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This supplement features the discussions, research, and solutions emanating from two major international ocean sciences conference held at Nelson Mandela University, Port Elizabeth, in March this year, namely the Second International Indian Ocean Expedition (IIO-E2) and the South Africa–Norway Research Co-operation on Blue Economy, Climate Change, the Environment and Sustainable Energy (SANOCEAN).

Mouth of the Sundays River Estuary, Eastern Cape. Photo: Dr Tor F. Næsje.

Collective Ocean Action

Professor Sibongile Muthwa

We have reached the hour when we need to know what is being done to conserve our oceans and to ensure that the so-called blue economy is sustainably developed. To achieve this we need new modes of thought and novel solutions that engage all our communities, locally and globally, and address poverty and inequality.

As we know, the oceans cover 70% of our planet and are a critical source of oxygen, food, marine resources, employment, and subsistence. We have lost more than 40% of the biodiversity in the ocean in the past 40 years, and the latest International Panel on Climate Change report shows that since the 1970s about 93% of the excess heat from greenhouse gas emissions has been absorbed by the oceans. At the same time the oceans are under pressure from unsustainable resource extraction. This is a crisis call for collective action.

> Solutions for the conservation and sustainable development of the oceans are urgently required

What is encouraging is that a growing network of outstanding research and innovation initiatives in South Africa, the continent and internationally are collaborating to better understand this vast body of water and to implement solutions for its conservation and sustainable development.

Contributing to this, two pivotal international ocean sciences conferences were held at Nelson Mandela University in Port Elizabeth in March this year.

The first of these was the Second International Indian Ocean Expedition (IIO-E2). Hosted for the first time in Africa, the conference brought together partners from throughout the world, including the major ocean sciences nations. IIO-E2 is the single largest effort to study the Indian Ocean in a transdisciplinary manner, in order to advance our understanding and enable informed decision-making.

The second conference was Sanocean, the South Africa-Norway Research Co-operation on Blue Economy, Climate Change, the Environment and Sustainable Energy. The long-term programmes in this partnership enhance the knowledge base for policies and decisions for sustainable development in the areas of oceans and ocean space (the blue economy), environment (with emphasis on oceans and pollution), climate change and sustainable energy in South Africa and Norway.

Nelson Mandela University is positioning itself as the hub for ocean sciences in Africa and the Western Indian Ocean: *https://oceansciences.mandela.ac.za/*. As a coastal university we partner with the national and international marine and maritime research community. British high commissioner Nigel Casey and Norwegian ambassador Astrid Helle are good friends of Nelson Mandela University and attended the respective conferences.

Our countries partner on several key marine and maritime programmes and research chairs that are discussed in this publication, as are our collaborations with other coastal countries in Africa and globally, other South African universities, the Nelson Mandela Bay Metro, government and key industry players.

Our faculties and dedicated Ocean Sciences Campus (the first of its kind in South Africa) offer a range of qualifications and programmes to support ocean sciences development, conservation and a sustainable, well-managed blue economy.

Our Faculty of Law's FishFORCE programme works closely with Norway in combatting the major problem of organised fisheries crime *https://law.mandela.ac.za/*. The university collaborates with several Norwegian universities and institutions on ocean research, innovation and sustainable industry for the blue economy.

We are also positioning ourselves as a maritime hub. Last year the Faculty of Engineering, Built Environment and Information Technology (EBEIT) launched a Marine Engineering degree, and this year we launched our Marine Robotics Unit. *https://ebeit.mandela.ac.za/*

We welcome the United Nations declaration of the Decade of Ocean Science for Sustainable Development from 2021 to 2030. It will hopefully be the largest driver ever to protect the oceans, address ocean warming, use the space sustainably, and bridge science, policy and practice.

With South Africa's coastline spanning about 3 000km, bordered by three oceans — the Atlantic, Southern and Indian oceans — we are perfectly placed to contribute to and benefit from the much-anticipated "blue decade".

Professor Sibongile Muthwa is vice chancellor of Nelson Mandela University

Reception area of the Ocean Sciences Campus, Nelson Mandela University. Photos: Supplied

Professor Sibongile Muthwa is vice chancellor of Nelson Mandela Univerty. Photos: Supplied

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Ocean Sciences

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No single nation has the capacity

Heather Dugmore

"The reality is that no single nation has the resources, capacity or mandate to undertake all of the research and effort needed to resolve the questions and issues facing our oceans, particularly the least researched Indian Ocean," said Dr Nick D'Adamo at the Second International Indian Ocean Expedition (IIOE-2) conference held at Nelson Mandela University in March this year.

