SOUTH AFRICA'S

OCEANS AND COASTS ANNUAL SCIENCE REPORT, 2018

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SOUTH AFRICA'S OCEANS AND COASTS
ANNUAL SCIENCE REPORT, 2018

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SUMMARY FOR DECISION AND POLICY MAKERS

South Africa occupies a unique geographic location at the meeting of globally important ocean areas, the Indian, South Atlantic and Southern Oceans. It is also alone amongst the African nations in conducting large-scale oceanographic studies in three oceans, and thus has a capacity building role to play on the continent. This is reflected in South Africa's Oceans and Coasts Annual Science Report, 2018. The report presents results of monitoring and research by the Department's Chief Directorate: Oceans and Coastal Research on a number of physical, biological and chemical aspects of the oceans and coasts (including estuaries) around South Africa, in the Southern Ocean, or other parts of the African ocean regions. In previous years, this report was referred to as the "State of the Oceans and Coasts around South Africa Report Card".

The activities of the Chief Directorate are guided by a medium-to long-term ecological research and monitoring (LTERM) plan. This plan was developed for the period 2016–2030. The plan is centered on describing and documenting marine biodiversity and its status, understanding complex ecosystem functioning and processes, including impacts of climate change, pollution and conservation measures. It seeks to achieve this through developing human capacity and technological innovation in the marine sciences while always ground-truthing its relevance to accommodate emerging issues or opportunities. Underlying the plan is the understanding that the most valuable scientific data collections or observations are those taken within a long-term context. However, within a framework of long-term programmatic work aimed at providing continuous or sustained observations (monitoring) and descriptions of key aspects of the marine environment, some shorter-term research elements are conducted as projects.

All projects support the objectives of the Department, in particular the purpose of the Branch: Oceans and Coasts which can be defined as "the promotion, management and strategic leadership of oceans and coastal conservation in South Africa". Data and information products generated from the research and monitoring activities must be useful for informing managers and policy makers, as well as the broader scientific community and the public. In addition to the national needs and priorities, the plan takes into account the goals, requirements or guidance of international and regional organisations and agreements to which South Africa is a party. These include United Nations Sustainable Development Goals (SDGs), Aichi targets of the Convention on Biological Diversity (CBD), the Strategic Action Programme of the Benguela Current Convention (BCC), the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the Intergovernmental Panel on Climate Change (IPCC) and numerous others.

Undertaking of the plan is guided by several broad principles, including (but not limited to): active pursuance of partnerships (nationally, regionally and internationally) to achieve goals, taking a developmental approach so as to maximise human capacity development within and outside the Department, producing high quality products and publishing findings in peer-reviewed literature, and aiming for open dissemination of the data and data products that are generated.

Of these principles, the importance of partnerships and capacity development will be apparent in the various contributions to this report, which are summarised below. At the end of the report is the list of scientific outputs for 2018 including peer-reviewed publications and other products that speak to both the volume and quality of work accomplished (note that in the main these published outputs would be based on data that were collected before 2018). Not mentioned in this report is the Chief Directorate's Marine Information Management System (MIMS), but this is because the MIMS is still under development. Once ready, it will provide an easily accessible, data-rich information system to support decision-making and allow for open dissemination of data through a variety of standard protocols and interfaces. Much of the data managed in the MIMS system will be freely available as various data products and support tools through the National Ocean and Coasts Information System (OCIMS). This is a national system of information distribution that is being developed in partnership with the Department of Science and Innovation.

The body of this report is made up of 22 contributions. Each separate contribution is termed a "report card" and the prefix "R" is used when referring to them by number below. Ten of the report cards are listed under the heading "Monitoring programmes" and 11 under "Research highlights". Under each of these main headings there is a distinct subsection, presenting findings of the Southern Benguela Integrated Ecosystem Programme and the Second International Indian Ocean Expedition, respectively (four report cards each). The last report card is a single contribution against the heading "Research support".

Monitoring programmes

One of the main functions of the Department is to maintain long-term measurements of environmental variables, called Essential Ocean Variables (EOVs), across South Africa's immediate ocean space as well as in the deeper ocean surrounding it. The EOVs are supported by a number of other related measurements to better understand the changes and variations observed. This understanding contributes to the knowledge base on which to build policy and other management actions. Collectively, these variables will give an indication of how healthy and productive the oceans around South Africa are, as well as how much it is changing in the short-, medium- and longer-term.

The ability of the ocean to support biological life is very dependent on the presence of microscopic marine plants (phytoplankton) and animals (zooplankton) that form the base of the ecosystem and the food web. Like most plants on land, phytoplankton contain chlorophyll *a* (termed chlorophyll *a*,), which gives them their characteristic green colour. The green of the chlorophyll *a*, can be observed and quantified from satellites in space. The higher the concentrations of chlorophyll *a*, the more phytoplankton there are, and therefore the greater the productivity and the ability of the ocean to support other biological life such as fish. The first two report cards show ocean productivity, as explained by chlorophyll *a*, measured from satellite images. Department monitoring programmes routinely measure ocean productivity for the areas off the West Coast and the Agulhas Bank off the South Coast. Both of these areas are of considerable economic importance because they support important commercial fisheries. The data show that in 2018, there was an increase in productivity when compared to 2017, both off the West Coast and over the Agulhas Bank, although this pattern was not uniform throughout either area. The longer term data for both areas show gentle but nevertheless significant declines in productivity. This is concerning but substantially more years of data are required properly to separate the long-term trends from the considerable seasonal and year-to-year changes that characterise the data series.

Zooplankton along the West Coast and Agulhas Bank are dominated by tiny creatures called copepods, which make up most of the zooplankton biomass. These copepods feed mainly on phytoplankton.

The biomass of copepods has been measured in most years since 1988. Although copepod biomass on the South Coast was very low in 2017 (R3), relatively high values for 2016 and especially 2018 suggest a possible reversal of a long-term decline that was evident between the 1980s and 2011. This decline was thought to be linked to a long-term increase in their predators, in particular small shoaling fish such as sardine and anchovy. The possible reversal of the decline may be due to a recent decrease in these fish species, which have shown below average biomass over the past few years.

Two of South Africa's most iconic seabirds, namely the Cape gannet and the African penguin, have continued to decrease (R4). Their declines have been evident since at least the early 2000s and both species have been listed as *Endangered* in terms of IUCN (International Union for Conservation of Nature) criteria. On the West Coast, analyses of these birds' prey (food) species have indicated that their decline in numbers was due to not having enough of the right food to eat. This is because the abundance of their favourite food items, sardine and anchovy, has declined on the West Coast since the 1990s. To lessen the severity of this decline on seabird colonies, closure of fisheries around key breeding islands and careful management of interactions between seabirds and seals have been proposed.

South Africa's active role in seabird monitoring, research and conservation management in the Southern Ocean was highlighted in 2018 by successfully hosting the sixth session of the Meeting of the Parties to the Agreement on the Conservation of Albatrosses and Petrels, a treaty to which South Africa is a party (R5). Seabird populations at the Prince Edward Islands (PEIs), a South African territory in the Southern Ocean midway to Antarctica, have experienced significant deaths from incidental capture in longline fisheries as well as disease. Breeding success, a measure of bird pairs being able to produce young, has also been impacted by less food availability and effects of warming at the islands. Ongoing monitoring at Marion Island (one of the two PEIs) by the Department has shown that population declines of Rockhopper and Macaroni penguins appear to have stabilised in recent years, while a decline in Sooty albatross numbers appears to have reversed. This reversal might be a consequence of the longline fisheries implementing measures to lessen the impact of birds being incidentally killed. However, declines in Light-mantled albatrosses at Marion Island and Emperor penguins in the vicinity of the SANAE IV base in Antarctica are cause for concern.

The number of whale strandings (when whales are washed up or swim onto the beaches) along the Western Cape coastline during 2018 was the highest on record (R6), continuing an increasing trend since 2014. Most animals are found dead, and those found alive usually have little chance of survival. A third of the stranded animals were Southern Right or Humpback whales. International protection of these whale species which resulted in their population numbers increasing has probably contributed to this increasing trend in strandings. However, improved reporting effort in recent years is also likely to have played a role. Cause of death is often difficult to determine, but there is evidence that ship strikes and entanglement (mainly in fishing gear), the occurrence of which also increased during 2014–17, have contributed.

Preliminary findings of some projects that contribute to the Southern Benguela Integrated Ecosystem Programme (IEP), an end-to-end ecosystem monitoring programme initiated in 2013, are presented in R7–R10. The Southern Benguela is the cold water ocean ecosystem that supports the various fisheries along the west and south coasts of South Africa. In the IEP, EOVs (Essential Ocean Variables) are routinely measured in situ at specific points (or stations) situated along established monitoring lines off the West Coast from the Research Vessel (RV) Algoa, four times a year. The data are used to explain and monitor key aspects of the natural changes and variations that occur in the Southern Benguela. The IEP also provides a platform for collaboration on oceanographic research with other institutions such as the universities, and hands-on experience and training in ship-based research and monitoring including the use of sophisticated oceanographic equipment. In 2018 for example, there were 15 berths for interns during research cruises. Three of the four IEP report cards presented here were led by university students, including two (R7 and R10) by Department staff who are conducting their PhDs part time (with the University of Cape Town (UCT) or Nelson Mandela University (NMU) as the academic base) and one by a UCT PhD student (R8). The remaining IEP report (R9) was led by a UCT postdoctoral fellow.

The measurements of how carbon dioxide (CO_2) is exchanged between the air and the surface waters of the ocean over the Southern Benguela are summarised in R7. This enables ways of identifying areas that absorb CO_2 into the ocean (carbon sinks) or release CO_2 from the ocean back into the air (carbon sources). The preliminary results support previous findings that the Southern Benguela along the west coast of South Africa generally acts as a small sink area for CO_2 from the air.

The smallest plankton in the Southern Benguela, called picoplankton, have been largely overlooked in ecosystem studies (R8). However, recent studies have shown that they are far more important than originally thought, and in fact contribute up to 80% of the process of trapping carbon in the ocean, as well as in primary productivity. This initial study (R8) showed clear differences in numbers or abundance of picophytoplankton between different seasons and years.

It is said that we know less about the ocean bottom than about space. This is being addressed in the Southern Benguela by surveying the seafloor using underwater cameras. R10 presents preliminary findings for the distribution patterns of mainly sessile (attached to the seafloor) animals that could be identified in the camera images, and further sampling that is planned will provide basic knowledge of these types of animals and habitats. Knowing what is "down there" is essential for management and conservation planning, particularly for the location of Marine Protected Areas (MPAs), and will provide a baseline for monitoring of future changes.

Research highlights

Whereas the above reports present findings of established or newly-established Department monitoring projects, the next seven reports provide highlights from research projects. Most of these research projects have been conducted collaboratively with other institutions. Six of the seven reports provide findings, or preliminary findings, from five different postgraduate student projects conducted collaboratively with academic institutions, including one with UCT and four with NMU. The number of reports from NMU is due to a Memorandum of Understanding between NMU and the Department on collaboration in scientific research, development, training and dissemination of knowledge. Three of the student projects were at Master's level (R11, R12 and R15) and two at PhD level (R13, R16 and R17, the latter of which are from the same PhD thesis).

The immediate ocean space along South Africa's southeast coast, which is strongly influenced by the warm, fast-flowing Agulhas Current, is one of the least studied areas in South African waters.

R11 reports on the general environmental conditions in this area, based on the first detailed marine survey of the area, which took place during a Department research expedition undertaken with the African Coelacanth Ecosystem Programme (ACEP). This cruise was done under the umbrella of the Operation Phakisa: Ocean Economy initiative. The slower-moving waters surrounding the fast-flowing Agulhas Current interact with the current to produce clockwise (cyclonic) or anticlockwise (anticyclonic) circular flowing oceanic features known as eddies. The research expedition documented how such passing clockwise or cyclonic eddies increased the ocean productivity at the surface of areas that are normally not very productive places. New MPAs were recently declared in this area and therefore understanding the environmental conditions of the area and the processes that influence them will contribute to effective MPA management and design.

Sea turtles carry many different passengers on their shells called epibionts, and these passengers have a story to tell us. For example barnacles can live for up to three years on a turtle. During this time they store the various chemical signatures of the environment in which they grow in their calcareous shells. R12 shows that, by sampling the barnacles and analysing their chemical signatures, we can estimate their movement ranges at sea. Knowing where the turtles go is essential for conservation and management planning. While it does not provide anything like the data collected from satellite transmitters attached to their shells, this "natural" approach is considerably cheaper, meaning that spatial information can be obtained for a greater number of turtles at much less cost.

Biodiversity management and conservation planning relies on knowing what species exist in the area and how these animal or plant communities change over time. The usefulness of museum collections of preserved species as sources of such data is well recognised. However, as improved knowledge and methods cause classifications of various species to change, there is a need to revisit and update museum records from time to time. How this was undertaken for South Africa's East Coast deep-water coral collection, housed at the Oceanographic Research Institute in Durban, is shown in R13. This revision resulted in the number of known deep-water coral species for South Africa to be adjusted from 73 to 63, a nearly 15% reduction that will have implications for future biodiversity assessment and planning.

Rare environmental events can be perceived as harmful to the ecosystem and importantly change how these ecosystems are available to the economy of South Africa. These events however, often provide scientists with opportunities to observe "experiments" happening in nature. An estuary is that area where fresh water from rivers mix with the salty ocean waters. The first closure of the Orange River estuary mouth in 25 years, which was due to the combination of low river flow and rough seas, provided Department scientists with such an opportunity. Initially, the river mouth was open followed by salty sea water rushing up the river and a temporary period where the river mouth was closed by sand. R14 describes how bottom or benthic plant and animal community composition changed between these different periods during this natural experiment.

R14–R16 report on dolphin research in the inshore areas of Plettenberg Bay and the adjacent coastline. Dolphins are not easy to study: nearly 700 boat hours and the processing and analysis of thousands of photographic images to identify individuals from their fins, were required to come up with a population estimate for the inshore dwelling Indian Ocean bottlenose dolphin (R14). Comparison of the abundance estimate for Plettenberg Bay itself with another estimate that was obtained 12 years previously, showed a 72% decrease in population size for this area. Similar temporal comparisons at other locations will be required to properly inform future review of the population status of this species in South Africa, which is currently listed as *Least Concern*. Comparison was also made of the distribution of Indian Ocean bottlenose dolphin sightings with the distribution of preferred habitat types and MPAs (R15). It showed that there is generally a mismatch between areas of high dolphin activity and MPAs. This was because two of the three MPAs in the study area contained mainly habitat that was not preferred by the dolphins. Reducing boat traffic at dolphin "hotspot" areas outside of MPAs would reduce disturbance and benefit protection. A problem with visual/photographic surveys of dolphins is that they are restricted by daylight hours and weather conditions. Dolphins are marine animals that use sound and therefore a useful way to monitor them is to use instrumentation that records these sounds underwater. R16 details how such instruments were placed in the water at Plettenberg Bay and recorded dolphin activity around the clock from their click and whistle sounds. The recordings showed higher night-time than day-time occurrence by dolphins, with lowest occurrence in the morning. Avoidance of human disturbance may have affected the day-night activity patterns, but further research will be needed to support this.

The Second International Indian Ocean Expedition, or IIOE-2, was endorsed by South Africa as a legacy initiative in relation to the country chairing the Indian Ocean Rim Association (IORA) during 2017–2019. At this time, South Africa was also preparing to celebrate 100 years of Nelson Mandela, through whose vision the IORA was established. The Indian Ocean is of strategic importance to South Africa and the region as the warm Agulhas Current on our East Coast influences our Climate over land directly. Therefore, understanding how this ocean and ocean current changes is important for profiling environmental risk, economic health and food security. One of the main objectives of the IIOE-2, through making our research infrastructure available, was to increase the scientific capacities and capabilities of countries in the region in order to advance their own desire for developing an Ocean Economy.

The next four reports include some preliminary results from two regional training initiatives conducted onboard the research vessel *SA Agulhas II (dedicated to Miriam Makeba*) in the Western Indian Ocean during October/November 2017 and June/July 2018. These research expeditions formed part of South Africa's contribution to the IIOE-2. The IIOE-2 is the second major international effort since the original IIOE (1959–1965) to focus on the Indian Ocean, the least explored ocean compared to the Atlantic and Pacific Oceans. In the first Department-led initiative which explored the ocean off Mozambique and Tanzania in 2017, surveys were conducted of the physical, chemical and biological oceanography, as well as the benthic biodiversity, seabirds and marine mammals. The expedition included 55 trainees (including 25 women) from six African countries and India. The second initiative, in 2018, extended the sampling of Tanzanian waters, then went across to and around the Comoros. The team included 38 trainees (14 of them women) from seven African countries, with the majority of them being from Comoros, Tanzania and Kenya. Many African countries along the Indian Ocean rim lack their own research vessels, so these cruises provided the first sea-going opportunity for many of the trainees. The cruises also opened the door to building collaborations with partners and institutes within the West Indian Ocean.

Ocean acidification is a process whereby the ocean absorbs carbon dioxide from the air causing it to become more acidic. Coral reefs are particularly vulnerable to the double threats of ocean acidification and ocean warming (including extreme warming events). Ocean acidification reduces the ability of sea life such as corals and mussels to build strong skeletons or shells. R18 reports on the vertical and horizontal distribution of the carbon chemistry off the coasts of Mozambique and Tanzania during the IIOE-2 surveys in both 2017 and 2018. Waters with relatively high acidity (low pH) and lower availability of calcium carbonate for building shells may pose a threat to ocean plants and animals sensitive to these acidic conditions. Such conditions were seen in deeper waters off Mozambique and Tanzania. When these deeper ocean waters are brought into the near-shore shallow surface environment (termed upwelling), which is common along the narrow coast of northern Mozambique, this may pose a greater threat to ocean plants and animals that need calcium carbonate to build their shells and skeletons.

Zooplankton are small ocean animals that drift at the mercy of currents. While sampling of zooplankton in the upper 200 m off Mozambique in 2017, the greatest concentrations were found on the Sofala Bank, mainly downstream from the Zambezi River delta (R19). This supports earlier studies which showed the central Sofala Bank to be one of the most productive areas on the Mozambique shelf, where there is an important shallow water shrimp fishery. Sampling of the surface zooplankton (neuston layer) also indicated highest concentrations in the south, between Beira and the Zambezi River, with a secondary peak to the north near the Angoche upwelling region. Interest in the neuston layer is growing due to its role as a nursery area for larval fish and a rich food source for larger fish and turtles. This role is under threat from accumulating plastic debris, oils and environmental pollutants.

