump can be used to age a tree.

FLOWS AND OFFSHORE FISHERIES

During floods, the low salinity and high sediment load of the Orange River outflow may act as a temporary barrier to fish movement in the region of the mouth. Demersal (or deep-sea) trawl surveys on South Africa's west coast have revealed, however, that the biomass of St Joseph shark, tongue sole and Cape gurnard has peaked in flood years. Indeed, the biomass of St Joseph shark was treble the average during the flood or high-flow years of 1988, 1997 and 2000. Also known as elephant-fish, the species is targeted by 'treknet' fishers operating from the shore, but is also taken as by-catch in the hake-directed demersal trawl fishery, as are tongue sole and Cape gurnard.

In South Africa the demersal trawl fishery on the west coast operates at the shelf edge, mostly at depths of 300 to 800 metres, although off Hondeklip Bay there is some activity at 150 to 200 metres depth. Offshore trawling is prohibited within five nautical miles of the shore. In Namibia, demersal trawling occurs within a similar depth range, and is not permitted in waters shallower than 200 metres. In both countries, demersal longlining for hake occurs in similar areas of operation.

Given that the continental shelf is approximately 200 kilometres wide at the Orange River mouth, any hake-directed fishing effort in the vicinity takes place well offshore, and neither the river nor the mud-belt derived from its sediments are believed to have any impact on fishing activities. There is speculation, however, that sediment originating from the river may influence the distribution of juvenile hake to some extent. Hake spawning occurs south of Cape Town, after which the eggs, larvae and juveniles are carried northwards up the west coast. The juveniles remain south of the Orange River until they reach a length of at least ten centimetres, when they begin moving out to the shelf edge. They then disperse south and north, with a large proportion going northwards into Namibian waters.

There is no inshore trawl fishery operating on the South African west coast nowadays, but in the past this sector operated in the Orange River mouth region, targeting west coast sole. The fishery, which had been established in the 1930s, collapsed by the mid 1970s and ceased operating. In 1990, permits were issued for an experimental fishery involving two vessels operating out of Port Nolloth, but this too was abandoned after a few years.

In Namibia, sole are caught as by-catch in the trawl fishery targeting monkfish, which is in turn caught as by-catch in the hake trawl fishery. Monkfish do occur in the region of the Orange River mouth – it is one of two spawning areas for the Namibian stock – but since the fishery operates out of Walvis Bay and Lüderitz and relies on small trawlers, activity is concentrated further north, where the 200-metre permissible trawling limit is easily accessible.

Likewise, west coast rock lobster occurs to depths of 100 metres in both countries, but the areas adjacent to the Orange River mouth are not commercially important for the trap and hoop-net fisheries that target the resource. Other fisheries on the west coast – the purse-seine fishery for pelagic fish such as anchovy and pilchard, the tuna pole fishery, the pelagic longline fishery for tuna and shark, and the deep-water trawl fishery for orange roughy and alfonsino – either do not operate in the vicinity of the Orange River mouth or are active too far offshore to be affected by the river's flow and sediment discharge.

The productive waters off the west coast of southern Africa support a number of offshore fisheries, including demersal trawling (left) for hake, purse-seining (top right) for anchovy and pilchard and longlining (bottom right) for tuna and shark.

FISHING ACTIVITY

Recreational angling is the dominant fishing method in the Orange River estuary, with approximately one tonne of line-fish caught annually. The catch mainly comprises silver and Angolan kob, white and west coast steenbras, and elf (also known as shad). Commercial line-fishing is not permitted in estuaries according to South Africa's Marine Living Resources Act of 1998, but there is a small Port Nolloth-based fishery operating in the coastal waters south of the mouth. Turbidity caused by the Orange River outflow may increase the catchability of fish that move into the plume in search of prey.

Cast-netting and illegal gill-netting also take place within the estuary, the latter accounting for an estimated five to 10 tonnes per annum. Both target harders, but other species are caught in limited quantities. A 'treknet' fishery for harders operates from beaches to the south of the mouth.

SHELTER FOR INSHORE FISH

While the Orange–Senqu River is believed to have little if any effect on offshore fish resources, the same cannot be said for those in the nearshore environment and the estuary.