D'Adamo is head of the Perth Programme Office of Unesco's Intergovernmental Oceanographic Commission (IOC) and director of the Australian node of the IIOE-2 joint project office. The IIOE-2's mission statement is "to advance our understanding of the Indian Ocean and its role in the Earth System in order to enable informed decisions in support of sustainable development and the wellbeing of humankind".

Countries worldwide urgently need to join forces to resolve the global warming and sustainability issues affecting the entire Indian Ocean — a region with a population of over three billion. This includes researching the ocean's structure and currents and addressing its warming, changing anatomy, increasing acidification, the stress on its fisheries, changes in its oxygen levels, rapid increases in industrial usage, including marine mining, prospecting and much more.

Dr Nick D'Adamo, director of the Australian node of the IIOE-2 joint project office. Photo: Supplied

A gateway ocean

D'Adamo explained the Indian Ocean's global earth role. "It's a pathway ocean for global flows, and a gateway ocean that plays a pivotal role in the great ocean 'conveyor belt'. The Indian Ocean's surface temperature idiosyncrasies have a profound effect on weather patterns, which affect countries far and wide, including China, Japan, the whole of Africa, northern and western Asia, and the Pacific."

He added that the Indian Ocean has become an increasingly important transport route for trade and geopolitical reasons, and many more countries are bringing their scientific interest to bear on the Indian Ocean because of these geopolitically strategic imperatives.

Ocean's GDP is at least US$2.4-trillion

A 2015 Worldwide Fund for Nature (WWF) report states: "Goods and services from coastal and marine environments amount to about $2.5-trillion each year – that would put the ocean as the seventh largest economy in the world, if put into terms of Gross Domestic Product."

But the report adds that these goods and services are dwindling fast: "More than two-thirds of the annual value of the global ocean relies on healthy conditions to maintain its current output. However, habitat destruction, overfishing, pollution, and climate change are endangering this economic engine and the security and livelihoods it supports. Marine resources are in a rapid decline and our oceans are changing faster than we have ever seen before."

> 'The oceans are a global savings account from which we keep making only withdrawals'

"The oceans are our 'natural capital' — a global savings account from which we keep making only withdrawals," said Brad Ack, senior vice president for oceans at WWF. "To continue this pattern leads to one place: bankruptcy. It is time for significant reinvestment and protection of this global commons."

Big stakes in the Indian Ocean

D'Adamo elaborated on the underplayed dependence on the Indian Ocean and blue economy of so many countries, including South Africa, which has large stakes in the Indian Ocean, and how countries need to increase the emphasis in developing a comprehensive conservation, marine spatial planning and economic strategy.

"Collective ocean observations and research is essential to predict the consequences of climate change, and to design mitigation strategies for the oceans, which play an overarching role in what happens to the planet," he added.

UN Decade of Ocean Science

This collective action is a key goal of the United Nations Decade of Ocean Science for Sustainable Development (2021–2030), coordinated by Unesco's Intergovernmental Oceanographic Commission.

One of the largest ocean science focuses in history, it will enhance and even transform elements of oceanography as a driver to bring together nations to understand and protect the oceans, and to use their space sustainably, bridging science and policy. For the first time, the global ocean community will collaborate in planning the next 10 years in ocean science and technology in order to deliver "the ocean we need for the future we want".

For more information: ***ioc.unesco.org. https://en.unesco.org/ocean-decade***

The IIOE-2 conference brought together the "Big Five" committees that play a significant role in steering Indian ocean science endeavours:

- IIOE-2 Steering Committee
- Indian Ocean Global Ocean Observing System (IOGOOS)
- Indian Ocean Observing System (IndOOS)
- Indian Ocean Research Programme (IORP)
- Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER)

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International Indian Ocean expedition

In the 1960s, Australia made a significant contribution to the first International Indian Ocean Expedition through repeated voyages along the 110°East meridian in the southeast Indian Ocean. Now, nearly six decades later, a major voyage is underway to repeat this 110°East meridian line voyage as part of the second International Indian Ocean Expedition (IIOE-2).

"From May 13 to June 14 2019 a multi-institutional team of 30 oceanographers from around the world will headed offshore from Fremantle on board the 93m Australian Research Vessel Investigator. "We will be studying the oceanography of the southeast Indian Ocean," said Lynnath Beckley, Professor of Marine Science at Murdoch University, Perth, Western Australia, who is originally from Port Elizabeth and an alumna of the University of Port Elizabeth, now Nelson Mandela University.

Beckley is leading the multi-national study. "We'll travel about 6 500km from temperate areas through to the subtropics and tropics, sampling a whole range of water masses, 550km away from the west Australian coast.