The distribution and amount of plastics with a size of 5–25 mm (called mesoplastics) floating in the neuston layer off the coasts of Mozambique and Tanzania during the 2017 IIOE-2 research expedition is discussed in R20. This study was led by researchers from UCT, as part of a larger project on plastic pollution in the region. They found mesoplastics densities to be greatest close to major river mouths (the Zambezi in Mozambique and Rovuma in Tanzania) and off Dar es Salaam, the main urban center in the sampling region. This study will provide baseline data for future marine pollution monitoring research in the Western Indian Ocean. Results of the mesoplastics sampling will be combined with observations of macro-debris and abundance of microplastics (<5 mm) during the research expedition to estimate the total abundance of plastic in these waters. Complementary microplastics sampling was conducted on both the 2017 and 2018 research expeditions by students from North-West University.

Moving deeper in the ocean, R21 describes patterns in the coastal and deep-sea bottom plant and animal life of Tanzania and the Comoros from the 2018 research expedition. Two main habitat types could be identified, namely a shallow (20–80 m) habitat with coarse sand, shell fragments and a diverse community of organisms, and an offshore (250–500 m) mud/silt habitat with fewer species that mainly comprised scavengers or detritus feeders. Novel camera footage inside the national park of Moheli, the local MPA in the Comoros, showed the presence of diverse biological communities including beds of red algae that resemble coral and provide habitats for other bottom organisms (rhodolith beds), corals, giant sea-fans and sponges. Data from these surveys will contribute to building bottom (benthos) species lists, improved understanding of the processes influencing benthos distribution patterns, and integrated habitat maps.

Concluding remarks

Ten of the 21 report cards summarised above present findings or preliminary findings based directly on data collections from research vessels. The research vessel used mostly around South Africa is the 45-year old Environmental Affairs-managed *RV Algoa*, which is also the only dedicated environmental platform to undertake this kind of work. R22 emphasises that it is well overdue for replacement. In terms of its lifespan the *RV Algoa* has in fact exceeded the normal lifespan for a research vessel by about 15 years. This has implications for its functionality, cost-effectiveness and safety. The risk associated with such an old research vessel breaking down is that all the important science being undertaken to inform management decisions would not be done. Therefore, the replacement of *RV Algoa* is of utmost importance to this country and its decision and policy makers. Through the Operation Phakisa: Ocean Economy Strategy, it is planned to replace both the *RV Algoa* as well as the *FRS Africana*, which is mainly used for fisheries-related research. These local build projects will provide a demonstration of South Africa's excellent ship design and build capabilities for vessels of this size class.

The report cards presented within this document do not cover the full range of scientific research and monitoring projects within the Chief Directorate Oceans and Coastal Research, but from looking at the content covered in this report, areas can be flagged where greater emphasis appears to be needed. Given the many challenges of adapting to natural and man-made global change, such areas include climate change-related issues, ocean acidification and pollution in the marine environment, especially with the emerging understanding of the potential impacts of plastic pollution on marine life and also on the Ocean Economy. With regards to plastic, a source-to-sea pollution monitoring programme was started off the West Coast during 2018, which will investigate how many tiny plastic pollution particles are in the ocean, what chemicals they are made of, and how they affect the food for many animals in the ocean.

Given current unprecedented interest in the Ocean Economy including recognition of its potential in terms of job creation and growth of the gross domestic product (GDP), and at the same time appreciation of the need for sustainable solutions, research that has socio-economic implications is perhaps all too obviously lacking. A rethink and new strategy around this is needed and it must be incorporated into science themes.

Finally, based on the results presented by the various report cards it is clear that the ocean space around South Africa is vast and challenging. A wide range of measurements have indicated that the ocean environment shows many positive trends, as a result of improving conditions or management interventions giving good results. However, there are other issues that have experienced less positive outcomes, or that require much greater scientific investigations before drawing any conclusions. The Department has been leading initiatives within South Africa and beyond to better understand the complex relationship between people-ocean-atmosphere-land, termed the Earth System. This relationship is complicated by the natural environment being impacted by climate change. It is often difficult to separate natural changes from those caused by Climate Change, therefore long-term continuous measurements, i.e. monitoring, together with specific research questions in the ocean are required to better inform South Africans.

PERSPECTIVE

Dr Alan Boyd (outgoing director of Biodiversity and Coastal Research)

South Africa's Oceans and Coasts Annual Science Report (previously referred to as the "State of the Oceans and Coasts around South Africa Report Card"), now eight years old, is entering a new phase concurrent with the widespread emergence of a new phrase. This phase is called "evidence-based". Although the need for good motivation for undertaking a new course of action in the form of research or a programme with management objectives has been with us for a long while, motivations now require evidence. A lack of evidence, or unexplained contrary evidence, may be a set-back for otherwise crucial motivations, such as were experienced with climate change mitigation efforts a decade or two ago. Evidence-based also should not be taken as contradicting the "precautionary approach" which motivates for protective action even in the face of uncertainty. Rather it means that one needs to be upfront about what evidence we have or lack in a particular context. And we also need to be thinking about possibly changing the ways we are gathering and presenting evidence.

When looking at the Table of Contents of this report, a relatively well-defined pattern emerges. One can see that the first ten articles, which were mainly focused on the West Coast and to a lesser extent, the South Coast (the exception being a single article on the Prince Edward Island), were grouped under the heading "Monitoring Programmes" (because they present the results of monitoring). The second group of eleven mostly deal with new studies under the heading "Research Highlights". Why the general distinction between monitoring and the West Coast as a locale, and the East Coast as an exploratory and "highlight" area?

A partial answer could be because process and exploratory studies were done earlier on the West Coast (often related to fisheries in previous decades) and this area is in a more "mature" monitoring phase, whereas the East Coast is still being explored. Another contributing factor could be that the West Coast has simpler and more productive ecosystems, where the main trends can be assessed from monitoring a few key components, and the East Coast richer biodiversity whose complexity needs a different approach. However, the reason may also partly be organisational in that we have yet to build capacity to monitor the oceans and biodiversity on the East Coast, whilst (on the other hand) we may possibly be treating West Coast work too much in a "business as usual" fashion. If this is so, even to an extent, how could this be addressed?

A process that has not been covered in this report card is the comprehensive review that Oceans and Coastal Research has just completed of its current and incipient research and monitoring projects. This review may result in a more favourable geographic coverage of monitoring in the east and somewhat address the east-west dichotomy. The review may also lead us to taking a fresh look at West Coast research, including collaboration with other countries of the African Atlantic Region similar to the successful Second International Indian Ocean Expedition (IIOE-2).

1. CHLOROPHYLL VARIABILITY IN THE BENGUELA ECOSYSTEM

Phytoplankton play a crucial role in a number of key marine processes, such as the modulation of food webs, CO_2 exchanges, and the cycling of carbon and other nutrients. On the west and south coasts of Southern Africa, the Benguela upwelling system and the Agulhas Bank are ecologically and economically significant as they host productive ecosystems with a complex trophic structures that supports numerous commercially harvested resources. Satellite ocean colour data is used globally to better understand marine ecosystems, for both research and monitoring purposes. To monitor conditions along the southern African coast, an index of chlorophyll *a* concentration is routinely computed by integrating satellite-derived surface chlorophyll *a* concentration from the coast to the 1 mg m^{-3} level further offshore (Fig. 1a). Higher values are usually associated with greater phytoplankton biomass and a more productive ecosystem, while lower values indicate lower phytoplankton biomass and a less productive ecosystem.

Along the west coast of southern Africa, the highest index values are found off Namibia (16–26°S; Fig. 1b). During the first half of 2016, higher index values suggest a more productive ecosystem than in 2013, 2014, and 2015. During 2017, index values were similar to those in 2015, except for July, when peak values were more similar to those in 2016. The 2018 values were lower overall throughout the Namibian region, suggesting reduced phytoplankton biomass compared to 2016 and 2017.

Along South Africa's West Coast (28–34°S), elevated index values occur in the areas influenced by the Namaqualand, Cape Columbine and Cape Peninsula upwelling cells. During the first half of 2015, the index showed higher values than in 2013 and 2014. During 2017, values were lower overall than those in 2015 and 2016, suggesting a decrease in productivity. In contrast, higher values off Namaqualand during the second half of 2018 reflect an increase in the productivity of the region, compared to 2017.

Along South Africa's South Coast (18.5–29°E), chlorophyll index values were generally lower than on the West Coast. During 2016, the index was lower overall compared to 2015. Throughout 2017, index values were higher than those in 2016, suggesting an increase in productivity, with maxima occurring in the central part of the region in May and September. Whereas elevated biomass was evident in the western portion of the region between January and May 2018, with much lower values across the rest of the region, values were high across most of the central and eastern part of the South Coast during November 2018

Recent research has shown that the apparent large increase in index values on the West Coast post-2002 is due to a platform change from the SeaWiFS to the MODIS Aqua sensor. When accounting for this change, there is a small but significant long-term increasing trend in chlorophyll *a* off Namibia, and a decrease off the west coast of South Africa and on the Agulhas Bank. Nevertheless, these trends are much smaller than the seasonal and interannual variations that usually occur in this region, and substantially more years of data are required to properly distinguish the long-term trends from the seasonal and interannual variations.

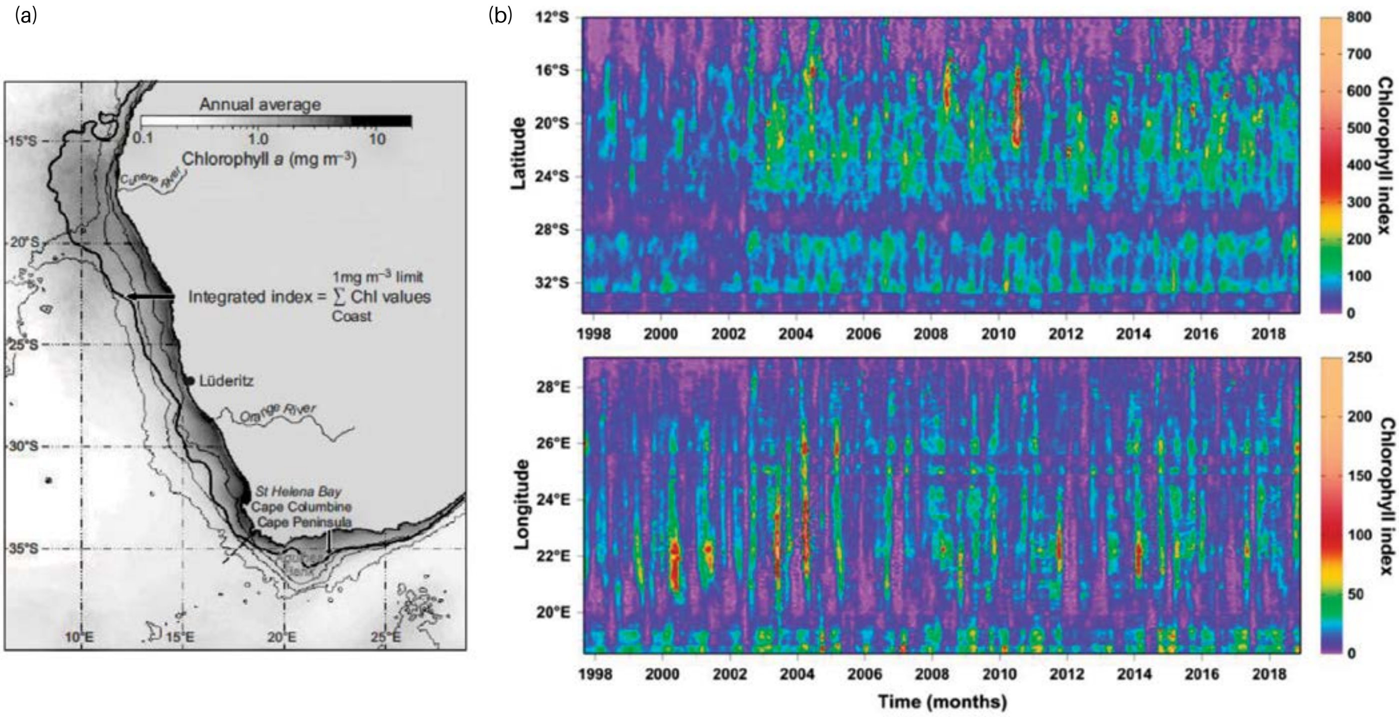

Figure 1: a) Annual average chlorophyll a *concentration and the location of the 1 mg m-3 contour (thick line), b) Monthly chlorophyll indices for the Benguela ecosystem from September 1997 to December 2018, for the west coasts of Namibia and South Africa (top panel) and for South Africa's South Coast (bottom panel)*

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2. SURFACE CHLOROPHYLL *A* CONCENTRATIONS ALONG THE ST HELENA BAY MONITORING LINE

St Helena Bay on the west coast of South Africa is one of the most productive areas of the Benguela ecosystem and has been the focus of environmental research and monitoring for a number of decades (Fig. 1).

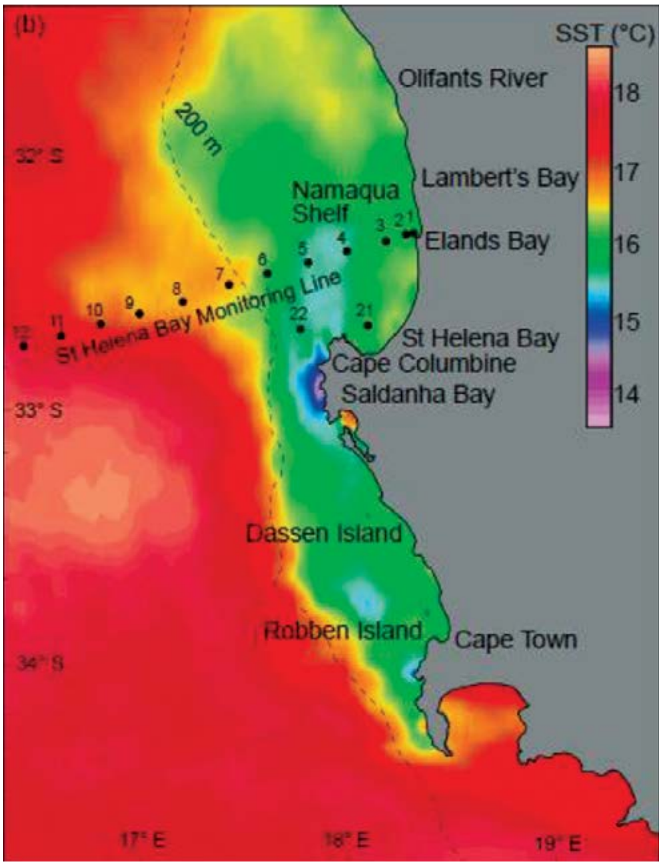

Figure 1: Map of Sea Surface Temperature (SST) illustrating cooler waters typically found inshore and warmer waters offshore, as well as the location of the St Helena Bay Monitoring Line

Satellite-derived surface chlorophyll *a* concentrations show a clear seasonal signal, with maxima in spring/early summer and late summer/autumn (Fig. 2). Higher values are usually associated with greater phytoplankton biomass and a more productive ecosystem, while lower values indicate lower phytoplankton biomass and a less productive ecosystem.

Generally, higher concentrations occur close to the coast and decrease with distance offshore. During 2015, concentrations > 20 mg m^{-3} occurred close to the coast in autumn (March) and late spring/early summer (September to November), and elevated chlorophyll (> 5 mg m^{-3}) extended c. 110 km offshore in March – the furthest offshore extension for such high concentrations since March 2010.

In contrast, concentrations > 20 mg m^{-3} were observed close to the coast between August and October 2016, and only during June, August and December 2017. In 2016, the furthest offshore extent (c. 80 km) for concentrations > 5 mg m^{-3} was observed in February, while in January 2017 and January 2018, such concentrations extended only c. 70 km offshore. The lower concentrations near the coast in 2017, and even lower values throughout 2018, suggest that the ecosystem has been less productive over the past two years.

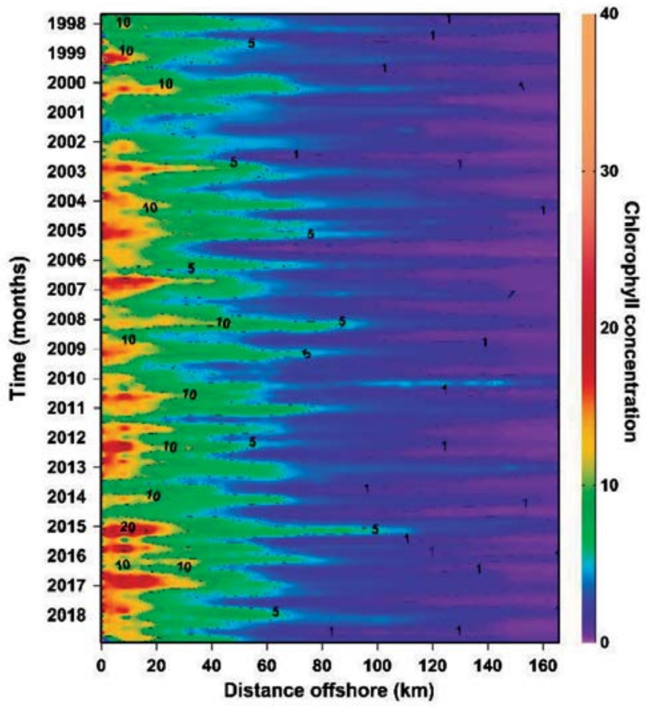

Figure 2: Time series of monthly chlorophyll a *(mg m^{-3}) along the St Helena Bay Monitoring Line between September 1997 and December 2018*

<u>Author</u>: Lamont T (DEA)

<u>Contributor</u>: Britz K (DEA)

3. LONG-TERM VARIABILITY IN COPEPODS OFF THE SOUTH COAST DURING SPRING, 1988–2018

Copepods dominate the zooplankton community and are an important food source for organisms such as fish and squid. With their short life-spans, they respond quickly to their environment and make excellent indicators of changing conditions in marine ecosystems. Annual sampling of copepods off the south coast of South Africa during spring to early summer (October-December) was initiated in 1988 (Fig.1), although there was a four-year vessel-related hiatus in sampling from 2012 to 2015.

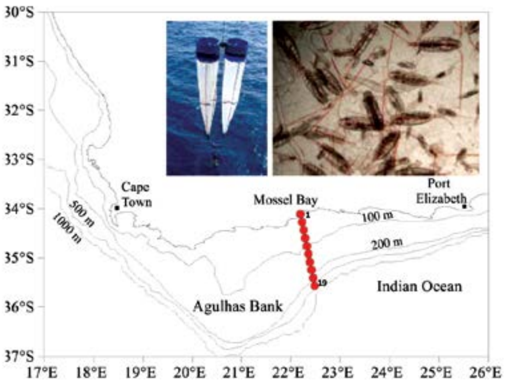

Figure 1: Location of sampling stations 1-19 along the Mossel Bay monitoring line on the Agulhas Bank

There was a significant long-term decline in total copepod biomass including that of *Calanus agulhensis*, the dominant large copepod on the Agulhas Bank, along the Mossel Bay monitoring line between 1988 and 2011 (Fig. 2). The copepod composition indicates a decline in the proportion of *C. agulhensis* for most of this period, until 2007–2008, and a corresponding increase in the proportion of small calanoid copepods (Fig. 3).