The river's nutrients probably enhance the productivity of phytoplankton in the vicinity of the mouth, and hence the zooplankton that feed on them. The plankton communities are in turn a source of food for larval, juvenile and adult fish. Detritus too provides a food supply for invertebrates and certain fish, including the commercially important harder, while sediments replenish nearshore habitats that are continuously eroded by ocean currents. These habitats may be important for fish with specific requirements in terms of foraging, spawning or nursery areas, such as sole and monkfish. Sediment suspended in the water column also increases turbidity, providing a refuge from predators for some fish species, while allowing others to increase their success in catching prey.

During summer, when wind-induced upwelling along the west coast brings cold bottom waters to the surface, the warmer river water flowing into the sea may also provide a refuge from low temperatures that potentially suppress growth rates. Some fish species will even enter the estuary itself in order to escape cold coastal waters, as well as low-oxygen conditions. For example, in South Africa the Angolan cob is mainly caught by anglers on beaches immediately adjacent to the mouths of the three main west coast estuaries – the Orange, Olifants and Berg – and has only been recorded inside estuaries during low-oxygen conditions in coastal waters. Likewise, Angolan stocks of elf and leerfish are thought to disperse southwards during Benguela Niño years when Namibian waters are warmer and upwelling events less frequent. The Orange and other estuaries on the west coast may provide a warm-water refuge when upwelling resumes.

A total of 33 fish species from 17 families has been recorded from the Orange River estuary to date. Of these, 34% live and breed in estuaries, or are wholly or partly dependent on estuaries for at least the first year of their life, using them as nursery areas. Some 24% are marine species that occasionally venture into estuaries, while 42% are freshwater species that can tolerate higher salinities.

In the nearshore environment, the river's plume provides a cue for migration of marine and estuarine-dependent fish into the estuary. Within the estuary, higher flows encourage marine species to return to the sea, and estuarine and freshwater species to swim upstream or retreat to the inundated floodplain or salt marshes to prevent being washed out.

Nowadays, however, the reduction in the river's mean annual runoff, alteration of natural flow patterns, and man-made obstructions in the estuary probably disrupt these movements to some extent. Given that the Orange River estuary is one of only three large estuaries on the west coast, further changes that risk destroying the estuary's functioning could shrink the range of estuarine-dependent species by at least 400 kilometres southwards to the Olifants River estuary.

Right: Harder, found in the estuary and along the sandy beaches, is commercially important.

Clockwise from top left: Pelicans flying at the beach; Cape fur seals bask within the concession granted to the state-owned diamond mine Alexkor, at Alexander Bay; mouth of the Orange River with sand bank to the left; fish research in the Orange River estuary.

AN ESTUARY UNDER THREAT

The Orange River estuary covers an area of about 2,000 hectares and consists of a channel system between sand banks, a salt marsh on the south bank, a tidal basin separated from the sea by a sand bar, and the river mouth. The estuary was ranked the second most important in South Africa in a 2007 review that prioritises estuaries on the basis of size, type, habitat diversity and biodiversity, but a 2003 study on the estuary's ecological functioning and health described its condition as 'largely modified' and on a negative trajectory of change.

The estuary's decline is mainly attributed to the drastic reduction in runoff due to higher water demands for anthropogenic developments, the suppression of all but major floods, and the increase in winter flows, which prevents the mouth from closing. Irrigation schemes, together with hydropower operations that regulate releases from the Gariep and Vanderkloof dams, have resulted in a more than 50% lower freshwater input and a disruption of seasonal flow variability. Natural flows would have been highest in the summer months, but dam releases for hydropower generation were until recently primarily during the interior's dry winter months. With little surplus water in the system, dam releases are now largely limited to meeting the needs of downstream users, resulting in a more natural seasonal flow pattern.

In the past, the estuary mouth closed briefly about once every four years during dry periods, but today more regulated flow keeps it permanently open. Back-flooding brought about by mouth closure would be the only mechanism of inundating the salt marsh now that small floods are retained by the dams. Under natural conditions, the effect of these floods would probably have persisted for a few weeks at a time during summer, while spring high tides coinciding with relatively high flows would have ensured a more regular wetting. On occasions when the mouth has closed during recent decades, it has been artificially breached by the diamond-mining concessionaires on either side of the estuary to prevent flooding of low-lying infrastructure, agricultural land and a golf course.

Dykes built in 1974 to protect such investment, as well as an embankment and causeway constructed on the southern bank in the 1960s for road access to the beach, reduced the penetration of flood and tidal waters into the salt marsh. The lack of flushing combined with high evaporation rates turned a 400-hectare area of the salt marsh into a barren desert, and an isolated channel behind the dunes into a highly saline lake.