"On the month-long voyage we will repeat the 110°East line to examine multi-decadal changes in the physics, chemistry and biology of the water column, investigate microbes, biogeochemistry and nitrogen sources, and study the pelagic food web from plankton through to the little-understood mesopelagic lantern fish.

"Lantern fish are the 'sardines' of the open ocean. About 10cm in length, they occur in the deep, dark waters where sunlight does not penetrate, but they rise towards the surface waters at night to feed. They are highly abundant and there are about 250 different species of them, with an estimated global biomass of 10 000 million tonnes. They are an extremely important component of the marine food web, but we know very little about their ecology," said Beckley.

Prof Lynnath Beckley and Investigator. Photo: Supplied

This will be part of the research, as will all sorts of other research missions such as conducting acoustic surveys of whales.

The May/June 2019 RV Investigator voyage can be tracked on

https://iioe-2.incois.gov.in/ website, where there will be updated news every day.

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Big thinking, big science

Prof Mike Roberts and ecoSUB - a new generation marine research robot. Photo: Supplied

Heather Dugmore

What is Africa doing about its oceans?

The Western Indian Ocean (WIO) region, extending up the eastern coast of Africa, has the most serious food security problem on the planet.

It is estimated that 60 million people in the WIO region directly depend on the ocean for their livelihoods at a time when the indications are that the WIO is warming faster than the world's other oceans, which impacts all levels of the marine food web. Overfishing, destructive fishing practices and high levels of pollution are causing the WIO marine environment to deteriorate further.

What is Africa doing to address this?

"We are pursuing intensive research to understand and address the key questions of what sustains marine food security, what are the underpinning ecosystems and how do they function in this era of climate change and changing global oceans," said marine specialist scientist Professor Mike Roberts, who heads the South African Research Chairs Initiative in Ocean Science and Marine Food Security.

"At the same time we are upscaling the number of South African, African and international scientists, PhDs and postdoctoral fellows pursuing pioneering ocean sciences research in South Africa and the WIO region."

Launched in May 2016, the chair is jointly hosted by Nelson Mandela University in Port Elizabeth, the University of Southampton and the Southampton-based National Oceanography Centre — the United Kingdom's leading marine science research and technology institutions.

All the way up the food chain

Roberts and his team's Western Indian Ocean Upwelling Research Initiative is a flagship project of the Second International Indian Ocean Expedition (IIOE-2).

Upwelling, he explains, is the upward movement of deep, cold, nutrient-rich water to the ocean surface, encouraging the growth of phytoplankton (microplants which form the base of the marine food web), which ultimately provides energy all the way up to the top marine predators. As the planet's climate changes, so does the ocean's upwelling system, affecting marine food security in the WIO.

Transdisciplinary research approach

"Researching this requires a transdisciplinary approach, investigating physical oceanography, biogeochemistry, plankton, trophic ecology, fisheries and food resources, and quantified by end-to-end ecosystem and socioeconomic modelling," said Roberts. "It further requires the development and use of advanced — and costly — ocean-atmospheric computer models and big data facilities."

Because Africa does not have these resources, Roberts' chair has developed the Innovation Bridge-Regional Hub approach. It builds strong, formal partnerships between top institutions in Africa and top, well-resourced institutions in the global north. "Through this alliance," Roberts explained, "we can increase southern hemisphere research capacity and critical mass to tackle developmental and ocean science challenges that are equally challenging for northern institutions, as the Indian Ocean is the least researched and understood in the world."

The innovation bridge will have a continuous flow of people and research between the global north and Africa, with regional projects extending from South Africa all the way up Africa's eastern coastline. The Ocean Science Campus at Nelson Mandela University, in partnership with Rhodes University — which brings fisheries science into the mix — forms the principal southern footprint of the bridge.

"Nelson Mandela University, with its African partner institutions, is focusing on growing the postgraduate ocean sciences pipeline to over 100 students, and we already have 50 master's and PhD students registered," said Roberts. A number of these postgraduate students have already spent time at the University of Southampton and the National Oceanography Centre to acquire specialist technology skills.

Two major ocean sciences case studies

Through the South African Research Chairs Initiative Chair in Ocean Science and Marine Food Security, Professor Roberts has secured R160-million from the United Kingdom's Global Challenges Research Fund SOLSTICE-WIO programme (Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in the Western Indian Ocean.) *https://www.solstice-wio.org/* These funds are being used for case studies in South Africa, Kenya and Tanzania.

Case Study 1

South African Squid Fishery Collapse 2013

Nelson Mandela University researchers are investigating the causes of the squid fishery collapse in the Eastern Cape between 2013 and 2016, when 2 500 squid fishermen lost their livelihoods, affecting an estimated 35 000 family dependants.