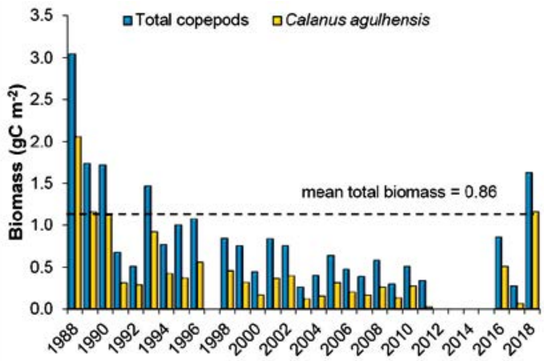

Figure 2: Mean total copepod and Calanus agulhensis *biomass along the Mossel Bay monitoring line*

In 2016, the biomass and proportion of *C. agulhensis* were greater than in 2011, an apparent reversal of these trends. Although low in 2017, both indices were significantly higher in 2018.

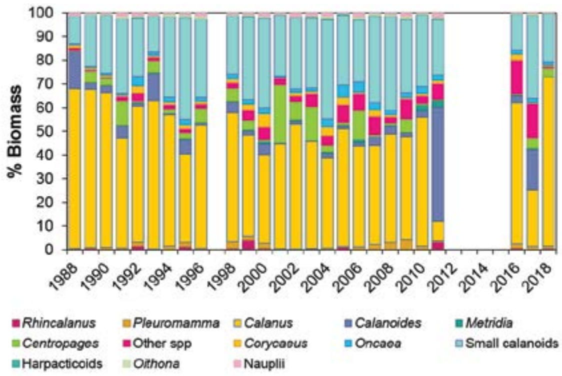

Figure 3: Copepod composition (% biomass) along the Mossel Bay monitoring line, in size order from large (bottom) to small (top)

Total copepod biomass in 2018 was 1.63 gC m^{-2}, while that of *C. agulhensis* was 1.16 gC m^{-2} (71% of total biomass), similar to levels in 1989 and 1990. Image analysis of surface water samples from each station revealed high numbers (50 L^{-1}) of large calanoid copepod nauplii (an index of copepod production; Fig. 4) over the inner Agulhas Bank, whereas the older stages (collected with Bongo nets) were concentrated further offshore (Fig. 5). The low abundance of large *C. agulhensis* stages at the three inshore stations coincided with highest biomass of anchovy located inshore, within 30 nm from the coast (Coetzee et al. 2018; FISHERIES/2018/DEC/SWG-PEL/38).

Figure 4: Copepod nauplii from image analysis of surface water samples

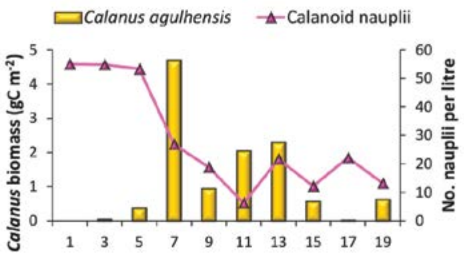

Figure 5: Biomass of C. agulhensis *and density of calanoid copepod nauplii per sampling station*

While zooplankton variability may reflect environmental variability, changes in copepod biomass and composition on the Agulhas Bank are thought to be largely driven by predation by pelagic fish. The recent increase in copepod biomass, particularly of the large species preferred by planktivorous fish, suggests a reduction in "top-down" predation impact from small pelagic fish. This is substantiated by below average biomass of both anchovy and sardine over the past 3–4 years, and in 2018 the lowest biomass of sardine east of Cape Agulhas since 1990 (Coetzee et al. 2018; FISHERIES/2018/DEC/SWG-PEL/38).

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4. SEABIRDS IN SOUTH AFRICA

Figure 1: African penguins breeding on the flats at St Croix Island (photo RJM Crawford)

Benguela endemics

Fifteen species of seabird breed in South Africa, of which seven are endemic to the Benguela upwelling ecosystem, off southwest southern Africa. Four of the endemic species compete with fisheries for prey and are listed by IUCN (International Union for Conservation of Nature) as Endangered: African penguin *Spheniscus demersus* (Fig. 1), Cape gannet *Morus capensis* (Fig. 2), Cape cormorant *Phalacocorax capensis* and bank cormorant *P. neglectus*. A fifth endemic species, the Damara tern *Sternula balaenarum*, is Vulnerable, whereas crowned cormorant *Microcarbo coronatus* is Near threatened and Hartlaub's gull *Chroicocephalus hartlaubii* is of Least concern.

The Endangered classifications of African penguins, Cape gannets, Cape and bank cormorants resulted from recent large decreases in numbers of these species off western South Africa. The decreases followed shifts to the south and east in the distributions of their prey, which brought about a scarcity of prey in the west that was likely further depleted by intensive fishing.

Figure 2: Cape gannets breeding at Bird Island, Algoa Bay (photo RJM Crawford)

In South Africa, numbers of penguins and gannets are assessed annually and those of cormorants, which breed at a larger number of localities, at periods of 3–5 years. The most recent assessments for Cape and bank cormorants were described in *State of the Oceans and Coasts around South Africa 2016 Report Card, Report No. 16* and are not repeated here.

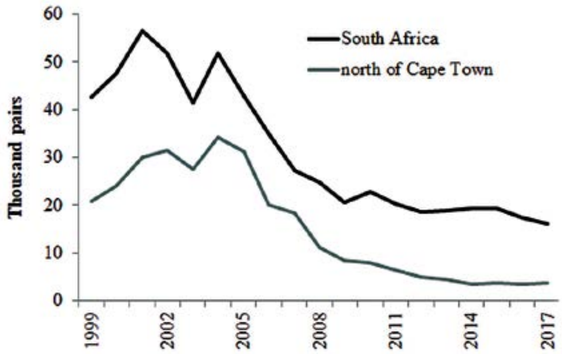

Figure 3: Numbers of African penguins breeding in South Africa and north of Cape Town, 2000–2018. It is apparent that the large recent decrease in South Africa was driven by the decrease north of Cape Town

Decreases of African penguins off western South Africa were evident by 2006 (Fig. 3), when it was requested that fishing of sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus* around two key southern localities be prohibited. However, this did not take place.

Following a meeting of stakeholders at Arniston (near Cape Agulhas) in 2010, a *Biodiversity Management Plan for the African Penguin* was gazetted in 2013 under the National Environmental Management: Biodiversity Act (NEM:BA) (No. 10 of 2004). It had aims: "To halt the decline of the African Penguin population in South Africa within two years of the implementation of the management plan and thereafter achieve a population growth which will result in a down listing of the species in terms of its status in the IUCN Red List of Threatened Species". Despite successful implementation of many of the actions listed in the plan, these aims were not attained and African penguins in South Africa have continued to decrease. The main reason for this was the scarcity of prey, which led to high mortality rates of birds. It is clear that this matter must be addressed if a second plan that is proposed to operate from 2019–2024 is to have any chance of succeeding. One way to achieve this may be to proclaim special management areas (SMAs) in terms of the National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008).

Numbers of Cape gannets breeding in South Africa decreased with fluctuations from about 145,000 pairs at the turn of the recent century to about 115,000 pairs in 2018 (Fig. 4). The decrease was attributable to the loss of > 30,000 pairs on South Africa's west coast north of Cape Town, where gannets breed at Lambert's Bay and Malgas Island. At both these localities Cape fur seals *Arctocephalus pusillus pusillus* have caught adult gannets ashore and fledgling gannets in the sea near the islands. Both types of interactions are damaging and have placed gannet colonies at risk.

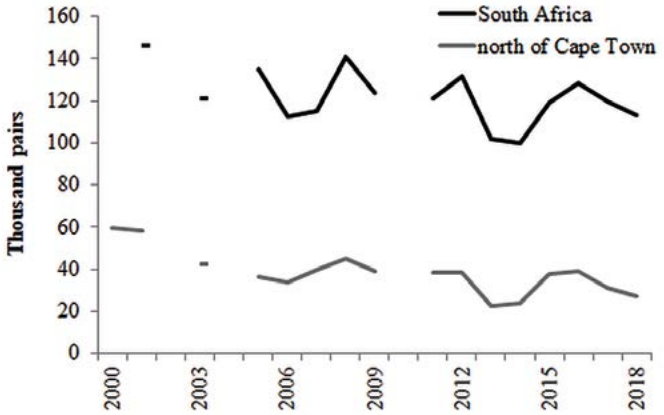

Figure 4: Numbers of Cape gannets breeding in South Africa and north of Cape Town, 2000–2018. The overall decrease was driven by the decrease north of Cape Town, where there has been a recent scarcity of prey

The diet of Cape gannets, which are wide-ranging birds that are able to switch prey, is thought to provide a reliable index of the availability of prey to predators that feed in the upper (epipelagic) portion of the water column. Since 1978, it has been monitored at gannet colonies found north of Cape Town during their September–March breeding season. There was noticeable alternation of energy-rich sardine and anchovy in the diet of gannets and, after the early 2000s, a marked reduction in the combined contribution of these prey species (Fig. 5). This suggests that the availability of sardine and anchovy to seabirds decreased off northwest South Africa. By contrast there was a recent increase in less nutritious food, such as offal of hakes *Merluccius* spp. discarded by bottom trawlers, or saury *Scomberesox saurus,* which occurs farther offshore and hence takes more energy to exploit, in the diet (Fig. 5). These findings corroborate the likelihood that recent decreases of African penguins, Cape gannets and Cape cormorants off northwest South Africa have resulted from food scarcity.

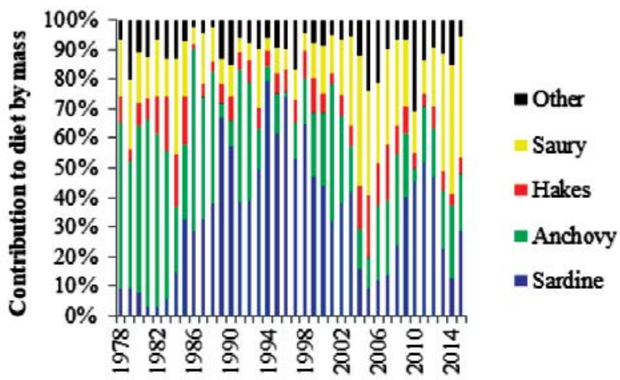

Figure 5: The contribution by mass of four main prey categories and other items to the diet of Cape gannets north of Cape Town in their breeding season (September to March), 1978–2015, showing the decreased consumption of energy-rich sardine and anchovy since the early 2000s

Although the Damara tern's global red list status is Vulnerable, it is classified as Critically endangered in South Africa, because of its small population, which is thought to be < 100 pairs. Recent decreases in western South Africa have been caused by loss of, or disturbance at, breeding habitat. Again implementation of SMAs is viewed as an option to address these issues. Hartlaub's gulls are not abundant but often frequent urban areas in western South Africa, to which they are attracted by the provision of safe nesting sites (e.g. on roof tops) and food discarded by humans. In such areas they may be regarded as undesirable on account of their smell and noise and because their nests may block gutters. It is probable that many Hartlaub's gulls in Cape Town have moved to the city from Robben Island and it may be possible to entice them to return to Robben Island by providing safe and undisturbed nesting habitat at that island.

Other species

The eight other seabirds that breed in South Africa include Leach's storm petrel *Oceanodroma leucorhoa,* Critically endangered in South Africa on account of its small population of < 10 pairs but abundant in the northern hemisphere and of Least concern globally; great white pelican *Pelecanus onocrotalus,* white-breasted cormorant *Phalacrocorax lucidus,* grey-headed gull *Chroicocephalus cirrocephalus* and Caspian tern *Hydroprogne caspia*, which all breed at inland water bodies as well as coastally; races of kelp gull *L. dominicanus vetula* and swift tern *Thalasseus bergii bergii* that are endemic to southern Africa (recent trends in numbers of swift terns breeding in South Africa were described in *State of the Oceans and Coasts around South Africa 2017 Report Card, Report No. 17*); and roseate tern *Sterna dougallii* (Fig. 6), of which 100–300 pairs breed annually at islands off the South Coast. All of South Africa's threatened or scarce seabirds are listed for protection in the Threatened or Protected Marine Species Regulations, published under the NEM:BA in 2017 (Gazette No: 40876).

Figure 6: Roseate terns at Bird Island, Algoa Bay (photo RJM Crawford)

Further information:

Anon. 2013. African Penguin Biodiversity Management Plan. Government Gazette No. 36966: 1–68

BirdLife International (2019) IUCN Red List for birds. Downloaded from HYPERLINK "http://www.birdlife.org/"http://www.birdlife.org on 07/02/2019

Crawford RJM, Makhado AB, Whittington PA, Randall RM et al. 2015. A changing distribution of seabirds in South Africa – the possible impact of climate and its consequences. Frontiers in Ecology and Evolution 3(10): 1–10

Authors: Crawford RJM, Dyer BM, Makhado AB, Makoala M, Upfold L (DEA)

5. SEABIRDS IN THE SOUTHERN OCEAN

Thirty species of seabird breed at South Africa's sub-Antarctic Prince Edward Islands (PEIs) in the southwest Indian Ocean, including penguins, albatrosses, petrels, storm petrels, diving petrels, cormorants, gulls and terns. Although no seabirds are endemic to these islands, they hold substantial proportions of the global populations of some species, for example 44% of the world's wandering albatrosses *Diomedea exulans* (Fig. 1), 33% of Crozet shags *Phalacrocorax [atriceps] melanogenis,* 19% of Indian yellow-nosed albatrosses *Thalassarche carteri* and 18% of sooty albatrosses *Phoebetria fusca*.

Figure 1: Photos of Wandering Albatrosses at Prince Edward Island – above an adult at nest, below a full-grown chick (photos RJM Crawford)

DEA initiated long-term research and monitoring of seabirds at the PEIs in 1994, a programme which has since run for 25 years. The main objectives of the programme have been to advise on the conservation of the seabirds, understand ecosystem change, inform ecosystem management and contribute to treaties to which South Africa is a party, including the Agreement on the Conservation of Albatrosses and Petrels (ACAP) and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). Research and monitoring conducted by other institutions, e.g. BirdLife South Africa, Nelson Mandela University and the FitzPatrick Institute at University of Cape Town, have also been invaluable in contributing to the attainment of these objectives. In 2018, South Africa hosted the 6th session of the Meeting of the Parties (MoP) to ACAP at Skukuza (Fig. 2). At this meeting Mr A Naidoo (Chief Director Research of DEA's Branch: Oceans and Coasts) was elected chair of the MoP until 2021.

Figure 2: Delegates to the 6th session of the Meeting of the Parties to ACAP at Skukuza, May 2017 (photo courtesy ACAP)

As elaborated upon in *State of the Oceans and Coasts around South Africa 2016 Report Card, Report No. 16*, there have been substantial changes in populations of some seabirds breeding at Marion Island, the larger of the two islands forming the PEIs. For example, sooty albatrosses decreased in the 1990s perhaps as a result of by-catch mortality in international long-line fisheries. They increased after the mid-2000s possibly as a consequence of uptake of measures to mitigate by-catch. By contrast estimates for light-mantled albatross *Phoebetria palbebrata* increased after the 1990s, likely as a result of better coverage of the island, but decreased after 2006, possibly as a result of warming at the island. Southern rockhopper penguins *Eudyptes chrysocome* decreased from > 170,000 pairs in 1994 to about 60,000 pairs at the turn of the recent century and have since remained stable with fluctuations. The decrease was associated with a reduced mass of adults returning to the island from winter feeding grounds and a diminished breeding success. Macaroni penguins *E. chrysolophus* decreased from > 430,000 pairs in 1994 to about 300,000 pairs soon after the turn of the recent century and have since fluctuated around that level. Outbreaks of disease caused severe decreases at the two largest colonies of this species.

Many of the seabirds that inhabit the PEIs range widely, moving through the high seas and waters of different national jurisdictions, where they are subject to various threats that include incidental capture and mortality in long-line fisheries and diminishing or displaced food resources. For marine spatial planning, it is important to understand the at-sea distributions of such species and this has been studied through the deployment of tracking devices. For example, it has been shown that distributions of Indian yellow-nosed albatrosses breeding at PEI were located between those reported for their conspecifics breeding at Ile Amsterdam and Atlantic yellow-nosed albatrosses *T. chlororhynchos* breeding at Gough Island. This suggests that yellow-nosed albatrosses partition their foraging grounds when breeding and may face different threats at sea (Fig. 3).

Additionally to the research at the PEIs, in 2016/17 and 2017/18, the DEA seabird research programme was expanded to gather much-needed information on seabirds breeding in the vicinity of South Africa's SANAE IV base. For emperor penguins *Aptenodytes forsteri,* counts were made from aerial photographs. At Atka Iceport in late December 2016 these numbered c. 5,600 chicks and c. 1,350 adults, compared to c. 8,000 chicks in late 1986 and c. 11,000 chicks in December 2007. At Muskegbukta, in December 2016 counts of chicks and adults were c. 4,000 and c. 750, respectively, and in December 2017 c. 3,250 and c. 440, respectively. These may be compared with an estimate from a satellite photograph of c. 3,200 penguins for September 2009. For snow petrels *Pagodroma nivea,* surveys of Robertskollen estimated that c. 105 pairs were breeding in December 2016 and c. 66 pairs in December 2017, both values being substantially lower than an assessment of c. 500 pairs in December 1987. Several impacts are thought to have contributed to the declines, including food availability, stormy weather and heavy snow falls during breeding periods.