In an attempt to reverse this situation, the causeway over a channel near the mouth was partially opened in 1995. A decade later, in July 2005, Working for Wetlands teams began breaching the remaining kilometre-long embankment in four places. However, the two inland breaches were delayed pending the removal and rehabilitation of sewage oxidation ponds constructed in river channels on the floodplain. Construction of a new wastewater works will allow this work to be completed, and it is anticipated that the existing breaches will be enlarged. Restoring old channels will bathe the salt marsh in freshwater and help flush out accumulated salts, while deepening the causeway opening will improve drainage, preventing pooling of water on the floodplain.

Top: The Vaalharts Irrigation Scheme is one of the largest in the world. It diverts water over 800 kilometres from the Vaal River to irrigate approximately 32,500 hectares of fields in the Northern Cape. There are many such water-transfer schemes on the river system, greatly reducing the amount of water reaching the estuary.

Bottom left: The salt marsh on the south bank of the estuary collapsed as a result of the construction of a causeway and embankment, which prevented periodic inundation. It has now now been partially restored.

Bottom right: Volunteers help eradicate invasive wild tobacco plants (*Nicotiana glauca*) at the estuary.

SEDIMENT DYNAMICS IN THE ESTUARY

Changes in the river's flow regime and the construction of dams and dykes have also affected the sediment dynamics of the estuary. Much of the sediment originating from the upper catchment is trapped by the large dams, reducing scouring downstream, although this is offset to some extent by increased erosion in the mid to lower catchment, largely due to farming activities. During floods the dykes on the estuary banks constrict flow, leading to faster flow velocities that increase erosion at bends in the watercourse. In the 1988 flood, approximately one million tonnes of sediment were eroded from the estuary's northern bank, and a deep channel was scoured out near the southern bank.

Fine sediment from mining activity and a slimes dam on the northern bank also finds its way into the estuary. Any increase in silt load in the water column can potentially alter ecological communities by smothering submerged plants and benthic invertebrates, although these are in any case thought to be poorly represented due to the high turbidity.

The absence of small floods means that the meandering channels in the upper estuary are more stable than in the past, and probably slightly narrower and shallower, while the lack of flow variability causes sandbanks to be more permanently exposed, and therefore more vegetated. Large volumes of accumulated sediment are still flushed from the estuary by major floods, but stabilisation of the sandbanks by vegetation implies that floods of higher magnitude are required to remove them.

Major floods also break down large parts of the sand bar across the mouth. Although the mouth remains permanently open nowadays due to flow regulation, major floods may reset the position of the mouth. Its location has a significant influence on the intrusion of seawater and possibly also marine sediments into the estuary. For example, when the mouth is on the southern side, considerable amounts of seawater enter the adjacent salt marsh at spring tides.

The overall reduction in river flows probably allows marine sediment to extend slightly further up the estuary than under natural conditions, and seawater intrusion has likely increased. Tidal variation in water level can be detected some 14 kilometres upstream of the mouth, beyond the Sir Ernest Oppenheimer Bridge, but seawater only penetrates about seven kilometres into the estuary during low-flow conditions. In summer, cold, nutrient-enriched seawater associated with coastal upwelling may dramatically reduce temperatures in the lower reaches, and elevate nitrogen concentrations.

Top: Lower Orange River.

Bottom left: Mining activities (Namdeb).

Bottom right: Flooding, March 1988.

Left: Purification of water contaminated by mining at Rand Uranium's Cooke plant and shafts 1 and 2, Randfontein.

Top: Basin-wide survey, lower Orange River.

Bottom: Water sources can potentially be polluted by agrochemicals washed off irrigated lands.

POLLUTION POTENTIAL

The Orange River estuary is surrounded by mining activity, and parts of its catchment are heavily developed. The impacts of these upstream developments appear not to have a major influence on the water quality of the lower Orange. This could change if upstream water quality is not effectively managed. Furthermore, the extent to which the estuary is polluted is currently unknown.

Upstream, nutrient concentrations in the river have likely increased due to irrigation return flows and wastewater discharges, but much of this is probably taken up by vegetation and phytoplankton before it reaches the estuary. Indeed, water quality monitoring conducted by South Africa's Department of Water Affairs at the Sir Ernest Oppenheimer Bridge shows that ammonia and orthophosphate concentrations are fairly low, while nitrate concentrations periodically peak. Occasional phytoplankton blooms in the river and its dams cause oxygen-depleted pockets that have been known to find their way down to the estuary, but its waters are thought to be generally well-oxygenated.