Ellen Khuzwayo, South Africa's research ship.

Both the fishing industry and the department of agriculture, forestry and fisheries (DAFF) need to understand what caused the collapse of the squid fishery, and if it could happen again.

In April this year a research team from Nelson Mandela University's Ocean Sciences Campus completed a two-week field study aboard the DAFF research ship Ellen Kuzwayo. "It requires a formidable research effort involving ocean models, satellite observations, marine robotics, ship-based surveys and laboratory experiments," said Roberts.

"The data from the research still needs to be analysed, but the satellite observations and ocean models lead us to believe there has been a regime shift in the Agulhas Bank ecosystem (a broad, shallow part of the southern African continental shelf), probably as result of climate change." If this is the case, we need big models to help us anticipate future shifts and if or when the squid fishery crash could happen again."

Case Study 2

East African Marine Ecosystems

Together with our partner institutes in Kenya and Tanzania and the UK National Oceanography Centre, we are busy with case studies on the north-western Indian Ocean, where there has been limited scientific research," said Roberts. This research will increase understanding of how the marine ecosystems function in this region, how they are changing and how this is impacting the ocean food resources.

The French Connection

In addition to the Africa-UK Innovation Bridge-Research Hub, an equally important innovation link is being built with leading French marine research institutions, notably the Institut de Recherche pour le Développement (IRD) in Marseille and the Université de Bretagne Occidentale (UBO) in Brest.

The first large ecosystem functioning research project with the French was on the Mozambique Channel. It looked at the impacts of mesoscale eddies on the Mozambican prawn fishery. Another research project is focused on a seamount 200km south of Madagascar. Seamounts, with their special shape and depth, are biodiversity hotspots. They attract top predators such as tuna, billfish and sharks near their summits.

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FishFORCE

Combatting fisheries organised crime

It should be addressed under the Prevention of Organised Crime Act, with severe penalties of 25 years to life.

Heather Dugmore

Organised crime linked to the illegal harvesting, processing and trading of fish and seafood is so huge globally that it is effectively a parallel economic system, undermining sustainable economic growth.

"Countries are being deprived of taxes; citizens of jobs, food and income; and fisheries and environments are being destroyed. Africa is particularly vulnerable and loses more than $20-billion per year," said Professor Hennie van As, who presented FishFORCE's multi-country programme at the SANOCEAN (South Africa-Norway Research Co-operation on Blue Economy, Climate Change, the Environment and Sustainable Energy) conference.

An admitted advocate, Van As is director of the Centre for Law in Action, Professor of Public Law at Nelson Mandela University and head of South Africa's first Fisheries Law Enforcement Academy, FishFORCE.

Established in 2016 by Nelson Mandela University in partnership with the Norwegian Ministry of Foreign Affairs and South Africa's Department of Agriculture, Forestry and Fisheries (DAFF), FishFORCE works to equip enforcement agencies to handle the increasingly complex investigations and prosecutions of fisheries crime throughout Africa and the world.

Buy-in from INTERPOL

FishFORCE has buy-in from the world's largest international police organisation, Interpol, the African Union and the United Nations Office on Drugs and Crime.

Fisheries crime, or "multi-crimes" affecting the fisheries sector, range from illegal fishing to human trafficking and forced labour, fraud, forgery, corruption, money-laundering and tax and customs evasion. These crimes pose a significant challenge to fisheries law enforcement agencies across the world.

"Fisheries law enforcement requires traditional policing methods and tools, and expertise in law, criminology, police science, as well as fisheries management and conservation," said FishFORCE chief operations officer Michael de Lange. "The aim is to achieve intelligence-led investigations and prosecutions of criminals engaged in fisheries crime."

25 years to life

Cases prosecuted as Illegal, Unreported, Unregulated (IIU) fishing have had very limited success, with penalties amounting to a rap on the knuckles and being seen as "the cost of doing business" by culprits. Instead, as Van As argued: "They should be addressed under the Prevention of Organised Crime Act, with severe penalties of 25 years to life. It is encouraging to see that three recent major abalone racketeering cases have done this, with sentences of 18 to 20 years.

"Together with the National Prosecuting Authority (NPA), we are getting to the bottom of why prosecutions for fisheries-related crimes often fail," continued Van As. "The regulating and policing of fisheries vessels in the past has been too compartmentalised and full of loopholes because of the many different players involved. We are now collaborating with the South African Police Service (SAPS), Defence Force, NPA and Home Affairs to develop a combined offensive."