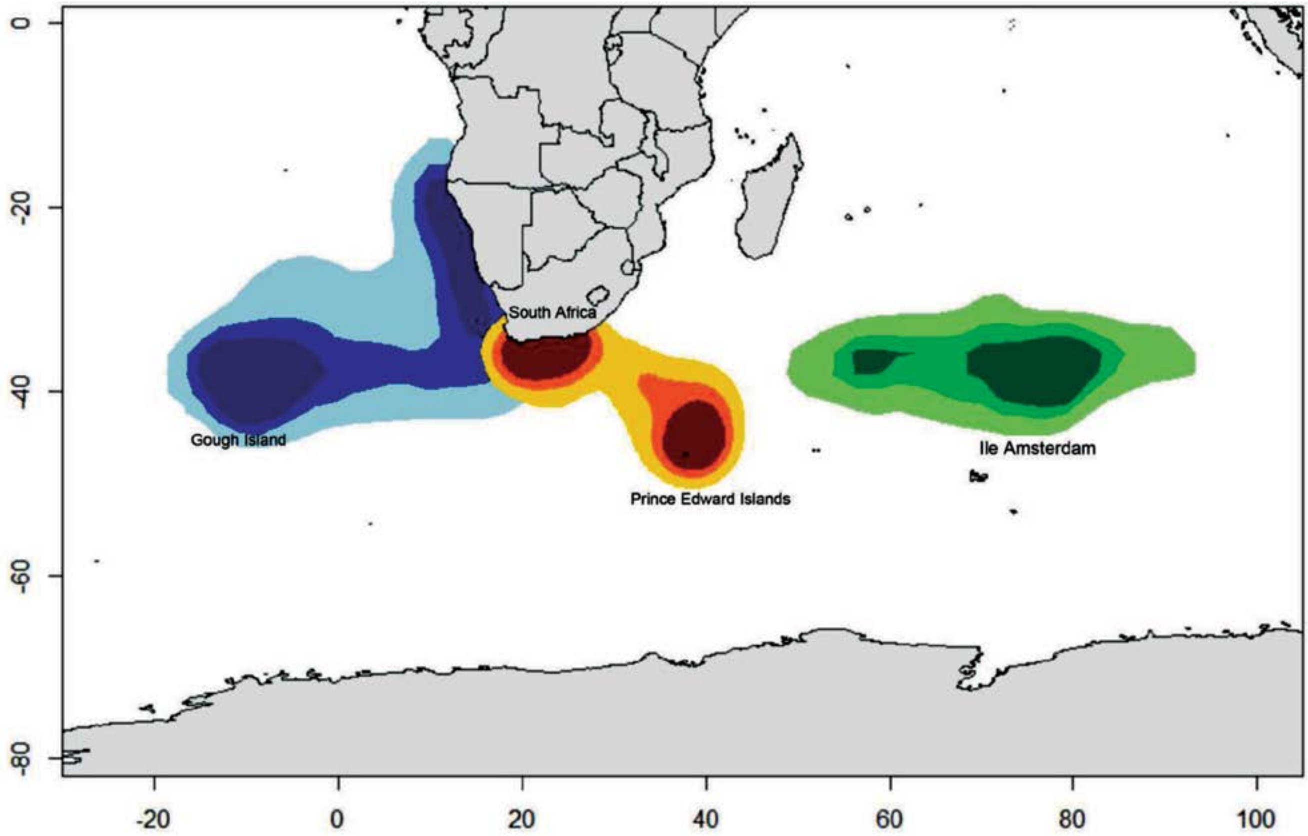

Figure 3: Kernel density distributions of breeding yellow-nosed albatrosses tracked from Gough Island (blue), Prince Edward Island (orange) and Ile Amsterdam (green) showing substantial partitioning of their foraging grounds. Colour gradients represent, from lighter to darker, probabilities of occurrence of 90%, 70% and 50%. The location of Prince Edward Island is shown by the black dot in the southern portion of the dark orange shading (reproduced from Emu – Austral Ornithology)

Figure 4: An aerial photograph of the emperor penguin colony at Muskegbukta in December 2017 (photo BM Dyer)

Figure 5: Threat display of a snow petrel on its nest at Robertskollen (photo BM Dyer)

Authors: Makhado AB, Crawford RJM, Dyer BM, Makoala M, Upfold L (DEA)

Further information:

BirdLife International. 2015. *Important Bird Areas in Antarctica 2015.* BirdLife International and Environmental Research & Assessment Ltd., Cambridge.

Makhado AB, Crawford RJM, Dias MP, Dyer BM *et al.* 2018. Foraging behaviour and habitat use by adult Indian yellow-nosed albatrosses *Thalassarche carteri* breeding at Prince Edward Island. *Emu – Austral Ornithology* 118: 353–362.

6. TRENDS IN WHALE STRANDINGS ALONG SOUTH AFRICA'S SOUTHWEST COAST, 1997–2018

Occurrence of whale strandings along South Africa's coast dates back centuries and early inhabitants along our coastline depended heavily on them not only as a source of food but also for building material. More recently strandings have been recognised as an important source of biological data for whales, which is not only preferable to lethal sampling but often provides the only source of information for highly elusive species. Thus DEA and its stakeholders have collected biological data from stranded whales along the coast since the 1980s, with DEA focusing mainly on strandings along the southwestern coast of South Africa (Fig.1).

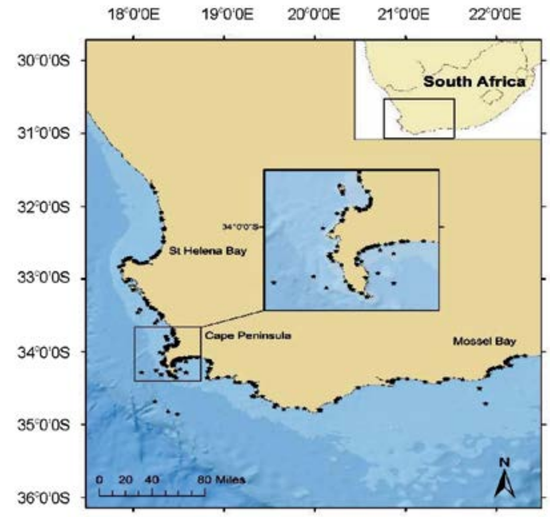

Figure 1: Reported stranding locations between the Olifants River Mouth and Mossel Bay, South Africa

Stranding hotspots appear to be at St Helena Bay and the Cape Peninsula and Mossel Bay areas. One of the reasons for this could be higher rates of reporting by members of the public in these areas. On average, five whales stranded annually during the period 1997–2006 but this increased to 18 from 2007–2017, a more than three-fold increase. There were 34 records of strandings in 2017 alone. Trends in annual numbers of reported whale entanglements and ship strikes also appear to follow this trend (Fig. 2).

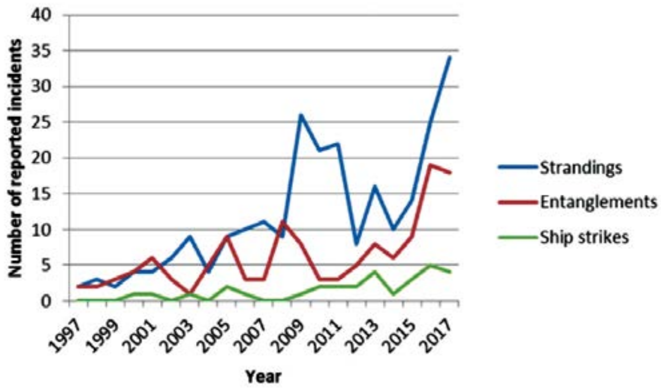

Figure 2: Trends in strandings, entanglements and ship strikes in the study area between 1997 and 2017

Large migratory whales, in particular the southern right whale *Eubalaena australis* and the humpback whale *Megaptera novaeangliae* which are seasonally common off the coast, accounted for 33% of all reported strandings (Fig.3). Surprisingly, the pygmy sperm whale *Kogia breviceps* accounted for nearly 18 % of all strandings, although it is very rarely sighted at sea (Fig.3).

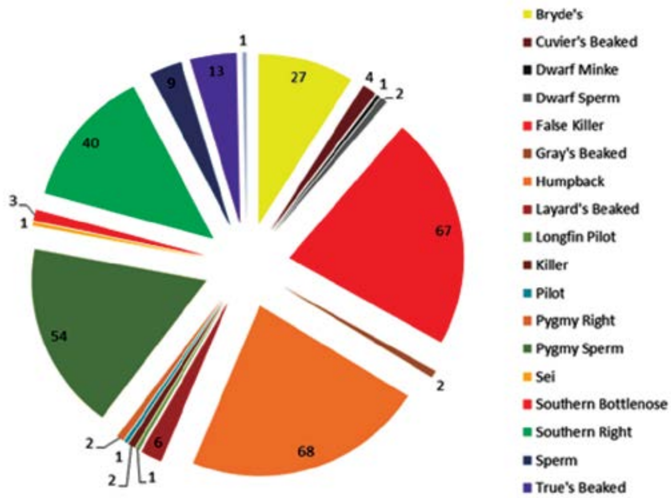

Figure 3: The breakdown of strandings by species during the assessment period. False Killer whale numbers include two mass strandings, at Kommetjie in 2009 (42 individuals) and Noordhoek in 2013 (20 individuals)

Causes of death are not always possible to determine but evidence of old age, disease, entanglements and ship strikes have been found.

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Contributors: Meÿer MA, Swanson S (ex-DEA)

7. SURFACE WATER pCO_2 DISTRIBUTION OFF THE WEST COAST OF SOUTH AFRICA

The world's oceans exchange carbon dioxide (CO_2) with the atmosphere and as a result the oceans are taking up most of the CO_2 that humans are releasing into the atmosphere through the burning of fossil fuels for energy. The ocean is not uniform in its capacity to absorb CO_2; while there are "carbon sinks" where CO_2 is absorbed in the ocean, other parts of the ocean release CO_2 to the atmosphere and are therefore "carbon sources". The extent to which CO_2 dissolves in seawater is thermodynamically driven by the difference in partial pressure (pCO_2) between seawater and the overlying air. When dissolved in seawater, CO_2 produces carbonic acid and lowers the ocean's pH, resulting in a process commonly known as ocean acidification. Increasing acidity reduces the ability of many marine organisms to build their calcareous shells and skeletons and is thus a major threat for the healthy functioning of marine ecosystems. Knowledge of the temporal and spatial variability in the distribution of pCO_2 in the ocean and identification of carbon sources and sinks is thus key to addressing the impacts of ocean acidification on marine ecosystem health. We investigated the distribution of surface water pCO_2 concurrently with O_2 and temperature off the west coast of South Africa (Fig. 1) in order to map its seasonal and spatial variability in this important upwelling system. The pCO_2 measurements were taken using the General Oceanics underway pCO_2 system on board the *RV Algoa* during scientific voyages of the Department of Environmental Affairs' Southern Benguela Integrated Ecosystem Programme. Underway oxygen measurements were taken using an Oxygen Optode.

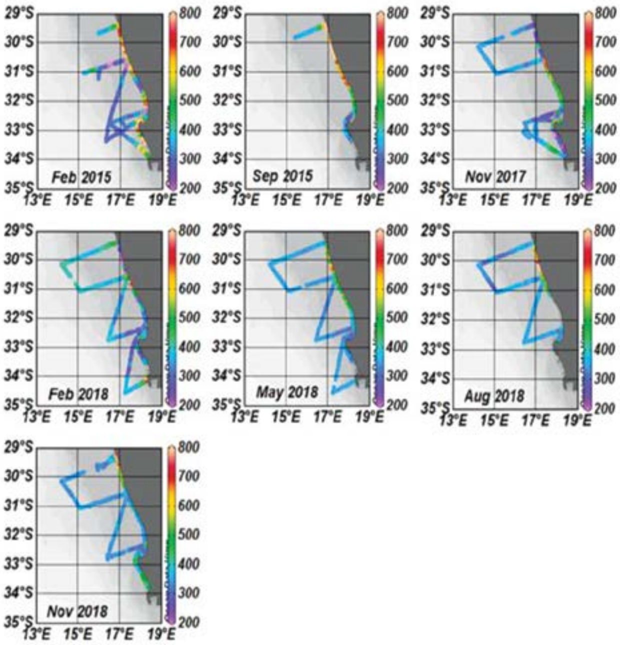

Figure 1: Distribution of surface seawater pCO_2 off the west coast of South Africa. The pCO_2 is presented in µatm units and the scale is shown on the right axis of each plot

High surface water pCO_2 values (600–1,200 µatm) that were above the current atmospheric CO_2 level of 410 µatm, were found north of St Helena Bay in September 2015, November 2017, February 2018, May 2018 and August 2018. In the near-shore area of St Helena Bay, pCO_2 reached a maximum of 1,560 µatm in February 2015, coinciding with a low oxygen value of 1.56 ml/L and a low sea surface temperature (SST) value of 10.4°C (Fig. 2). This cruise coincided with the occurrence of a harmful algal bloom which may have led to the removal of dissolved oxygen in subsurface layers during its degradation phase. The occurrence of high CO_2 waters with low SST values indicate that upwelling brought high CO_2 waters with low O_2 to the surface. High CO_2 waters may affect marine life along our coastline.

In the near-shore region (Fig. 2), pCO_2 generally increases northwards from St Helena Bay while dissolved oxygen and temperature decrease. High pCO_2 values indicate that the near-shore area north of St Helena Bay acts as a source of CO_2 in most seasons. However, the CO_2 values offshore fell below the atmospheric CO_2 level corroborating the previous finding that the Southern Benguela is a net sink for atmospheric CO_2 (Gregor et al. 2013, *Afr. J. Mar Sci*. 109: 1–5).

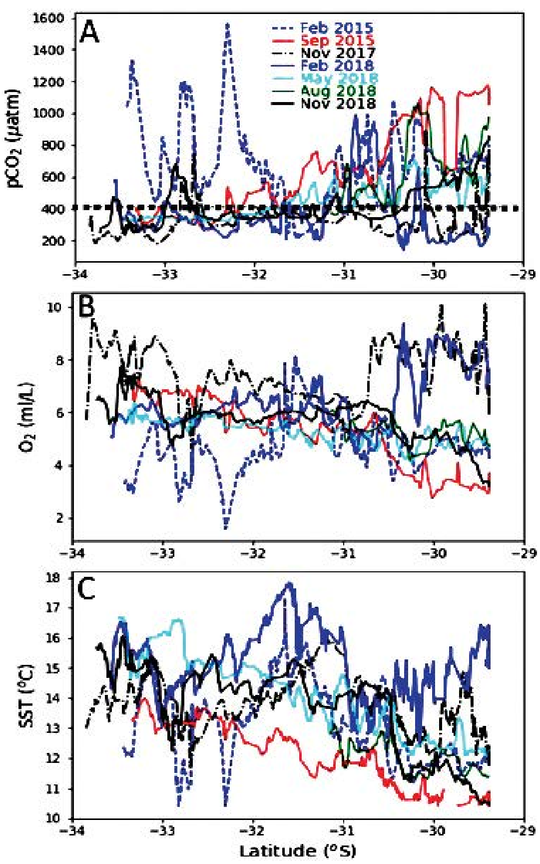

Figure 2: Measurements for pCO_2 (A), O_2 (B) and SST (C) obtained concurrently along the near-shore region of the West Coast, in relation to latitude. The current atmospheric CO_2 level is represented by the dotted line at 410 µatm

Long-term observations of changes in the ocean's CO_2 content and uptake rates provide critical information for assessments of climate change impacts. While seasonal data, as presented here, are valuable, higher temporal resolutions are needed to fully understand the variability of the system in terms of sources and sinks.

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8. SEASONAL DISTRIBUTIONS OF PICOPHYTOPLANKTON IN THE SOUTHERN BENGUELA

Photosynthesis is essential to life on Earth, and half of the primary production that supports all photosynthesis takes place in the ocean, by planktonic microorganisms. The smallest of single-celled organisms, also called picoplankton (0.2–2 µm), were originally overlooked, yet recent findings suggest that they contribute up to 80% to carbon fixation and primary production in the oceans. To quantify their importance in the Southern Benguela upwelling region, this study focused on the most abundant picophytoplankton taxa, namely *Prochlorococcus* and *Synechococcus*, as well as several picoeukaryote groups.

Seawater samples were collected seasonally over a period of two years (2015–2017) along four transects spanning the Southern Benguela upwelling region (Fig. 1). A flow cytometer was used to identify and count picoeukaryotes, *Synechococcus* spp. and *Prochlorococcus* spp. in these samples.

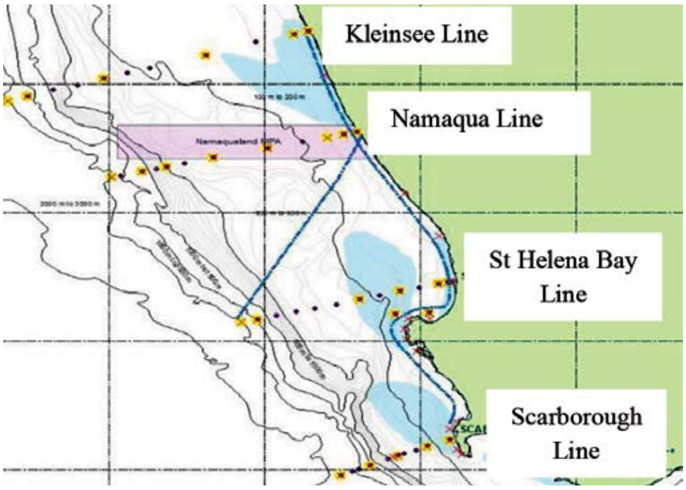

Figure 1: Map showing the transect lines and stations of the Department of Environmental Affairs' Southern Benguela Integrated Ecosystem Programme. Stations sampled for this study are highlighted with yellow

The seasonality of different picophytoplankton groups varied between the two years of sampling (Fig. 2). In the first year, a clear spring bloom was observed with substantially higher abundances of *Synechococcus* and picoeukaryotes than during other seasons. In the second year no such bloom was observed. Statistical models that relate the abundance of picophytoplankton taxa to environmental variables suggest that temperature, salinity and nutrient availability are all drivers of the observed differences. Samples were only taken once per season and a higher sampling frequency will be required to understand the exact mechanisms that drive the dynamics of these photosynthetic organisms.

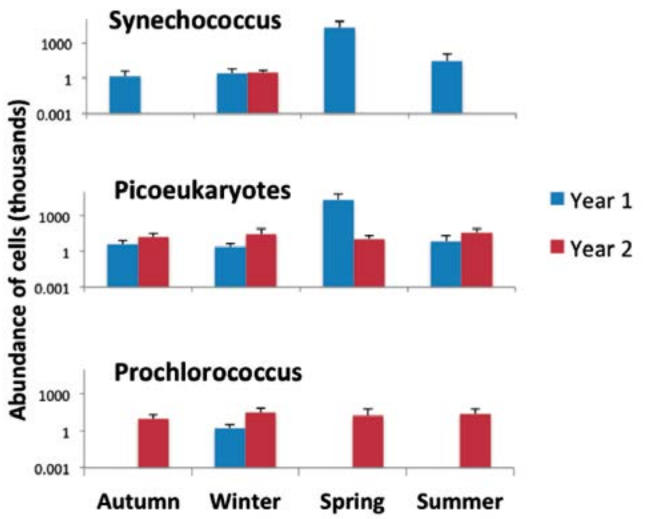

Figure 2: Abundance of the three most common picophytoplankton taxa in different seasons of 2015–16 (Year 1, blue bars) and 2016–17 (Year 2, red bars). The absence of some bars indicates missing data due to instrument error

This study is the first to quantify the abundance of different picophytoplankton groups throughout the Southern Benguela upwelling region. Clear differences between seasons and years can have far-reaching effects on the dynamics of ocean biogeochemistry and primary production. These results should therefore be incorporated in ecosystem models, to understand links between the smallest of plankton and the food web as a whole.