Trace metals were measured in river water at Sendelingsdrift, about 70 kilometres from the estuary mouth, on 25 occasions between 1998 and 2003, and were found to be low. Likewise, a survey of trace metals in estuary sediments conducted in 1979 recorded low concentrations, but with accumulations in the fine, anoxic sediment layers that are indicative of depositional areas. It could not be determined whether the accumulations were natural or a result of pollution. The trace metals analysed – cadmium, copper, lead and zinc – are released by some mining and smelting activities, coal combustion, waste incineration, the discharge of wastewater and sewage sludge, and the use of fertilisers and pesticides – all of which take place within the basin – although some also occur as natural components of rocks and soils.

Traces of persistent organic pollutants (POPs) have in the past been recorded from the sediments of Alexander Bay, but there was not enough information to draw definitive conclusions about their origins. POPs are chemical substances such as PCBs, dioxin and DDT that accumulate through the food web and pose a threat to human health and the environment. They are often found far from where they originated as they can be transported long distances by wind and water.

A survey of trace metals and POPs in riverine sediments, fish and aquatic birds was therefore included in the first Joint Basin Survey, launched by ORASECOM in 2010. The survey also included aquatic ecosystem health assessments and water quality sampling from sites throughout the basin. Contamination by metals and POPs was found to be low in the lower Orange River, and there was no evidence of significant transport of these substances through the Orange–Senqu system.

THE STOCKHOLM CONVENTION ON POPS

The Stockholm Convention is a United Nations environmental treaty that aims to eliminate or restrict the production, use and/or release of selected persistent organic pollutants (POPs). All four countries in the Orange–Senqu River Basin are Parties to the Stockholm Convention and are therefore bound by its provisions. Very little was known about the the presence and concentration of the POPs listed under the Stockholm Convention in the Orange–Senqu River system before the Joint Basin Survey.

A WETLAND OF INTERNATIONAL IMPORTANCE

The first comprehensive survey of the Orange River estuary's birdlife took place in January 1980, when 21,512 individual birds belonging to 51 species were counted. The second survey in December 1985 yielded even higher numbers, at 26,653 individuals of 56 species, prompting consideration of the estuary as a Wetland of International Importance under the Ramsar Convention.

South Africa was among the first group of seven countries to accede to the Ramsar Convention on Wetlands in 1975. The site met Ramsar criteria of supporting more than 20,000 birds, including at least 1% of the southern African and global populations of certain species, as well as some rare and endangered species. The South African component of the estuary was therefore designated a Wetland of International Importance in 1991.

Following Namibia's accession to the Convention, the Namibian component of the estuary was designated a Ramsar site in 1995. In the same year, however, the site was listed on the Montreux Record – a register of Ramsar wetlands where significant ecological degradation has occurred – due to the collapse of the salt marsh. By then, bird numbers had also decreased to below 10,000 individuals, although species richness remained relatively constant.

The lower counts were largely a result of a decline in Cape cormorant and common tern numbers, attributed primarily to food shortages linked to environmental perturbations. This included the 1995 warm-water event or 'Benguela Niño' in Namibian waters, fluctuations in anchovy abundance, and the eastward displacement of sardine in South African waters. Cape cormorant colonies in South Africa were also reduced by outbreaks of avian cholera. Both species subsequently began breeding in large numbers at Sandwich Harbour in Namibia, some 600 kilometres north of the Orange River mouth, which implies that disturbance by humans and availability of roost sites might have played a role in their abandonment of the Orange River estuary.

Facing page, clockwise from top left: black-winged stilt; terns; spoonbill; goliath heron; great egret.

Ramsar

CONVENTION ON WETLANDS

(Ramsar, Iran, 1971)

DETERMINING ENVIRONMENTAL FLOWS

ORASECOM's preliminary transboundary diagnostic analysis (TDA) of the Orange–Senqu Basin, as well as a recent Ramsar Situation Assessment, recommended that an environmental flow requirements (EFR) study be undertaken for the lower Orange River and the estuary. EFR studies define the present ecological state at various representative sites along the river and the environmental flows needed to maintain them.

Environmental flow requirements for the upper sections of the river were determined for Lesotho during the first phase of the Lesotho Highlands Water Project, whilst an EFR study for the Orange–Senqu River upstream of its confluence with the Fish River was initiated by ORASECOM with funding through GIZ (German Agency for International Cooperation) in 2009. South Africa's Department of Water Affairs also conducted a similar project on the Vaal River.