FishFORCE research and training

A cornerstone of FishFORCE is to facilitate research and innovation so that fisheries law enforcement officers have the most updated information, techniques and tools available.

Above: **FishFORCE training on Fisheries Crime Law Enforcement in South and East Africa, led by Professor Hennie van As and attended by Kenyan and South African officials and universities.**
Below: **FishFORCE training in Tanzania. The FishFORCE Academy is helping to build fisheries law enforcement capacity along the east coast of Africa.**

"FishFORCE is currently training fisheries control officers, police officers and prosecutors in South Africa and Kenya, where there is already a FishFORCE academy. Others are being opened in Angola, Namibia, Mozambique, Tanzania, Madagascar, Mauritius and Seychelles," said de Lange. "We are also assisting with training along the Indian Ocean Rim, including countries like Indonesia. Organised fisheries crime knows know borders, and neither do marine living resources."

The training developed and delivered by FishFORCE provides formal qualifications, such as a Higher Certificate in Criminal Justice and a Diploma in Law Enforcement. These were specifically developed in order to professionalise the sector, promoting fisheries law enforcement as a career choice.

For more information visit FishFORCE ***http://fishforce.mandela.ac.za/***

Padima. Photo:Prof Rose Boswell.

A woman seaweed farmer called Padima

Padima is a mwani (seaweed) farmer. She said that cultivating mwani is a difficult, smelly job. The seaweed has to be checked regularly, which involves many hours of labour, wading in the low tide under the hot sun. Women carry up to 10kg of mwani on their shoulders from the "plantation" to the beach. One kilogramme of seaweed fetches about one US dollar. Women working hard can make up to 50 dollars a week, which is significant for Zanzibaris — this is about 50 000 Tanzanian shillings. The seaweed is bought by Zanzibari middlemen, who sell it to Chinese merchants at the docks. The seaweed is used in anti-ageing and health products in the West and in the East it is used in a wide array of culinary dishes and as complementary medicine for physical and spiritual balance.

Indian Ocean Africa

Perfume, politics and a rich world of expression

'To understand the earth's oceans, one must also understand the people who inhabit coastal areas and islands. This includes human use of lagoons, beaches and sea," said Professor Rose Boswell, executive dean of Arts, Nelson Mandela University, whose exhibition of photos was titled Indian Ocean Africa.

"This was my first photographic exhibition and it consisted of images from my anthropological field research in the south-west Indian Ocean islands of Zanzibar, Madagascar and to a lesser extent, Mauritius," said Boswell, who was born in Mauritius.

"The historian Edward Alpers described the ocean off the east coast of Africa as 'Indian Ocean Africa'. Yet for a very long time the story of this socially diverse Indian Ocean region was not well known, and, to a large extent, one might argue, this is still the case.

"My journey into the region began in Mauritius in 1999. I wanted to follow the story of African descendants in Mauritius to understand why so many are still socially and politically marginalised. I also wanted to know why their story had been silenced for so long, what riches their communities held and how I, also an islander, was connected to other islanders in the region.

"Since 1999, my work has focused on the identity, the political situation and the rich intangible cultural heritage of the islanders. Heritage being the cultural 'gifts' passed from one generation to the next – songs, poetry, ritual practices and languages. What I found was an incredibly rich world of aroma, sound, emotional expression and oratory. A world of alternative 'starting points' for identity formation. The work also revealed the extraordinary creativity and resilience of Africans and their descendants."

Maasai woman and man on the beach in Zanzibar. Photo:Prof Rose Boswell.

Rendering of REV I, the largest, most advanced marine research platform in the world, currently being built. Photo: REV Ocean.

Triton: a three-person ocean research vessel with a diving depth of 2300m that will be used by researchers on REV I. Photo: REV Ocean

World's most advanced ocean research vessel

Heather Dugmore

When completed in 2021, the $350-million REV l will be the largest and most advanced marine research platform in the world.

REV I is part of REV Ocean https://revocean.org/, a new international marine research initiative targeting climate change, acidification, marine pollution and the overexploitation of marine resources with innovative ocean research and solutions.

The initiative comprises three interconnected platforms: the Research Expedition Vessel (REV), the World Ocean Headquarters (WOH), and the Ocean Data Platform (ODP).

REV I

The first REV I research mission, in the last half of 2021, will be to Arctic Norway and Greenland.

International scientists, research institutes, and innovative thinkers will submit proposals: if successful, they will have free access to the vessel and its state of the art technology for at least three years.

The 183m-long vessel will accommodate 60 scientists and 30 crew. It will be equipped with scientific trawls, sonar systems, a moonpool, underwater vehicles, advanced communication equipment, live streaming facilities, laboratories, classrooms and an auditorium.