Authors: Gebe Z, Rocke E (University of Cape Town); Pfaff M (DEA); Moloney C (University of Cape Town)

9. MICROBIAL COMMUNITY COMPOSITION AND DIVERSITY IN THE SOUTHERN BENGUELA: A SPATIO-TEMPORAL STUDY

Coastal upwelling regions are considered to be among the most biologically productive ecosystems in the world's oceans. Microbial communities play a fundamental role in nutrient cycling in these regions. Nutrient cycling is essential for food web stability and functioning and is the basis for a healthy ecosystem. In this first assessment of microbial communities of the Southern Benguela upwelling region, microbial sampling took place in St Helena Bay (Fig. 1) in September, November and February of the 2015-2016 upwelling season. Community dynamics were assessed at stations both inside and outside a plume of upwelled water in St Helena Bay.

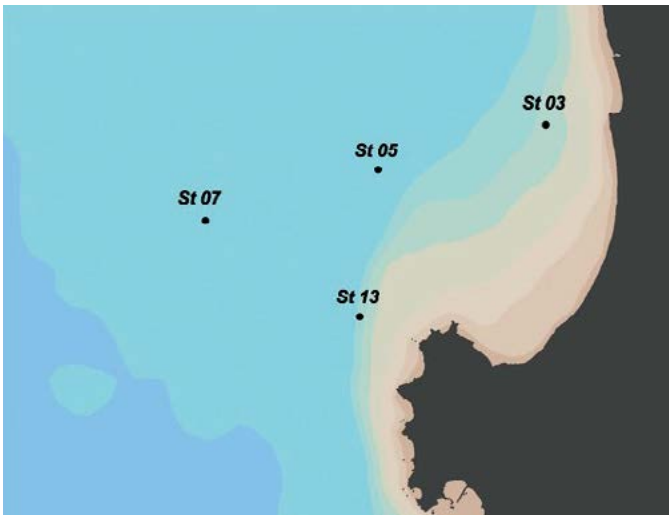

Figure 1: Map of the study area and location of sampling stations in St Helena Bay. The station numbers correspond to those sampled for the Department of Environmental Affairs' Southern Benguela Integrated Ecosystem Programme, which provided the platform for this study

DNA sequencing results revealed differences in microbial community structure among months and among sites during the upwelling season. Parasitic dinoflagellates (Syndiniales) dominated in February, diatoms (Mediophyceae) proliferated in November, and the less common nitrite-oxidising bacteria *Nitrospina* sp. was most abundant in hypoxic waters in September (Fig. 2). The significant abundances of parasitic and nitrifying microbes in particular have far reaching implications with regard to biogeochemical cycling in this region, as discussed below.

Parasitic Syndiniales are known to infect crustaceans, fish, algae, cnidarians and other micro-algae, including those that form harmful algal blooms (HABs). Parasites control the abundance of their hosts and are thus important controlling agents of marine ecosystems. On the west coast of South Africa, where HABs pose an imminent threat to coastal economies, parasites of HAB-forming species are of particular importance. The way microbial parasites impact ecosystems is, however, complex: On one hand they might prevent harmful blooms by reducing the abundance of HAB-forming species. On the other hand, they might induce epidemic mortalities of their hosts followed by bacterial decay of dead cells, and thereby generate low oxygen events. Such events have led to mass mortalities of many marine species and the stranding of hundreds of tons of west coast rock lobsters, leading to great economic losses in fisheries and aquaculture industries. More studies are needed to find out how parasites affect algal bloom formation and termination in the Benguela region, and what their socio-ecological roles are.

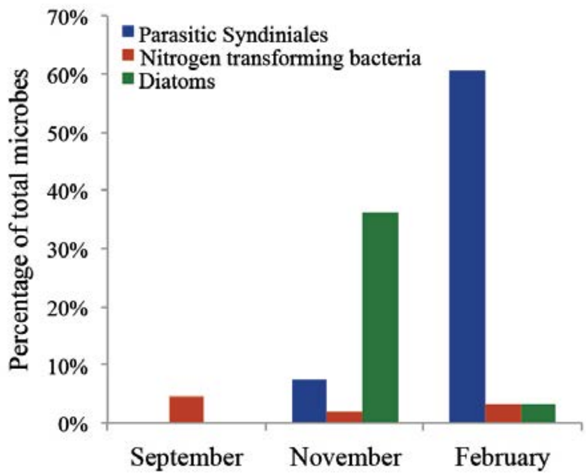

Figure 2: Relative abundance of parasitic Syndiniales (blue bars), nitrogen transforming bacteria (orange bars) and diatoms Mediophyceae (green bars) in different months

Nitrogen is an essential element needed for the growth of microalgae. Metabolising bacteria, such as those found during this study, are responsible for transforming sources of nitrogen that are unusable by algae (e.g. ammonia) to usable forms, such as nitrate. The oxidation of nitrite to nitrate by nitrite-oxidising bacteria is particularly important for retaining nitrogen in the ocean and preventing losses to the atmosphere. Therefore the presence of these bacteria is a positive sign, and provides evidence that waste products are being recycled in the surface waters of the Benguela region, allowing for healthy growth of small algae in the region. Further studies are underway to measure the exact abundances of these organisms and their potential association with low-oxygen conditions in the Southern Benguela region.

This is the first time that entire microbial communities have been investigated in such detail in this region. Bacterial communities are key drivers of the nutrient cycle and thus fundamental to the functioning of marine ecosystems. Continued research and monitoring are needed in order to develop a bacterial indicator or proxy, which could contribute towards describing the health state of the water column in the region.

Authors: Rocke E, Gebe Z (University of Cape Town); Cheung I, Liu HB (Hong Kong University of Science and Technology, China); Pfaff MC (DEA); Dames N, Moloney C (University of Cape Town)

10. PRELIMINARY FINDINGS FROM VISUAL SURVEYS OF OFFSHORE BENTHIC HABITAT ALONG THE WEST COAST OF SOUTH AFRICA

The importance of benthic invertebrates as indicators of ecosystem health has long been recognized. However, offshore benthic communities in South African waters have not yet been well described, mainly because of the challenges associated with sampling the benthos in deep waters. In light of this, a benthic project was proposed within the Department of Environmental Affairs' Southern Benguela Integrated Ecosystem Programme in 2015, with the aims of (i) establishing a baseline for epi-benthic invertebrate distributions; (ii) verifying the benthic ecosystem types as they have been defined by the National Biodiversity Assessment; and (iii) identifying benthic indicators for long-term monitoring within the pre-determined IEP monitoring lines.

Thirteen benthic stations (Fig. 1) were surveyed from on-board the *RV Algoa*, using a towed under-water benthic camera. The camera was fitted with a CTD probe to measure point specific temperature, GPS for area-specific geo-location, and lasers to enable area determination. Three of the 13 stations surveyed could not be analysed due to poor image quality. The remaining ten included five stations from the Kleinsee line, four from the Namaqua line and one from the St Helena Bay line. The stations were further classified according to depth, with four deep (> 430 m) and six shallow stations (< 230 m). Between nine and 30 images from each station were processed using TransectMeasure software after calibration files were generated using CAL software (www.seagis.com.au). Only clear, in focus images of the seabed, with three laser points visible, were processed (Fig. 2).

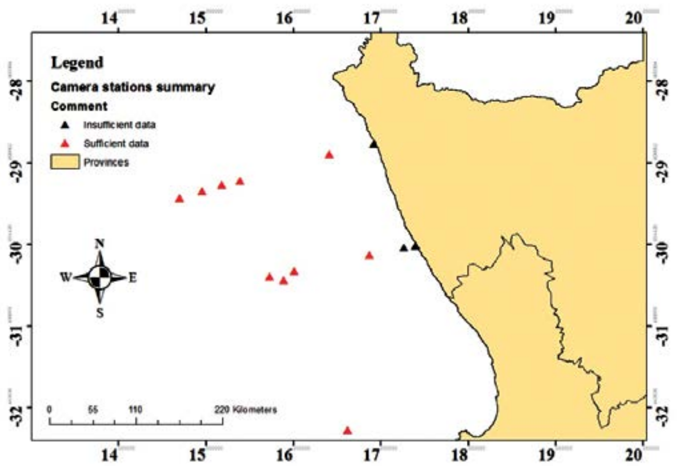

Figure 1: Map showing surveyed stations; red triangles represent stations for which there were sufficient data for analysis, and black triangles show stations for which image quality was too poor for analysis

All visible species were identified to the lowest possible taxonomic level and counted within a quantified area demarcated on each image. The abundance of species was standardised per m^2 and 4^{th} root transformed. A Bray-Curtis similarity index was used to generate a resemblance matrix and a non-metric multidimensional Scaling (MDS) plot of 167 processed images was generated, with monitoring line and depth as factors (Fig. 3).

Authors: Filander Z (DEA); Atkinson L, Wozniak D (South African Environmental Observation Network); Snyders L (DEA)

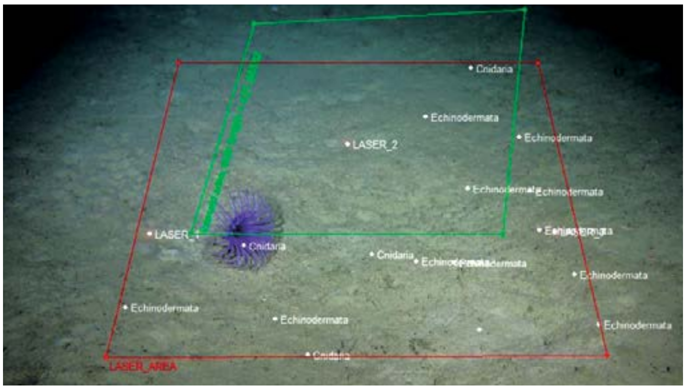

Figure 2: A screen shot captured during image processing using TransectMeasure SeaGIS (www.seagis.com.au)

The MDS showed separation between shallow and deep stations and between the Kleinsee and Namaqua monitoring lines, but strong similarity between Namaqua Deep and St Helena Bay Deep, while Kleinsee Deep separated out from the other deep stations. The eight Namaqua Shallow stations to the bottom left of Figure 3 are outliers as they represent mosaic habitats made up of sand with rocky outcrops which host different epifaunal species. Overall, the species that typified the shallow stations included the crab *Ebalia tuberculosa* and the brittle star *Ophiura costata costata*; the benthic shrimp *Parapontophilus gracilis*, brittle star *Ophiura trimeni* and burrowing anemones *Cerianthid* spp. characterised the deep stations. The Kleinsee area was characterised by *O. trimeni, Cerianthid* spp. and *E. tuberculosa*. The Namaqua area was also typified by the burrowing anemones and *E. tuberculosa* but additionally hosted *O. c. costata* and *P. gracilis*. Species characteristic of the St Helena Bay line included *P. gracilis* and an unidentified polychaete.

These preliminary findings represent a limited number of stations that were successfully sampled to date (57% of all possible stations). Further sampling and image processing is required for a complete baseline of invertebrate distribution patterns and the verification of ecosystem types in the area. Such data, once acquired, will be pivotal in identifying potential benthic indicators for long-term monitoring.

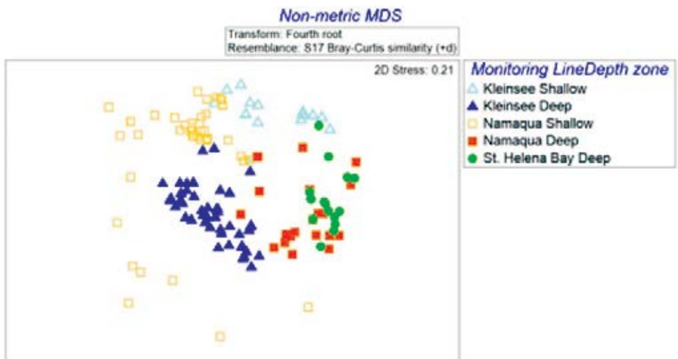

Figure 3: A non-metric multidimensional scaling plot of the 167 images processed

11. HYDROGRAPHIC CONDITIONS ON THE SOUTHEAST AFRICAN SHELF DURING SUMMER AND WINTER 2017

The shelf region along the southeast coast of South Africa is strongly impacted by the warm, fast-flowing Agulhas Current. As a result of limited societal drivers, such as marine mining and large-scale fisheries, it is one of the least studied and most under-sampled areas around southern Africa. The majority of previous research in the area has been carried out using satellite data and model output. Earlier in situ studies have been conducted at either a bay-scale, which falls short of accurately identifying shelf-wide impacts of larger surrounding oceanographic features, or at a wider scale at much coarser resolution, which unsuccessfully captures the details of the shelf circulation. New marine protected areas (MPAs) were recently declared off the south east coast and understanding the hydrographic conditions of the area and the processes that influence them will contribute to effective MPA management. In order to begin addressing the lack of in situ data in this region, and to establish a baseline of shelf-wide environmental conditions, the Department of Environmental Affairs (DEA), together with the African Coelacanth Ecosystem Programme (ACEP) Phakisa Ocean Cruises Initiative, conducted multi-disciplinary research cruises during January/February (summer) and July/August (winter) 2017. The cruises also enabled at-sea training of postgraduate students and interns.

Here we summarise the hydrographic conditions observed during the two cruises, as well as their physical driving mechanisms. Seasonal differences in temperature and salinity across the shelf were evident within the upper layers of the water column. A difference of 4°C in surface temperature was observed, with higher values during summer and lower values in winter.

Generally, lower salinities were observed across the shelf during summer, possibly due to freshening driven by summer rainfall in the area. Particularly low salinities were noted in the nearshore region close to the Mzimvubu River mouth near Port St Johns, as a result of elevated river outflow during summer.

In contrast to the South African west coast, where frequent low dissolved oxygen events have negative impacts on marine organisms, oxygen conditions on the southeast African shelf (> 3.00 ml L^{-1}) appeared to be adequate for survival of the existing shelf organisms.

Irrespective of season, the Agulhas Current and passing cyclonic mesoscale eddies were observed to introduce cooler, less-saline, nutrient-rich waters onto the shelf. The input of elevated nutrients into the surface layers of a shelf system which is usually nutrient-poor, resulted in increased productivity, with much higher chlorophyll *a* in January/February.

These two cruises constitute the only high-resolution sampling of this region to date. In light of the potential impacts on MPAs, the implementation of systematic and routine monitoring of the hydrographic conditions and their influence on shelf biology is recommended.

Authors: Russo C (University of Cape Town); Lamont T (DEA); Barlow RG (Bayworld Centre for Research and Education)

Contributors: Jacobs L, Makhetha M, Tutt G, van den Berg M (DEA)

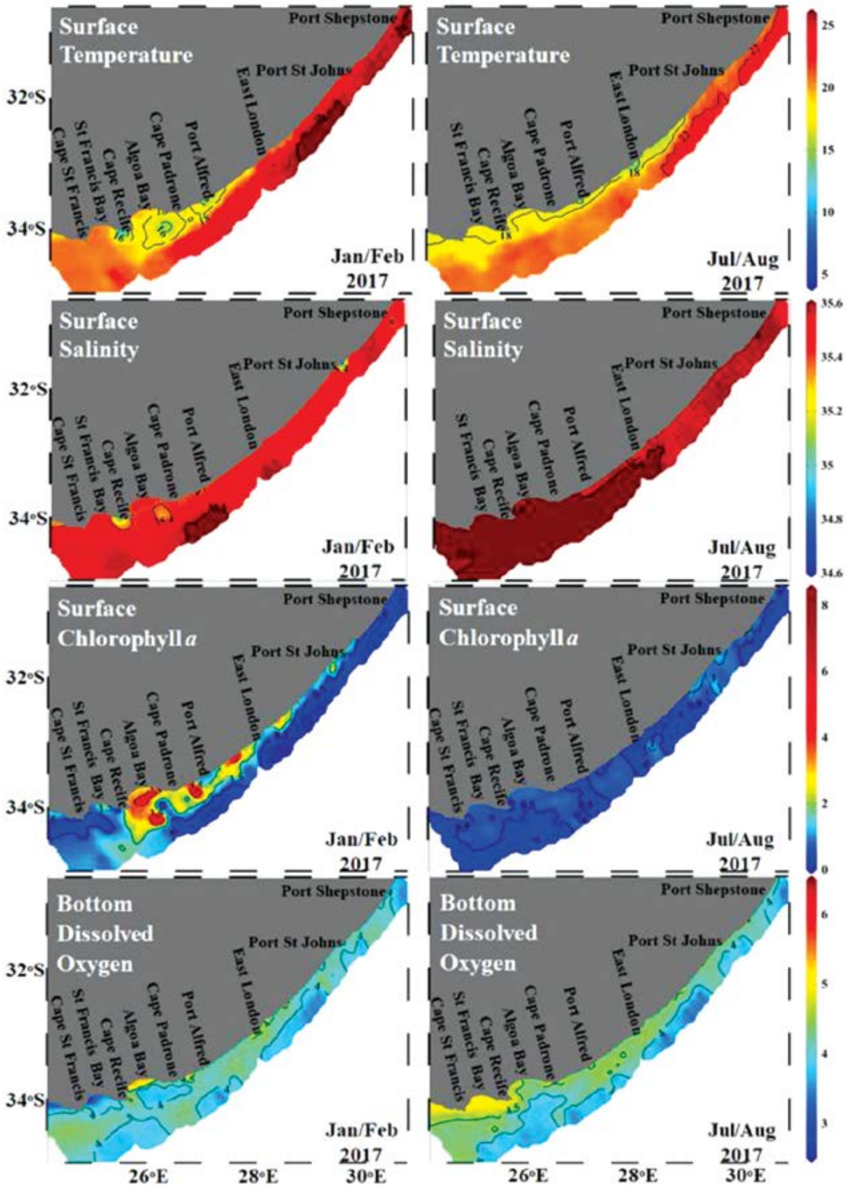

Figure 1: Hydrographic measurements (Conservative Temperature - °C; Absolute Salinity – g kg^{-3}; Chlorophyll a *concentration – mg m^{-3}; Dissolved Oxygen concentration – ml L^{-1}) during January/February and July/August 2017*

12. STABLE ISOTOPE ANALYSIS OF EPIBIOTIC TURTLE BARNACLES FOR TRACKING THE MOVEMENT OF LOGGERHEAD SEA TURTLES

Sea turtles provide a substrate to a diverse range of epibionts, which can be used to infer their host's ecology. Turtle barnacles, for example, can live for up to three years on a turtle and store chemical signatures of the environment in which they grow in their calcareous shells. The oxygen ($\delta^{18}O$) isotopic signatures in different growth layers of barnacle shells (Fig. 1) can be related to distinct ocean regions. Thus, the isotopic analysis of turtle barnacle shells can be used to identify migration routes and feeding habitats of turtles that periodically arrive to nest on beaches, offering a cost-effective, complementary tool to other tracking methods, such as satellite tags and mark-recapture studies.