Currently, a research project – conducted as part of the Orange–Senqu Strategic Action Programme – is focussing on the environmental flow requirements of the ephemeral Fish River, the Orange River below the confluence with the Fish, as well as the estuary.

A previous EFR study of the estuary conducted by South Africa's Department of Water Affairs in 2003 was a rapid, desktop assessment that relied on limited available information. The current, more detailed study being undertaken as part of the Orange–Senqu Strategic Action Programme will determine the present ecological state of the estuary and its flow requirements. Specialist reports will be prepared on abiotic aspects such as sediment dynamics, hydrodynamics and water quality, as well as the estuary's plant, invertebrate, fish and bird life.

The flow requirements of the Fish River will be investigated as a means of testing EFR methods that can account for both the flowing and non-flowing conditions in ephemeral rivers. Despite very low rainfall throughout its basin, the Fish River – which rises to the south-west of Windhoek, nearly 900 kilometres from the confluence – has a mean annual runoff (MAR) of around 450 million cubic metres per year, almost 5% of the Orange–Senqu MAR.

Furthermore, in recognition of the ecological links between the estuary and the nearshore marine environment, the study is exploring the flow requirements of coastal ecosystems. This component relies on available information, remote sensing and numerical modelling to assess the role of freshwater flows and sediment fluxes on primary production, invertebrates and fish.

Determining the flow requirements of the estuary and its associated rivers and marine environment is important, in light of the fact that two large dams are being planned for the region. Construction of the Vioolsdrift Dam, some 20 kilometres upstream of the Vioolsdrift–Noordoewer border post between South Africa and Namibia, was a recommendation emanating from the Lower Orange River Management Study, conducted between 2002 and 2004. The dam would allow flow releases from the Vanderkloof Dam to be re-regulated, increasing water availability to users in the lower Orange River and controlling flows to the estuary. The Neckartal Dam on the Fish River is to be constructed near Keetmanshoop to provide irrigation water and facilitate social upliftment of local communities. Once completed, it will be the largest dam in Namibia.

Top: The Fish River.

Bottom left: Orange River white-eye, one of the few birds associated specifically with the lower Orange.

Bottom right: Assessing fish populations in the lower Orange River, towards determining environmental flow requirements.

CLIMATE CHANGE

The South African Country Study on Climate Change in 1999 predicted that the western half of the country could experience a 10% decrease in runoff by the year 2015, with a 12 to 16% decrease in outflow at the Orange–Senqu River mouth by 2050. Other studies conducted since then have indicated that more rainfall will occur in the east of southern Africa, and less rainfall on the west coast and adjacent interior.

A 2011 study conducted for ORASECOM has suggested that reduced runoff in the west could perhaps be offset by a relatively small increase in precipitation in the mountainous areas in the east, such as the Lesotho Highlands, which are key runoff-producing areas. Likewise, lower annual rainfall in the catchment of the ephemeral Fish River may be partially offset by less frequent but more extreme rainfall events, resulting in flooding. Higher temperatures in the lower Orange River area would probably cause increased evapotranspiration in crops and heat stress in cattle, necessitating more irrigation and stock-watering.

SUSTAINING LIVELIHOODS, ENGAGING PEOPLE

As part of the environmental flow requirements study, the value of goods and services provided by the lower Orange and Fish rivers, the estuary and the adjacent marine environment are being assessed. Information is being collected on socio-economic aspects of these ecosystems such as fishing, farming, mining, tourism, conservation, recreation and flood protection, and predictions made on changes in benefits and costs under various future scenarios, including climate change.

In addition to the socio-economic evaluation, a stakeholder consultation programme will be initiated to involve various authorities and water users in the project. These stakeholders include the government bodies responsible for water, agriculture and the environment in South Africa and Namibia, water service providers, such as NamWater and local councils, power companies, mining operations, tourism ventures, irrigation projects and farmers, as well as various bodies involved in the management of these water and other natural resources, such as the Orange–Senqu River Commission (ORASECOM), the Permanent Water Commission, the Orange River Mouth Interim Management Committee (ORMIMC), the Orange–Fish Basin Management Committee (OFBMC) and /Ai-/Ais–Richtersveld Transfrontier Park Joint Management Committee.

The EFR study will guide these stakeholders on the way in which waters of the Orange and Fish rivers can be used to achieve an optimal balance between ecological protection and consumptive utilisation in the interests of economic development.