Government leaders will be invited to take part in dialogues and events on REV I to assist them in implementing effective marine conservation policies in their home countries.

The WOH will be an incubator for the global ocean research community. The ODP will be an open source platform. The aim is to foster better decision-making and more successful conservation and utilisation of ocean resources by improving availability, access and analysis of global ocean data for all.

South Africa On Board

Professor Asgeir Sørensen, director of the Centre for Autonomous Marine Operations and Systems, in the Department of Marine Technology at the Norwegian University of Science and Technology *https://www.ntnu.edu/amos* gave a presentation on REV Ocean at the SANOCEAN (South Africa-Norway Research Co-operation on Blue Economy, Climate Change, the Environment and Sustainable Energy) conference.

He said: "Ocean sciences research universities like Nelson Mandela University and other relevant stakeholders and organisations in South Africa will be welcome to submit proposals and participate in the scientific campaigns organised by REV Ocean.

"There will be calls for participation on selected science topics, and an international group of independent experts headed by Dr Alex Rogers, REV Ocean's science director, will evaluate the proposals and allocate ship time."

Rogers, formerly a professor of conservation biology at the University of Oxford, has spent over 25 years studying deep sea and coral reefs. His focus has been on marine biodiversity and its drivers, and how to mitigate human impact on the oceans.

Links to REV Ocean information and videos
https://www.facebook.com/pg/OceanREV/videos/?ref=page_internal

New marine robotics unit

Nelson Mandela University has been chosen by the IIOE-2 to be the hub for marine robotics in a Western Indian Ocean (WIO)-wide research network.

In March 2019 Nelson Mandela University's Faculty of Engineering, the Built Environment and Information Technology (EBEIT) launched its transdisciplinary Marine Robotics Unit (MRU). The MRU's engineering team is headed by Akshay Lakhani, Group Specialist: Systems and Control at eNtsa, a research and innovation hub within the faculty.

"Our oceanographic researchers need robotic technologies to collect in situ ocean data both in the coastal and offshore regions, and we need to develop innovative ways to assist robotic platforms to navigate in unknown and difficult regional ocean environments," Lakhani explains.

"Current methods of collecting ocean sciences data using conventional ships, amongst other methods, are very expensive and few developing countries have the resources to own and operate research vessels. Marine robotics offer a much needed solution as they are relatively inexpensive and easy to deploy, allowing our ocean scientists and research units to operate at a world-class level."

Marine robots for our oceans

"The MRU is collaborating with the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway https://folk.ntnu.no/assor/ in the development of new marine robotics and deployment systems, specifically designed for our oceans," says Lakhani. "This includes aerial platforms (i.e. drones), specialised sensor development, and optimised data-capturing, storage and sharing in support of ocean sciences."

The MRU will also manage the deployment and operation of existing robotics such as autonomous underwater vehicles (AUVs), subsurface ocean gliders, surface wave gliders and ARGO floats. These platforms can be deployed from small boats and remain at sea for anything from days to months. The MRU will host and maintain this equipment with dedicated Nelson Mandela University engineers, technologists and technicians.

For more information: ***www.ecosub.uk, www.planet-ocean.co.uk***

Akshay Lakhani

Boaty McBoatface - one of the National Oceanography Centre's autosubs - a long range autonomous vehicle that can travel for many kilometres and to great depths underwater, gathering scientific data. Photo: National Oceanography Centre (NOC)

Democratising Marine Research

Autonomous underwater vehicles (AUVs) are essentially small unmanned robot submarines used for monitoring and research. AUVs are equipped with powerful electronics and artificial intelligence to independently collect data using their onboard sensors.

There are a wide range of AUVs but they are expensive, ranging from £100K to £2M. "As battery and sensor technology, and electronic equipment got smaller, we saw an opening for smaller, far more affordable versions of this technology," says Terry Sloane, the co-owner and managing director of Planet Ocean Ltd which developed ecoSUB. "Our mission is to democratise the use of AUV technology because at the moment it is only available to wealthy institutions and we want to change this.

"We applied for and won UK government funding and developed the ecoSUB, which enables the use of AUV technology from a beach or jetty or from small boats. You can do excellent science and the benefit is they are very easy to use and one-tenth of the price. The half-a-metre long ecoSUB is around £10 000 and the one metre version is about £20 000."

Larger AUVs can carry several sensors, whereas the ecoSUBs carry one or two sensors and scientists use a 'shoal' of them, each with different sensors to monitor anything from the salinity and dissolved oxygen in the water to the chemistry, pH, zooplankton, phytoplankton and sound.