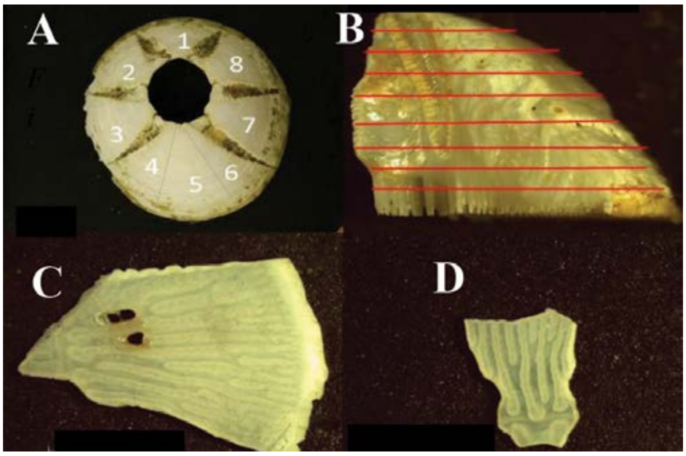

Figure 1: The shell of the turtle barnacle Chelonibia testudinaria*, showing (A) its eight wall plates; (B) a cross section of a wall plate and layers (red lines) analysed for stable isotopes, with the oldest layer on top and the most recent layer at the base; (C) a distinct growth layer; and (D) the portion of a layer analysed after the calcite edges have been removed*

In this study, oxygen isotopes were analysed in different shell layers of *Chelonibia testudinaria* barnacles sampled from nesting loggerhead sea turtles *Caretta caretta* at the Isimangaliso Wetland Park in Kwa-Zulu Natal**.** The isotopic signatures of the barnacle shells could then be aligned with known isotopic signatures of distinct ocean regions, given that oxygen isotope ratios vary latitudinally and with distance from the coast. Thus, by overlaying the isotopic range of a barnacle shell with an isoscape map, the at-sea distributions of the host turtle could be estimated (Fig. 2). Movement ranges were mapped in this way for eight turtles (only two shown here), indicating that six of them migrated northward from the nesting beaches, while two moved southward.

The movement patterns of loggerhead sea turtles as determined in this study, conform to those derived from satellite tracking studies of the same population. The tracks showed that after nesting on Kwa-Zulu Natal beaches, most animals migrate northwards but some move southwards. The use of isotopes in epibiotic barnacle shells has the added advantage of tracking turtles over a relatively long time period of up to three years, whereas satellite tags generally detach sooner. The isotope signatures suggest that turtles return to the same feeding region between nesting intervals. This study confirms that despite the relative low spatial resolution of data, this novel technique is an effective complementary tool for tracking movements of migratory species which are of high conservation importance.

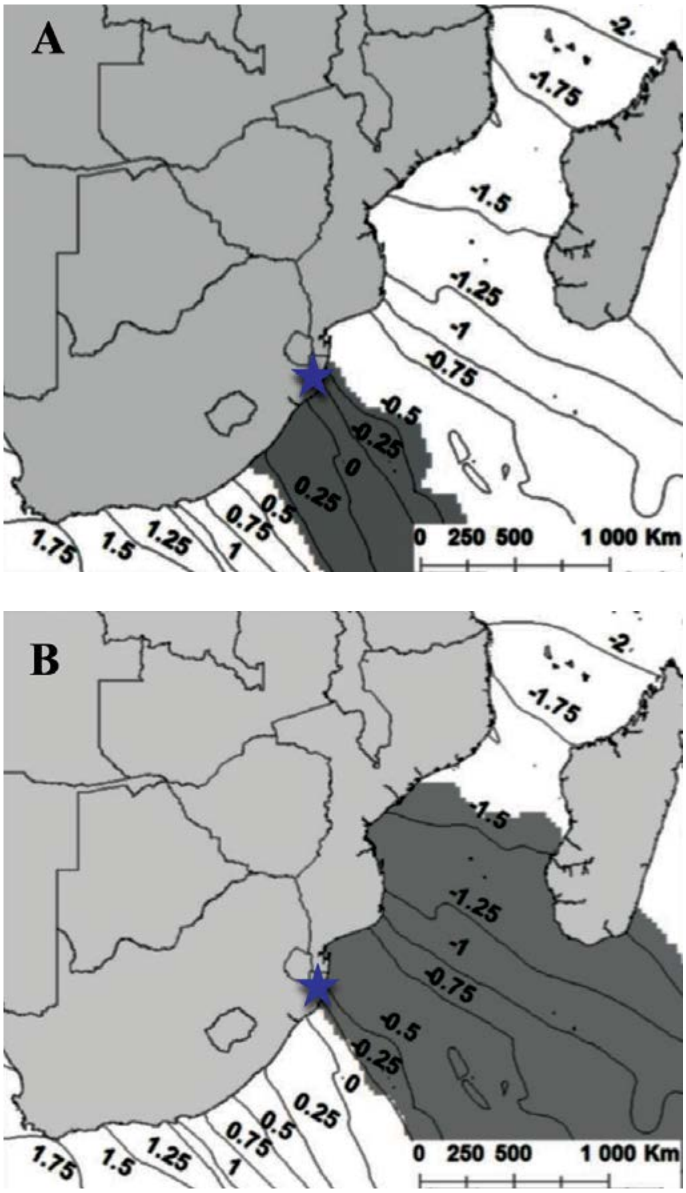

Figure 2: Movement range of two nesting loggerhead sea turtles (A and B) based on oxygen isotopic signatures of turtle barnacle shells sampled in the Isimangaliso Wetland Park (blue star). Turtle A utilised feeding habitats south of the nesting area, while Turtle B had been roaming further north

Authors: Nolte C, Nel R (Nelson Mandela University); Pfaff M (DEA)

13. TAXONOMIC REVISION OF SOUTH AFRICA'S EAST COAST DEEP-WATER CORAL COLLECTION

Scleractinian coral species, while mostly familiar from shallow, tropical and temperate forms, also occur in deeper and colder environments. The deep-water coral species lack the symbiotic relationship with photosynthetic algae called zooxanthellae, that is characteristic of most shallow-water species, and are therefore classified as being azooxanthellate.

Of 711 known azooxanthellate coral species across 14 families, 87% (n = 622) occur in environments deeper than 50 m. Less than 3% (n = 18) of the azooxanthellate coral species are recognised as reef-building forms, some of which have been the focus for most of the coral research and conservation efforts (Fig. 1); the remaining 97.5% are non-reef building.

Despite recent global efforts to address the lack of knowledge about non-reef-building azooxanthellate coral species, there is still a paucity of data on this group in South Africa. The accepted total number of species in this group for mainland South Africa's exclusive economic zone is 73 species across eight families. This is based on existing literature including various regional monographs and a species checklist for the East Coast deep-water coral fauna developed by Boshoff (1981: An annotated checklist of Southern African Scleractinia, Oceanographic Research Institute). However, the accuracy of the Boshoff checklist has been questioned, on the basis of incorrect identifications (possibly caused by Boshoff's poor eyesight), ambiguous locality information and an incomplete literature review.

To address this, the sample collection on which Boshoff's list was based, which is housed at the Oceanographic Research Institute in Durban, was re-assessed during August 2018. Eighty-four percent (n = 52) of the 62 samples in the collection were found to have been incorrectly identified and were re-classified based on the examination of their gross morphological features and expert opinion. This revision resulted in a reduced list of 36 species for the east coast of South Africa (as compared to the 46 reported by Boshoff), within 25 genera across five families. The total number of deep-water coral species for South Africa was thus adjusted from 73 to 63.

The value of taxonomy is often underestimated. Taxonomic data are an important basis for biodiversity assessments and hence planning for biodiversity management and conservation. The nearly 15% reduction in the number of species brought about by this taxonomic revision is not inconsiderable and will have implications for future assessments. This study emphasizes the importance of museum collections and of revisiting and updating the taxonomic records using up-to-date knowledge and methods.

Figure 1: Coral morphological types: solitary (left) and colonial (right)

Table 1: Identifications of deep-water corals as published by Boshoff (1981). Those with an asterisk were found to be correctly identified; the remaining entries have been revised and the updated identifications will be presented in a forthcoming publication

Sample No.	Species	Sample No.	Species	Sample No.	Species
BIVa1	*Stephanophyllia formosissima*	DIIIb1	*Ceratotrochus brunneus*	EIa2	*Balanophyllia bairdiana*
BIVa2	*Stephanophyllia fungulus*	DIIIb1	*Ceratotrochus brunneus*	EIa4	*Balanophyllia capensis**
CIC1	*Culicia tenella*	DIIIc1	*Goniocorella* sp.	EIa4	*Balanophyllia capensis**
CVbi	*Madrepora oculata*	DIIId1	*Desmophyllum cristagalii*	EIa4	*Balanophyllia capensis*
DIa1	*Fragilocyathus conotrochiodes*	DIIId3	*Desmophyllum cristagalii*	EIa5	*Balanophyllia cumingii sensu*
DIIa1	*Adkinsella* sp.	DIIIe1	*Heterocyathus aequicostatus*	EIa6	*Balanophyllia ponderosa*
DIIb1	*Flabellum thouarsii*	DIIIe1	*Heterocyathus aequicostatus*	EIb2	*Dendrophyllia exigua*
DIIb2	*Flabellum inconstans*	DIIIe1	*Heterocyathus aequicostatus*	EIb3	*Dendrophyllia micranthus*
DIIb2	*Flabellum inconstans**	DIIIf1	*Lophelia exigua*	EIb4	*Dendrophyllia coccinea*
DIIb3	*Flabellum harmeri*	EIa3	*Balanophyllia bonaespei**	EIb4	*Dendrophyllia coccinea*
DIIb3	*Flabellum harmeri*	EIa4	*Balanophyllia capensis*	EIb5	*Dendrophyllia miniscula sensu*
DIIb3	*Flabellum harmeri*	DIIIg1	*Paracyathus indicus*	EIB6	*Dendrophyllia ehrenbergiana*
DIIb4	*Flabellum pavoninum**	DIIIg2	*Paracyathus confertus*	EIb7	*Dendrophyllia diaphana*
DIIb5	*Flabellum rubrum*	DIIIi1	*Sphenotrochus aurantiacus**	EId1	*Endopachys grayi**
DIIc1	*Monomyces* sp.	DIIIi2	*Sphenotrochus gilchristi**	EId1	*Endopachys grayi*
DIIIa2	*Caryophyllia capensis**	DIIIi3	*Sphenotrochus dentosusa sensu*	EIe1	*Heteropsammia aphrodes*
DIIIa3	*Caryophyllia arcuata*	DIIIK1	*Stephanocyathus (Acinocyathus) spiniger**	EIg1	*Rhizopsammia fusca*
DIIIa4	*Caryophyllia gigas sensu*	DIIIK2	*Stephanocyathus nobilis*	EIg2	*Rhizopsammia* sp. *sensu*
DIIIa4	*Caryophyllia gigas sensu*	EIa1	*Balanophyllia annae sensu*	EIg3	*Rhizopsammia nuda*
DIIIa4	*Caryophyllia gigas sensu*	EIa2	*Balanophyllia bairdiana*	ELB4	*Dendrophylliia coccinea*

Authors: Filander Z (DEA); Zibrowius H (Marine Station of Endoume, France); Cairns S (Smithsonian Institute, USA)

14. ORANGE RIVER ESTUARY BENTHIC COMMUNITY STRUCTURE DURING A BACK-FLOODING EVENT

Physical disturbances as a result of floods and drought are known to be a major determinant of the spatial and temporal dynamics of benthic habitat and associated biotic communities of rivers and estuaries. Altered river flows caused by prolonged droughts and construction of dams in the catchment can negatively impact on sediment structure downstream. Estuaries with unstable substrate tend to have low species diversity.

Historically, the Orange River estuary between South Africa and Namibia used to close during 2–4 out of every 10 years for weeks to months at a time. This usually occurred during the winter and spring months due to the combination of low-flows and storm waves building up the berm across the mouth. However, at least during the last 50 years, the mouth was kept open in most years ostensibly to protect mining infrastructure.

Recently, in April 2018, the mouth closed for the first time in 25 years due to prolonged low-flow conditions and stormy seas. Closure of the mouth resulted in a temporary increase of the water surface area and volume as the estuary back-flooded upstream (Figs 1, 2).

Benthic invertebrates were sampled in the estuary in March 2018, prior to the mouth closing and during the back-flooding that resulted from the April closure.

Figure 1: Launch site under normal conditions (left) and during the back-flooding event (right)

Figure 2: Upstream site under normal conditions (left) and during the back-flooding event (right)

A total of 14 species were recorded in the system, six of which were excluded from the analysis because they were collected in relatively low numbers. The low number of species that were found accords with the low biodiversity levels that characterise the West Coast relative to the East Coast. Further, because the Orange River estuary is river-dominated, the hydrological and chemical environments are highly variable and only highly tolerant species are likely to successfully colonise the substrate.

This may also account for why there was very little difference in community composition between samples from before and during the back-flood event. (Fig. 3). Polychaetes *Desdemona ornata* and *Ceratonereis keiskamma* dominated at both sampling occasions, and there was little change in the relative abundance of other species between the periods, although there was an increase in freshwater non-biting midges (Chironomidae family). The dominance of polychaetes and their tolerance of the changing conditions is related partly to their ability to burrow into the substrate to their preferred salinity with the added benefit that the probability of them being washed away is small.

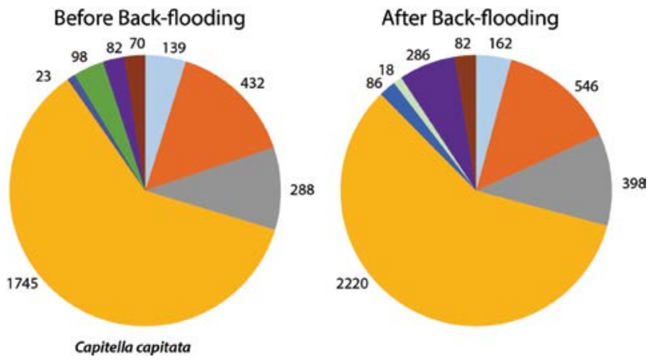

Figure 3: Dominant benthic invertebrates of the Orange River estuary before (March) and during the back-flooding event (April)

Author: J Nhleko (DEA)

Contributors: Bebe L, Mushanganyisi K (DEA); Erasmus C, Lamberth S, Williamson C (Department of Agriculture, Forestry and Fisheries)

15. ABUNDANCE ESTIMATES OF INDO-PACIFIC BOTTLENOSE DOLPHINS ALONG THE SOUTH COAST OF SOUTH AFRICA

The Indo-Pacific bottlenose dolphin *Tursiops aduncus* (Fig. 1) has been listed as 'Data Deficient' on the IUCN Red List of Threatened Species since this species was first assessed in 1996. In South Africa, the conservation status of the largest stock of this species, which occurs between False Bay in the Western Cape and Ifafa in KwaZulu-Natal, has been assessed as "Near-Threatened". This was based on known threats to the stock and a decline in abundance that was inferred though not established. One of the research priorities identified was further work to measure abundance and trends.

Figure 1: Indo-pacific bottlenose dolphins Tursiops aduncus

A study of the abundance of *T. aduncus* along a 145 km stretch of coastline on the South Coast (Fig. 2) was conducted using boat-based surveys during 2014–16. Survey effort totalled 662 hours. A photo-identification catalogue representing 817 identified individuals was the basis for mark-recapture modelling to estimate abundance. The large number of identified individuals in this study and the low re-sighting rates (28%) suggests *T. aduncus* from the study area are part of a much larger population. The selected open population estimate model (POPAN) provided an estimate of 2,295 individuals (95% CI: 1,157–4,553) for the entire study area.

For a portion of the study area, namely Plettenberg Bay, an abundance estimate had been obtained previously (2002–03). By resurveying this area in 2014–16, this study is the first in South Africa to measure a change in abundance between two time periods for this species. For the comparison it was necessary to employ a closed population model because the past estimate was based on such a model and the past data were not available for reanalysis. The comparison showed a 72.3% decrease in abundance between the estimates of the two periods, from 6,997 (95% CI: 5,230–9,492) in 2002–03 to 1,940 (95% CI: 1,448–2,600) for 2014–16. While use of a closed model on these data may not be ideal, the closed model estimate for the entire study area (1,940) was similar to that of the open model (2,295), supporting that the estimated change at Plettenberg Bay between the two periods based on closed models is dependable. The decline between the two periods was further supported by a decline in mean group size by 78% from 120 (range: 1–500) to 26 (range: 1–100) between the two periods.

While the driver(s) of the decline are not yet certain, *T. aduncus* is known to be vulnerable to multifarious anthropogenic pressures associated with their coastal distribution that could bring about shifts in behaviour or a population decline. In the study area such pressures include competition with fisheries, pollution, coastal development, increasing vessel traffic and associated disturbance (especially associated with boat-based ecotourism). The relatively low reproductive rate of this species aggravates the impacts. Precautionary measures or controls to reduce or mitigate disturbance to the population (e.g. areas where vessels are excluded or speed-limited) should therefore be considered. The results highlight the need for further research and monitoring in the area as well as the importance of assessing abundance changes at other sites to inform revision of the conservation status of *T. aduncus* in South Africa.

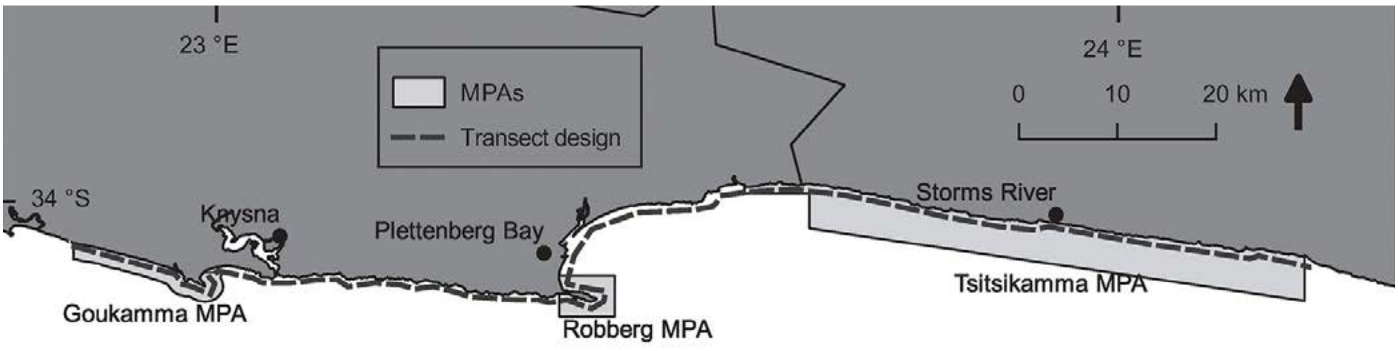

*Figure 2: Extent of the study area. River estuaries are indicated with the letters *A to *L and reefs with the symbol ***

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Contributors: Bouveroux T, Cockcroft V, Conry D, Pistorius PA (Nelson Mandela University)

16. DISTRIBUTION AND HABITAT USE OF INDO-PACIFIC BOTTLENOSE DOLPHINS ALONG THE SOUTH COAST OF SOUTH AFRICA

Studies of the distribution or movements of organisms are key for determining their habitat preferences and spatial needs. Such information can assist planners or managers in decision-making, e.g. with regard to prioritising areas for protection. For nearshore dolphin species such as the Indo-Pacific bottlenose dolphin *Tursiops aduncus*, which are susceptible to multifarious anthropogenic pressures associated with coastal areas (e.g. vessel traffic, coastal development, pollution), knowledge of spatial distribution and habitat preferences is especially relevant for conservation management.