Facing page: Scientists believe that the sensitivity of the slow-growing quiver tree, or kokerboom, to slightly higher temperatures is causing a shift in its distribution, making it ideal as an indicator of climate change.

Top to bottom: Harvesting grapes; Alexcor mine; canoeing on the lower Orange River is a popular tourist activity.

JOINT ACTION – FROM SOURCE TO SEA

Worldwide, there is increasing recognition that many coastal issues cannot be solved in isolation of river basin issues. Transitional waters, such as river mouths and estuaries, are essential ecosystems providing refuges and resources for freshwater and marine species, and are substantially influenced by their freshwater inflows.

As early as the 1950s, river water in the Rhine River – the most heavily used shipping waterway in Europe – was in such a poor state that the riparian states were forced to act. North Sea currents were sweeping the river's contaminated waters along the coasts of the Netherlands, Germany and Denmark, creating problems far from the sources of pollution.

Elsewhere in Europe, over-use of nitrogen and phosphate fertilisers in the Danube had resulted in significant eutrophication of the Danube Delta and Black Sea. The Water Framework Directive of the European Communities published in 2000 brought the importance of transitional waters into prominence and is considered best practice in respect of their management. It provided a framework for organisations such as the International Commission for the Protection of the Danube River and the Black Sea Commission to cooperate for the improvement of the environmental status of the Danube Delta coastal waters of the Black Sea.

By providing a framework for transboundary cooperation in the Orange–Senqu River Basin, ORASECOM is following the example of other international commissions and river basin organisations in ensuring that water resources are managed across national boundaries.

ORASECOM's joint initiative with the BCC, and its support of the current project to determine environmental flows for estuarine and coastal ecosystems, demonstrates its commitment to a holistic and integrated approach that takes a source-to-sea view of the Orange–Senqu River.

Facing page: The Lesotho Highlands, source of the Orange–Senqu.

Right: Monitoring aimed at determining flow requirements at the Orange River Estuary.

FURTHER READING

BCLME, 1999. *Benguela Current Large Marine Ecosystem Programme (BCLME) Transboundary Diagnostic Analysis (TDA)*. Windhoek: UNDP.

BCLME, 1999. *Strategic Action Plan for the Integrated Management and Sustainable Development and Protection of the Benguela Current Large Marine Ecosystem.* Windhoek: UNDP.

Clark, B, 2010. Scoping a Ridge to Reef Approach: Interaction between the Orange–Senqu River Basin and the Benguela Current Large Marine Ecosystem Scoping Report. UNDP–GEF Orange–Senqu Strategic Action Programme.

CSIR, 2011. Orange River Estuary Management Plan: Situation assessment. Report submitted to Eco-Pulse Environmental Consulting Services. CSIR Report No. CSIR/NRE/ECOS/ER/2011/0044/B. Stellenbosch.

Department of Water Affairs (South Africa), 2009. Development of an integrated water quality management strategy for the Upper and Lower Orange Water Management Areas. Desktop Catchment Assessment Study: Lower Orange Water Management Area (WMA 14). Report No. 2.2 (P RSA D000/00/7909/3). Edition 1, August 2009.

Louw, MD and Koekemoer, S (Eds), 2011. Deliverable 12: Volume 1: Environmental Flow Requirements. Produced for WRP as part of Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan.

Macfarlane, DM, 2011. Strategic Management Plan for the Orange River Mouth Ramsar site. Version 0.2. Report prepared for the Orange River Mouth Interim Management Committee.

ORASECOM, 2008. *Orange–Senqu River Basin Preliminary Transboundary Diagnostic Assessment.*

ORASECOM, 2011. *Joint Baseline Survey 1: Baseline Water Resources Quality State of the Orange–Senqu River System in 2010.*

ORASECOM, 2012. *Orange–Senqu River Awareness Kit.* www.orangesenqurak.com

ORASECOM, 2012. *Orange–Senqu Water Information System.* www.wisp.orasecom.org

ORASECOM, in prep. *Orange–Senqu River Basin Transboundary Diagnostic Assessment*. UNDP–GEF Orange–Senqu Strategic Action Programme.

Robertson, T, Jarvis, A, Mendelsohn, J and Swart, R, 2012. *Namibia's Coast: Ocean Riches and Desert Treasures.* Windhoek: Directorate of Environmental Affairs, Ministry of Environment and Tourism.

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Benguela
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