The ecoSUBs can stay in the water from a few hours to two days, and we are aiming for 100 and 200 km for the smaller and larger ecoSUBs respectively. The smaller ecoSUB currently goes down to 500m – the depth of most continental shelves – and the larger one can go down to 2500m.

Fish species overexploited or collapsed

No-take zones in estuaries may be the solution

By Dr Tor Næsje (Norwegian Institute for Nature Research) and Professor Paul Cowley (South African Institute for Aquatic Biodiversity)

For more than 100 000 years South Africa's fish have been an important food source for humans. Yet today, we find ourselves in a position where the populations of prominent species such as dusky kob, spotted grunter, white steenbras and leervis (garrick) are considered to be either collapsed or over-exploited.

Estuaries provide nursery areas for these species and they continue to use them to a certain extent as adults. Dusky kob, for example, spend most of the nine years they take to mature in the estuary, before they head out to sea, returning occasionally in adulthood. In ideal conditions, dusky kob live to about 50 years.

250 estuaries along SA's coastline

There are more than 250 sheltered estuaries along South Africa's coastline, which serve both as critical nursery areas and provide fishing opportunities for subsistence and recreational fishing. Based on the over-exploitation and collapse of many of the fish stocks, they are in need of urgent management attention.

The important management questions are: where do the fish like to be in the estuary, and for how long; when do they leave the estuaries and go out to sea; and, do they utilise multiple estuaries? It is also important to gain insights on the coastal migrations of adults, to identify spawning areas, and to know how and where the fish are exploited, and by whom.

In 2002 researchers from the South African Institute for Aquatic Biodiversity (SAIAB) and the Norwegian Institute for Nature Research (Nina), led by Professor Paul Cowley and Dr Tor Næsje, and officials from South Africa and Norway met and subsequently established a joint-financed research programme. One of the criteria of the South African-Norwegian partnership is increasing the presence of women in science, and approximately 75% of the researchers are female.

Subsistence fisher in Great Fish Estuary with dusky kob. Photo: Dr Tor F. Næsje

Dr Amber Childs and Professor Paul Cowley surgically implanting a transmitter in a juvenile dusky kob in the Sundays Estuary. Photo: Dr Tor F. Næsje

Following fish

Acoustic telemetry is used to study fish behaviour, area use and migrations. By attaching a sound transmitter with unique signals to fish, the researchers are able to detect their whereabouts and behaviour with acoustic receivers.

Receivers for monitoring fish movement have been deployed in estuaries and coastal waters from False Bay to the Mozambican border. This nationwide array of receivers forms the Acoustic Tracking Array Platform, which is managed by SAIAB.

Results from the first decade of fish telemetry studies have confirmed that the four species — dusky kob, spotted grunter, white steenbras and leervis (garrick) — are threatened, both from fishing exploitation, human-caused degradation of estuaries, and reduced rainfall resulting from climate change. This highlights the need for immediate management action to protect them.

No-take zones

Marine Protected Areas have been shown to be highly beneficial for the rehabilitation and management of fish stocks, but few studies have evaluated the benefits of Estuarine Protected Areas. To remedy this, Godfrey Padare, a master's student from the Department of Zoology and Entomology at the University of Fort Hare researched whether partial estuarine area protection in the form of no-take zones can reduce the vulnerability of the spotted grunter.

In this study, 14 spotted grunter were tagged with acoustic transmitters and monitored for an average of 310 days in the Goukou Estuary. His results confirmed high site fidelity by spotted grunter in this estuary and the positive value of no-take area closures as a potential management option.

Fishery policy lagging

However, these important findings have had little direct impact on fishery policy formulation. For the next four years, funding obtained through the Sanocean (South Africa-Norway Research Co-operation on Blue Economy, Climate Change, the Environment and Sustainable Energy) programme will be used for a follow-up project that aims to produce guidelines on how to communicate important fish and fisheries information to managers.

Nelson Mandela University is part of the SAIAB-Nina partnership, conducting case study research on the social, economic and governance dynamics of estuarine fisheries.

Sewage and contaminants in Cape Town sea

Wastewater contains many dangerous contaminants, which are now being measured

Professor Leslie Petrik, Department of Chemistry, University of the Western Cape

The City of Cape Town discharges a large volume of untreated or partially treated sewage effluent into the ocean via outlets located around the Cape Peninsula. This sewage contains a high degree of contaminants, including chemicals, pesticides, perfumes and disinfectants, which up until recently could not be accurately measured.

Many contaminants are able to pass through wastewater treatment systems without adequate removal, as well as through systems used in desalination plants, or through treatment systems for wastewater reuse. To make matters worse, 80% of wastewater treatment plants are only marginally functioning, a situation that deteriorated further with the concentrations of effluent caused by water use restrictions during the Cape's recent drought.