The distribution and habitat use of *T. aduncus* in the Southern Cape was investigated in 2013 –16 using bi-monthly boat-based surveys, over a distance of 145 km between the Goukamma and Tsitsikamma marine protected areas (MPAs; Fig. 1). This area is characterised by having a diversity of habitat types (57% rocky, 27% sandy and 16% mixed coastline) and a network of well-established MPAs. Therefore it is suited for studying habitat utilisation and preferences of this species, taking into account the location of MPAs.

Survey effort totaled 6,239 km and 751 hours. Encounters (n = 200) occurred throughout the area but encounter rates were highest in Plettenberg Bay and the Goukamma MPA (Fig. 1), both of which are characterised by sandy bottoms and sheltered areas. With regard to habitat type, encounter rates were lowest in rocky and exposed areas, but groups in such locations were larger and usually travelling (Fig. 2).

Sandy substrates were the habitat type associated with non-travelling *T. aduncus* behaviours and therefore represent an important feature for *T. aduncus* along South Africa's South Coast. There was a relatively low association of *T. aduncus* groups with MPAs, except for a sandy area in the Goukamma MPA in particular, suggesting some mismatch between favourable *T. aduncus* habitat and habitat protection. Control of boat traffic in an area such as the northeastern section of Plettenberg Bay, which appeared to be a "hotspot" of dolphin occurrence, would reduce disturbance and benefit protection of *T. aduncus* outside of MPAs.

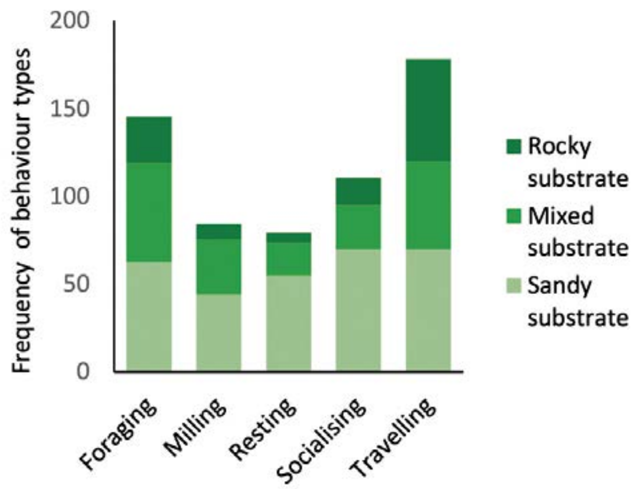

Figure 1: The encounter rate of T. aduncus *per 2 km² grid cell throughout the study area*

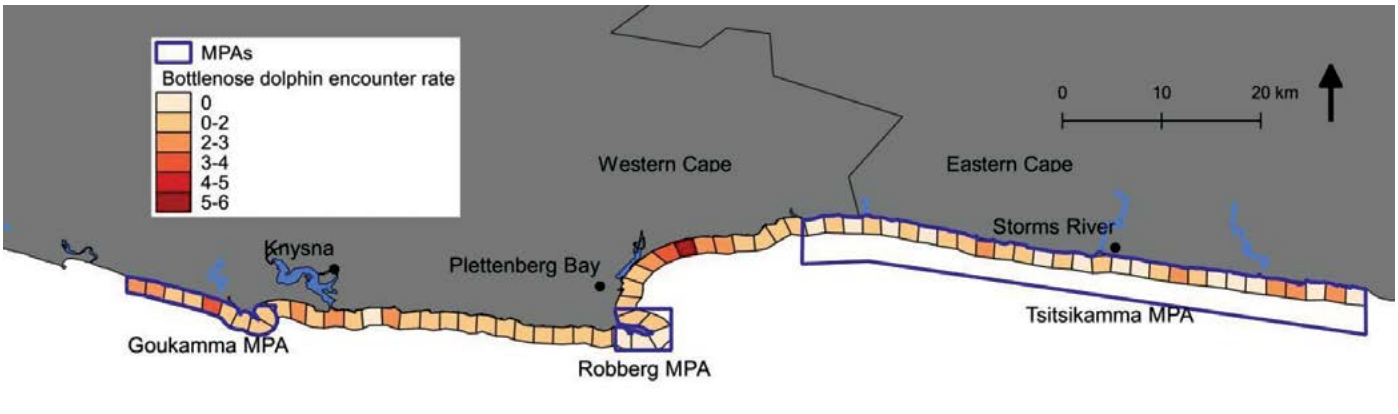

Figure 2: Frequency of behaviour types encountered per inshore benthic substrate type for T. aduncus *(standardised by the total coastal areas of each substrate type)*

Further information:

Vargas-Fonseca OA, Kirkman SP, Conry D, Rishworth GM et al. 2018. Distribution and habitat use of Indo-Pacific bottlenose dolphins Tursiops aduncus along the south coast of South Africa. African Journal of Marine Science 40: 439–450.

Authors: Vargas-Fonseca OA (Nelson Mandela University); Kirkman SP (DEA)

Contributors: Cockcroft V, Conry D, Pistorius PA, Rishworth G (Nelson Mandela University)

17. DIURNAL OCCURRENCE AND ACTIVITY PATTERNS OF TWO COASTAL DOLPHIN SPECIES

Concerns regarding their poor conservation status, declining numbers and vulnerability to multifarious human threats, have provided motivation for research on some of South Africa's coastal dolphin species. Visual surveys of these species are limited by daylight hours and weather conditions; an alternative or complementary approach is the use of acoustic surveys to detect dolphins underwater from their sounds. Passive Acoustic Monitoring (PAM) enables automated data collection around the clock as well as in weather conditions that limit or prevent the use of traditional visual surveys. This study made use of PAM to assess the diurnal occurrence and activity patterns of the Indian Ocean humpback dolphin *Sousa plumbea* (Endangered) and the Indo-Pacific bottlenose dolphin *Tursiops aduncus* (Near-threatened) in Plettenberg Bay, South Africa.

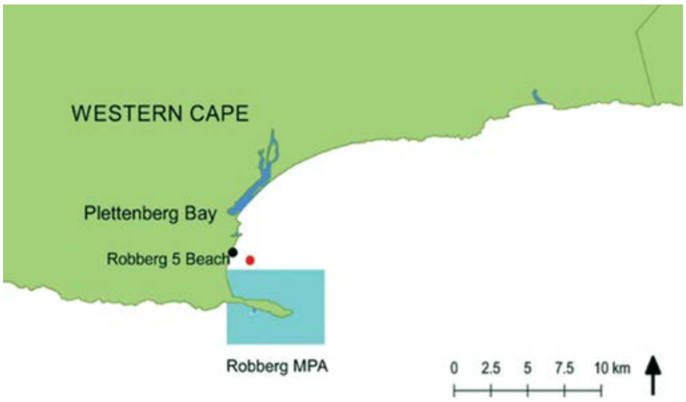

Figure 1: Map of Plettenberg Bay showing Robberg Marine Protected Area (light blue), location of the hydrophones (red dot) and location of land-based observations (black dot)

Acoustic recordings were collected using moored hydrophones from 2015–2017, in the vicinity of the Robberg Marine Protected Area (Fig. 1). Automatic detector algorithms were used to analyze the acoustic recordings and an automatic detection protocol was developed based on the performance of the algorithms. Patterns of occurrence and behaviour of dolphins were investigated based on the variation in detection rates of echolocation clicks (used during feeding) and whistles (used while travelling and socializing) between different periods of the day.

A significantly higher detection rate of clicks suggests that the dolphins frequenting the study area were mainly feeding groups. This was also supported by visual observations, conducted in the vicinity of the hydrophones during a subset of recording days, which showed a predominance of behaviour that was classified either as "foraging" or as "travelling with foraging" (Fig. 2).

Acoustic detection rates showed a diel pattern of dolphin presence with higher night-time than day-time occurrence and a peak in activity at dusk (Fig. 3). The higher night-time activity may be related to the crepuscular behaviour and distribution of their prey. For daylight hours, higher afternoon detection rates than during the morning were consistent with the findings of visual observations (Fig. 2c). Low morning detection rates from both visual observations and acoustic recordings, suggest that there has been a change in daily patterns compared with 50 years ago, when observations indicated a peak in occurrence during the morning. Such a change may be influenced by modified prey behaviour or distribution, or other factors (e.g. avoidance of human disturbance).

Further research and monitoring using PAM could potentially assist to better understand the drivers of dolphin occurrence and activity patterns in the area, and inform future policy decisions on dolphin vulnerability and the need for conservation measures..

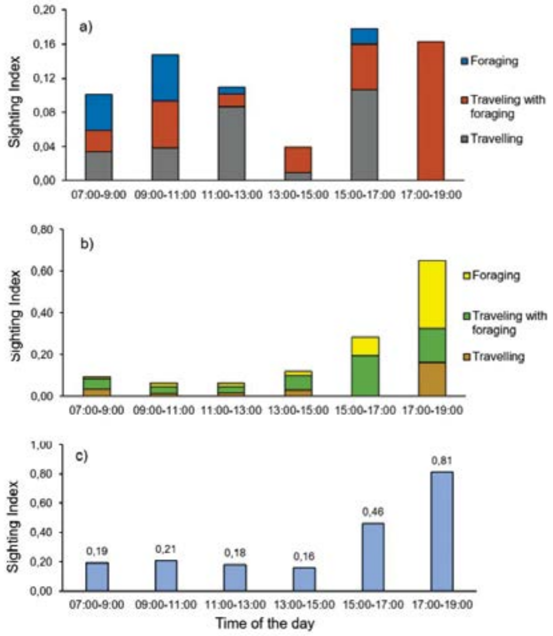

Figure 2: Diurnal occurrence patterns of dolphins, where a) shows behavioural patterns of S. plumbea*, b) shows the behavioural patterns of* T. aduncus *and c) represents occurrence patterns of the two species combined*

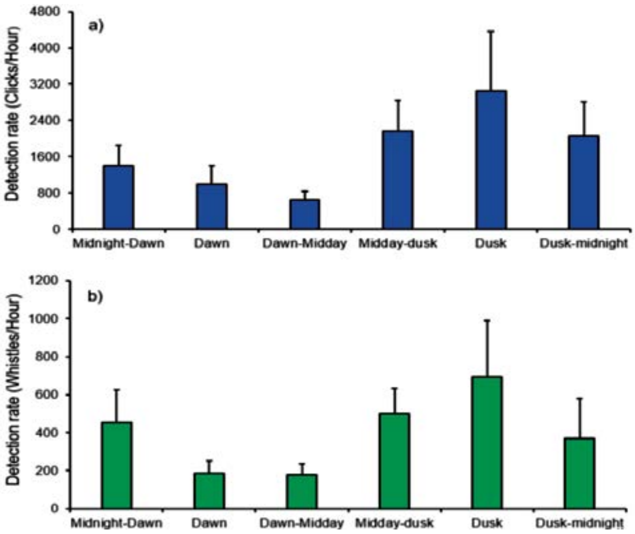

Figure 3: Mean detection rates (+ std. error) of (a) echolocation clicks and (b) whistles of dolphins, for six diurnal periods

Authors: Hlati K, Kirkman SP (DEA)

Contributors: Anders D (DEA); Lin H (Academia Sinica, Taiwan); Latha G, Mahanty MM (National Institute of Ocean Technology, India); Pistorius PA, Vargas-Fonseca OA (Nelson Mandela University)

18. CARBONATE CHEMISTRY OFF THE COASTS OF MOZAMBIQUE AND TANZANIA

Studies of the ocean carbonate system distribution are important for understanding the change in the global carbon cycle and the chemistry of seawater. The escalating reduction in the pH of seawater due to increased uptake of atmospheric CO_2 by the ocean, referred to as ocean acidification, and associated changes in the carbonate chemistry, may have negative impacts on marine life. For example, ocean acidification reduces the ability of organisms such as corals, shelled molluscs, pteropods and foraminiferans to build strong shells and skeletons. This report focuses on the distribution of the carbonate chemistry off the coasts of Mozambique and Tanzania during IIOE-2 surveys in November 2017 and June 2018 respectively. The aim was to map both horizontal and vertical variability in key chemical parameters, and to investigate the implications for ocean acidification.

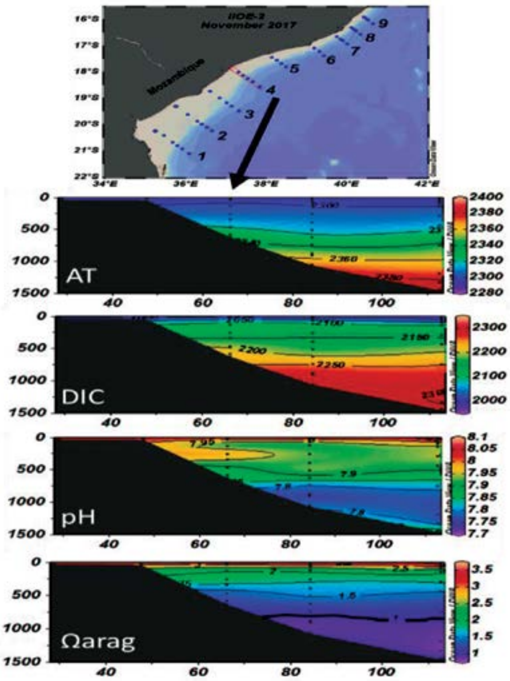

Figure 1: Map of the sampled area off Mozambique and the vertical distributions of total alkalinity (AT), dissolved inorganic carbon (DIC), pH and aragonite saturation state (Ωarag) along Line 4 during November 2017. The axis on the left represents the depth from surface to the sea floor and the units of measurement are on the right axis (AT - µmol/kg, DIC - µmol/kg). Black dots show the depths where water samples were taken

Surface waters

Dissolved inorganic carbon (DIC) in surface waters (within the upper 30 m) off both Mozambique and Tanzania ranged from 1,968–2,084 µmol/kg, whereas the total alkalinity (AT) ranged from 2,298–2,356 µmol/kg and partial pressure of CO_2 (pCO_2) ranged from 352–717 µatm. The pH ranged from 7.82-8.08, and aragonite saturation state (Ωarag) ranged from 2.39–3.61. On average, surface DIC was 2,007 ± 20.25 µmol/kg; AT was 2,315 ± 9.39 µmol/kg; pCO_2 was 414 ± 55.9 µatm; pH was 8.03 ± 0.04; and Ωarag was 3.40 ± 0.19.

Intermediate waters

DIC in intermediate waters (the layer between the surface and bottom waters) off both Mozambique and Tanzania ranged from 1,982–2,289 µmol/kg with an average of 2,106 ± 80.98 µmol/kg, whereas the AT ranged from 2,298–2,362 µmol/kg with an average of 2,317 ± 11.32 µmol/kg. The pCO_2 ranged 300–1229 µatm with an average of 504 ± 105 µatm; pH ranged from 7.60–8.14 with an average of 7.95 ± 0.09; and Ωarag ranged from 0.86–3.61 with an average of 2.30 ± 0.84.

Bottom waters

In bottom waters (the layer between the seabed and 100 m above the seabed, increasing to 500 m above the seabed offshore) off both Mozambique and Tanzania, DIC ranged from 2,006–2,298 µmol/kg with an average value of 2,204 ± 95.84 µmol/kg, whereas AT ranged from 2,297–2,385 µmol/kg with an average value of 2,342 ± 22,61 µmol/kg. The pCO_2 in bottom waters ranged from 385–797 µatm with an average value of 591 ± 118.90 µatm. The pH ranged from 7.72-8.05 with an average value of 7.87 ± 0.10; and Ωarag ranged from 0.79–3.44 with an average value of 1.50 ± 0.87.

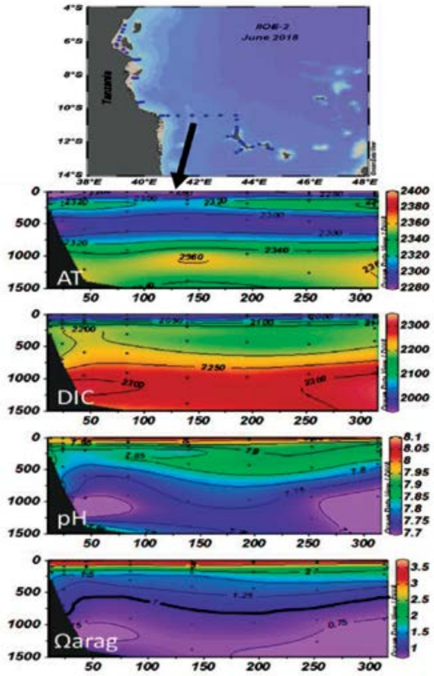

Figure 2: Map of sampled area off Tanzania and the vertical distributions of AT, DIC, pH and Ωarag during June 2018. The axis on the left represents the depth from surface to the sea floor and the units of measurement are on the right axis (AT - µmol/kg, DIC - µmol/kg). Black dots show the depths where water samples were taken

We observed high DIC waters with low pH and low Ωarag < 1 below 1000 m depth off the southern part of Mozambique and below 600 m depth off northern Mozambique and Tanzania (Figs 1 and 2). The southern part of Mozambique has an extensive area of shallow water whereas the northern part has a narrow coastline, with upwelling occurring along the northern shelf edge. Upwelling of low pH and low Ωarag (< 1) waters into the near-shore environment may pose a threat to organisms sensitive to these acidic conditions. As carbonate chemistry data is lacking in this region, more work needs to be done to understand the seasonal variations in the distribution of the carbonate parameters. Therefore, we suggest that temporal variability in carbonate chemistry distribution and the upwelling of aragonite under-saturated waters in this region should be monitored.

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Contributors: Kiviets G, Mdokwana BW, Mlambo K, Mpafa Z, Siswana K, Tutt G, Vena K, (DEA); Nohayi L (Council for Scientific and Industrial Research); Suleiman O (Institute of Marine Sciences, Zanzibar); Bustani HO (National Institute of Fisheries Research, Mozambique); El-Shorbagi E (National Institute of Oceanography and Fisheries, Egypt); Olubunmi N (Nigerian Institute for Oceanography and Marine Research)

19. ZOOPLANKTON BIOMASS ON THE SOFALA BANK, MOZAMBIQUE

There have been relatively few zooplankton studies conducted off the coast of Mozambique, although there has been interest in recent years in ecosystem functioning related to mesoscale eddies in the Mozambique Channel. Data from phytoplankton studies indicate that the most productive areas over the Mozambican shelf are the Delagoa Bight in the south, the central Sofala Bank which is influenced by seasonal nutrient input from the Zambezi delta, and Angoche in the north.

Zooplankton sampling was conducted at 44 stations over the Sofala Bank during the IIOE-2 survey on the *SA Agulhas II* in October 2017. Mesozooplankton samples were collected from the upper water column (≤ 200 m depth) using a 200 µm Bongo net, and the neuston community associated with the surface of the ocean was sampled using a 200 µm neuston net (Fig. 1).Mean mesozooplankton biovolume (a proxy for biomass) over the Sofala Bank (Beira to Angoche) was 0.19 ml m^{-3}, ranging from 0.04 to 0.95 ml m^{-3}. Greatest concentrations were located to the south (0.95 ml m^{-3}) and north (0.82 ml m^{-3}) of the Zambezi delta, in water depths of < 50m (Fig. 2). The southern maximum was associated with a region of relatively warm (26.4°C) and fresh (34.9 PSU) water presumably related to river outflow.

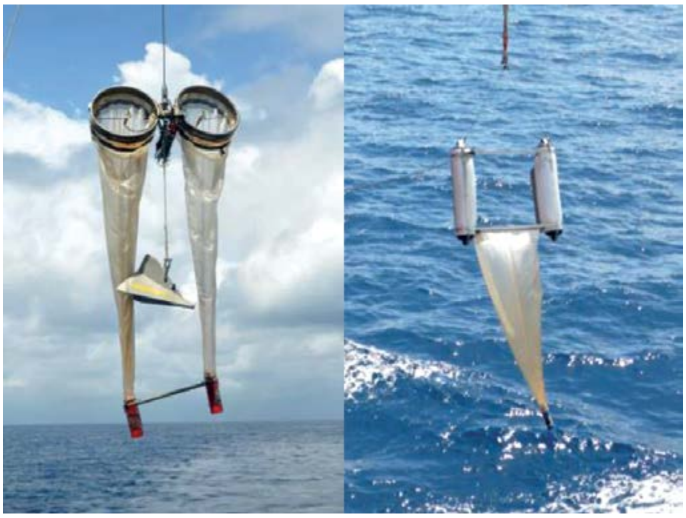

Figure 1: Bongo nets (left) and neuston net (right) used to collect epipelagic and neustonic zooplankton, respectively

Mean neuston biovolume was 0.30 ml m^{-3}, and ranged from 0.44 to 0.99 ml m^{-3}. Greatest concentrations were located over the southern part of the Sofala Bank between Beira and the Zambezi River (Fig. 3), with a secondary peak south of Angoche, associated with cool (< 25°C) water with elevated chlorophyll *a* (> 1 mg m^{-3}). Biovolume was greater but not significantly so at night (0.32 ml m^{-3}) compared to during the day (0.28 ml m^{-3}).

Microscope analysis of the zooplankton and neuston samples will be conducted to explore the species composition of these two planktonic communities. Interest in the neuston is growing due to its role as a nursery for larval fish and rich food source for larger fish and turtles, but with the concomitant threats of accumulating plastic debris, oils and environmental contaminants.

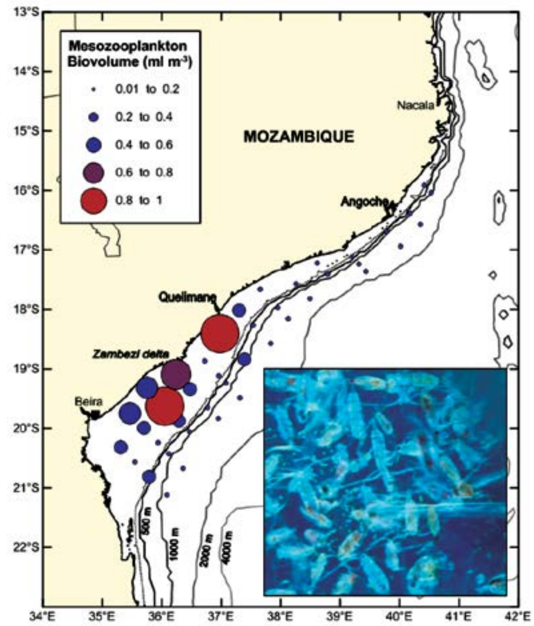

Figure 2: Mesozooplankton biovolume off the Mozambican coast

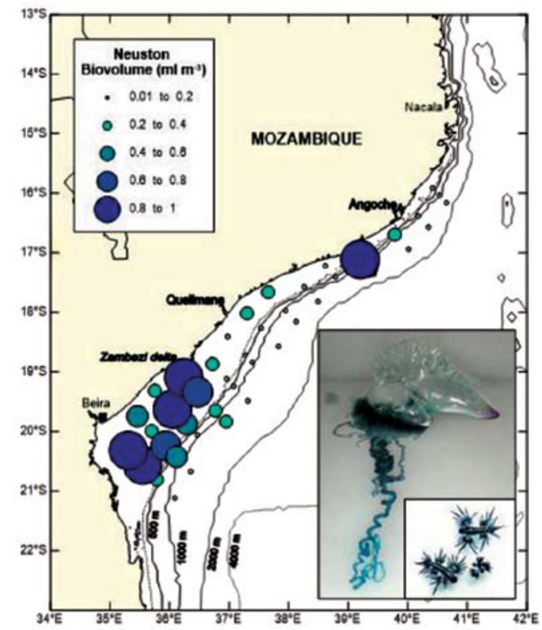

Figure 3: Neuston biovolume off the Mozambican coast

Authors: Huggett J (DEA); Thibault D (Institute for Research and Development & Aix-Marseille University, France); Malauene B (National Institute of Fisheries Research, Mozambique)

Contributors: Lamont T, Mdazuka Y, van der Poel J, Verheye H, Worship M (DEA); Chioze C, Taque M (National Institute of Fisheries Research, Mozambique); le Bozac C (University of Bordeaux, France); Daling R, Perold V (University of Cape Town); Iraba N, Mang'ena J (University of Dar es Salaam, Tanzania); Moodaley D (University of the Western Cape)

20. ASSESSING THE DENSITY AND DISTRIBUTION OF MESOPLASTICS OFF THE COAST OF EAST AFRICA

The distribution and abundance of mesoplastics floating at sea off the east coast of Africa was assessed as part of a larger project on plastic pollution in the region. This is an area with very little information on floating plastics and other debris. Samples were collected during the IIOE-2 research cruise in October–November 2017 aboard the *SA Agulhas II*. The sampling area was split into two regions: (1) the Mozambique Channel (n=44 stations) and (2) the Tanzanian coast (n=16 stations). At each station a Neuston net (200 micron mesh) was towed for 15 minutes at 2 knots parallel to the ship's track (Fig. 1). After retrieval, the net was thoroughly rinsed from the outside, and the cod-end with the sample was retrieved. Samples were sorted to separate all visible plastic items (Fig. 2). The density of mesoplastics per station was expressed as the number of items found per area trawled (km^2).

Figure 1: Neuston net deployment off the SA Agulhas II

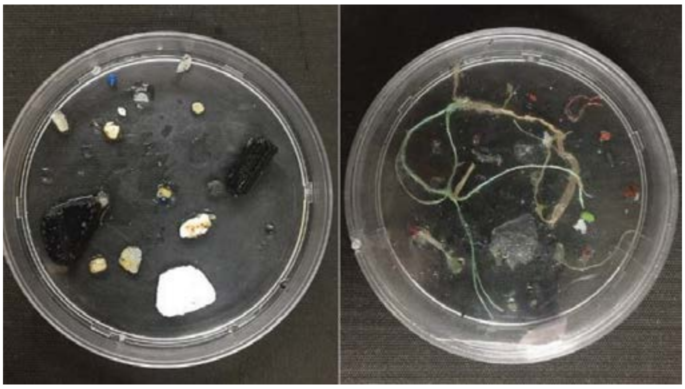

Figure 2: Examples of typical secondary user fragment pieces (left) and discarded fishing gear (right) sampled with the neuston net

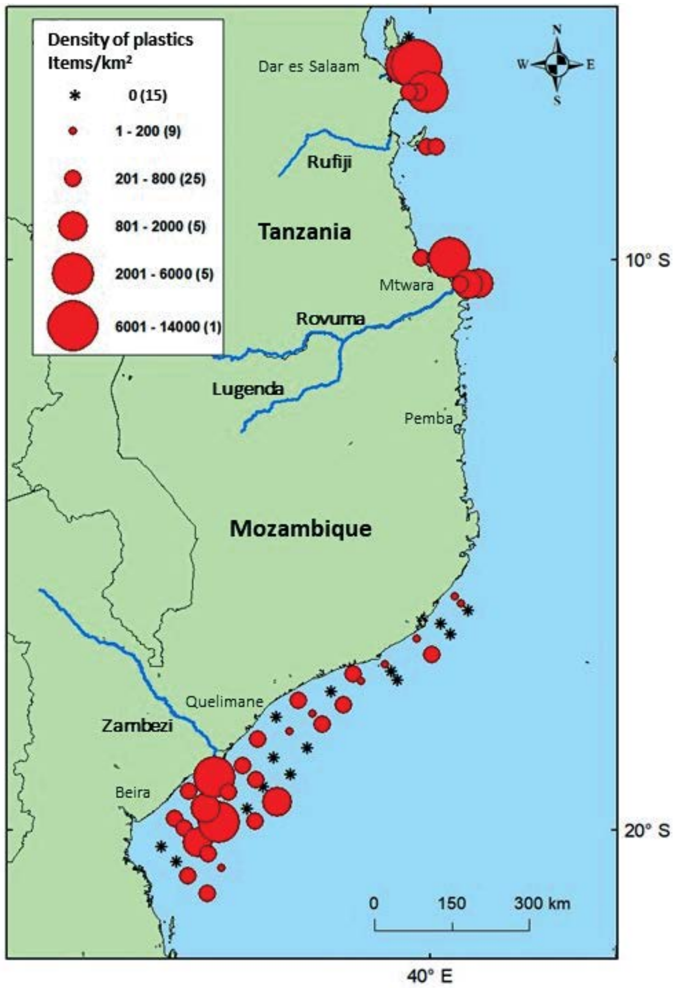

Figure 3: Map of sampling stations showing the density (items/km^2) of floating mesoplastics. Major rivers are indicated by blue lines; black stars = no plastic collected

Mesoplastics densities were greatest close to major river mouths (Zambezi and Rovuma) and off Dar es Salaam, the main urban centre in the sampling region (Fig. 3).

The average density of floating mesoplastics in the Mozambique Channel was 482 (± 149 std. error) items per km^2 whereas for Tanzania it was nearly fourfold greater at 1,966 (± 841 std. error) items per km^2 (Fig. 3). This is the first study to systematically assess the density and distribution of floating mesoplastics in these areas and will provide baseline data for future marine pollution monitoring research in the Western Indian Ocean. By combining these results with observations of macro-debris and microplastics, we can estimate the total abundance of plastic in these waters.

Authors: Perold V, Ryan PG (University of Cape Town)

Contributors: Taque M (Ministry of Sea, Inland Waters and Fisheries, Mozambique); Mang'ena J (University of Dar es Salaam, Tanzania)

21. BENTHIC INVERTEBRATE COMMUNITIES IN THE WESTERN INDIAN OCEAN

The Indo-Pacific is the largest marine biome on the planet, with high species diversity and endemism from coastal seas to the deep ocean. Large gaps still exist in our overall understanding of species diversity and distribution patterns in this biome. For example, the full scope of inshore and offshore benthic invertebrate communities remains largely unexplored. During the second IIOE-2 survey on the *SA Agulhas* II in 2018, the DEA, together with institutes within the Western Indian Ocean (WIO) region and beyond, set out to explore coastal and deep-sea benthos in Tanzania and the Comoros (Fig.1).

Figure 1: A total of 18 stations were sampled in Tanzania (TANZ) and nine in the Comoros (COM)

In Tanzania, preliminary results showed significant differences in benthic invertebrate communities according to depth (R = 0.537, p = 0.005, ANOSIM; Fig. 2). These same species assemblages that divided into two distinct depth zones, also differed significantly with substrate type (R = 0.633, p = 0.002, ANOSIM; Fig. 3).

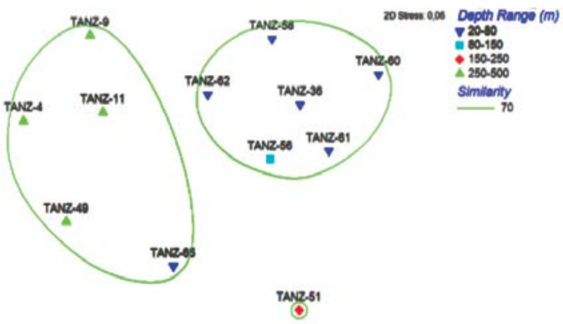

Figure 2: Non-metric multidimensional scaling plot of stations according to depth

Two habitat types each with their own unique features are identified (Fig. 4) as: (1) a shallow habitat type mostly between 20–80 m, with coarse sand, shell fragments and a diverse community of reef and filter-feeding organisms, and (2) an offshore mud/silt habitat mostly between 250–500 m where the benthos is relatively species poor and scavengers/detritivores are common.

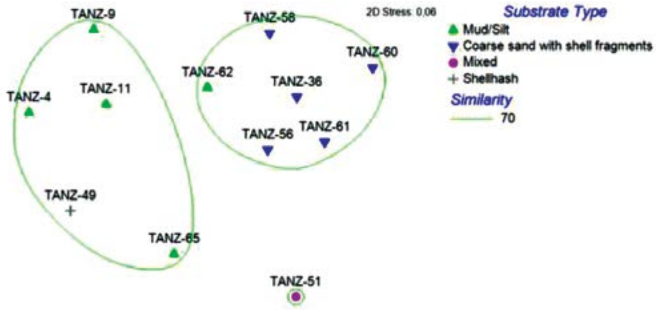

Figure 3: Non-metric multidimensional scaling plot of stations according to substrate type

Novel footage (Fig. 5) inside the national park of Moheli, the local marine protected area in the Comoros, showed the presence of diverse species assemblages including rhodolith beds, corals, giant sea-fans and sponges (e.g. *Xestospongia* sp.).

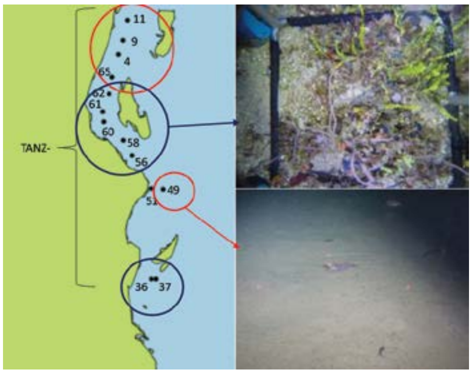

Figure 4: Habitat type 1 (20–80 m) in blue and habitat type 2 (250–500 m) in red

IIOE-2 proposed benthic biodiversity products:

- Comprehensive species lists of inshore and offshore benthos,
- Improved understanding of the spatial aspects of benthos in relation to processes influencing distribution and abundance of taxa,
- An integrated habitat map, and
- Sound and rewarding collaborations with partners and institutes within the WIO.

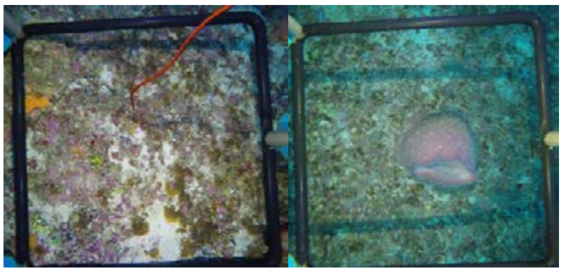

Figure 5: Jump camera footage at 74 m

Author: Haupt T (DEA)

Contributors: Janson L, Samaai T, Snyders L (DEA); Nadjim A, Kassim A, Moustarchid B, Abdoulatuf T (University of Comoros, Comoros); Muhando C, Iraba N, Kithakeni T Ndaro S (University of Dar es Salaam, Tanzania); Mokoele M, Ndibo S (University of Fort Hare); Payne R (University of the Western Cape)

22. AN URGENT QUEST TO REPLACE THE AGEING MARINE RESEARCH VESSEL *ALGOA*

The Research Vessel (RV) *Algoa* has been in existence for almost 47 years, since being commissioned as a French fish trawling vessel in 1972. The normal lifespan of a research ship to be functional, efficient and cost-effective is estimated at 30–35 years. However, the *RV Algoa* has surpassed the shipping sector expectations and looks set to establish a new longevity record for a vessel that has been used to conduct both oceanographic and fisheries research. Some highlights of the important work conducted onboard the *RV Algoa* for South Africa are inshore and offshore oceanographic research surveys, and marine biodiversity surveys that have contributed to the classification of seabed habitats. Such information has contributed to the refining of boundaries and zonation for some of the 20 proposed marine protected areas that were recently approved by National Cabinet, and which will expand the extent of South Africa's exclusive economic zone that is currently under protection from < 0.05% to approximately 5%.

The country has been dependent on the use of the *RV Algoa* to undertake its planned annual oceanographic research work, as reflected in several of DEA's business and strategic plan targets. The days at sea required, if all the needs are accounted for, can range between 180 and 240 days annually. During the 2018-2019 period, the vessel was at sea for over 180 days, notwithstanding temporary dry-docking and ad hoc repairs that were required.

Through presentations at Operation Phakisa Labs and at various other fora, DEA and other line departments including the Department of Mineral Resources (DMR), the Department of Agriculture, Forestry and Fisheries (DAFF) and the Department of Science and Technology (DST) have being lobbying the need to replace both the *RV Algoa* and another ageing and ailing marine research vessel, the Fisheries Research Ship (FRS) *Africana*. The estimated cost to replace both vessels is R3 billion according to 2019 rates.

Prerequisites are that the replacement vessels must be manufactured locally, in the interests of supporting South Africa's Ocean Economy and related sectors, and to support job creation and the development of small and medium enterprises in the country.

At the moment, DEA is preparing to present to the Inter-ministerial Committee on this project. Their endorsement and support for the proposal will ensure that it is elevated to the highest level in the government structure, including a proposal to the National Treasury. If successful, DEA will present the request for replacing the *RV Algoa* to National Treasury, who in turn will provide guidance on various funding models towards the replacement of this national asset. If finally approved, the ship replacement process will likely take three years to complete.

Author: Gulekana M (DEA)

OUTPUTS FOR 2018

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