Risks to humans

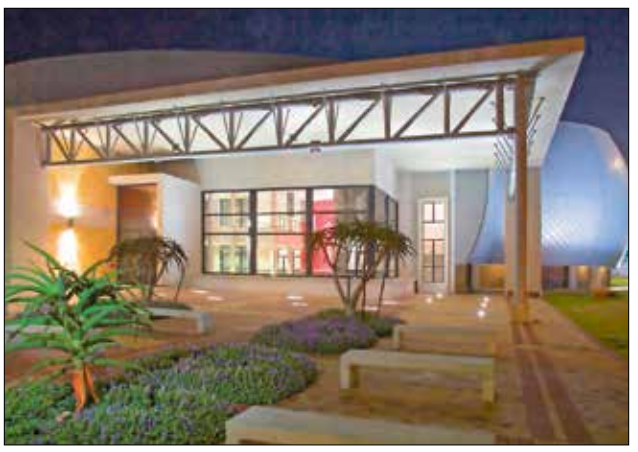
Uncertainty over the magnitude of risk of human exposure to these contaminants means it is necessary to measure their levels in the ocean, as well as in potential sources of potable "reclaimed" water, such as desalinated sea water.

Professor Leslie Petrik. Photo: Supplied

Senior scientists from the University of the Western Cape, the University of Cape Town and Stellenbosch University, in partnership with others from the University of Stavanger and the International Research Institute of Stavanger in Norway, are conducting a substantial study of the seasonal behaviour of the effluent outfall plumes around Cape Town and the current outfall flow rate impacts, neither of which have previously been studied. The areas being studied are Table Bay, the Atlantic seaboard and False Bay.

Ocean health directly impacts human health. Photo: Supplied

There is also a clear need for democratic participation in decision-making on the issue, for urban planners to be on board and for the public to become more aware of the consumer choices they make in respect of the purchasing and disposing of harmful chemicals and pharmaceuticals, which have direct effects on long-term wellbeing of humans and marine species.



Nelson Mandela University's Faculty of Engineering building Phase I. *(Right)* University of Southampton towing tank carriage and work station.

Maritime engineering and naval architecture

New degree in Engineering Technology in Marine Engineering

Marine Engineering PhD Boswell Douse (left) and John Fernandes lecturer in Marine Engineering at the University of Southampton. Photos: Supplied.

As part of Nelson Mandela University's growth in the marine and maritime space, in January 2018 its Faculty of Engineering, the Built Environment and Information Technology (EBEIT) launched its bachelor's degree in Engineering Technology in Marine Engineering .

"We are able to register up to 75 first-year students each year," said Howard Theunissen, EBEIT's Marine Engineering and Nautical Science Project Manager, who presented at the IIOE-2 conference. "The degree is accredited by the South African Maritime Safety Authority and the Engineering Council of South Africa, which is a signatory to the body of engineering councils around the world."

EBEIT plans to offer a Naval Architecture honours degree from 2022 and a master's thereafter, and is engaging with the Royal Institute of Naval Architects in this regard.

Naval Architecture PhD

Naval Architecture PhD candidate, Boswell Douse is doing his PhD at the University of Southampton, supported by the Faculty of EBEIT and Department of Higher Education and Training's New Generation of Academics Programme (nGAP). He explains that all fishing vessel hulls are designed for northern hemisphere ocean conditions, and our southern oceans are very different, which calls for a different design of hull.

"We have bigger, more powerful swells and the vessels roll a lot more in the southern hemisphere oceans, which is not comfortable for the seafarers on the boats," Douse explained. "Another factor that needs to be built into the design is the high temperature variability in the southern hemisphere oceans — from the cold temperatures when they go down south to the hot, tropical conditions up the east coast of Africa."

Key training partnerships: merSETA and Wärtsilä

The faculty has received considerable support locally and internationally for its marine and maritime programmes. "Credit is due to Dr Raymond Patel, the chief executive of the manufacturing, engineering and related services SETA (merSETA). His foresight as to what the growth of EBEIT's offerings can contribute to the blue economy, led to the SETA awarding the faculty an annual R10-million grant over the past three years," said Theunissen.

One of EBEIT's key industry partners is the Finnish marine manufacturing and engineering corporation, Wärtsilä. The company routinely trains engineers and technicians from all over the world, and is contracted to supply the engines and power train for the South African Navy's new hydrographic vessel — a scientific research and investigation vessel being built by the Southern African Shipyards in Durban.

Vehicle tyre particles a major marine polluter

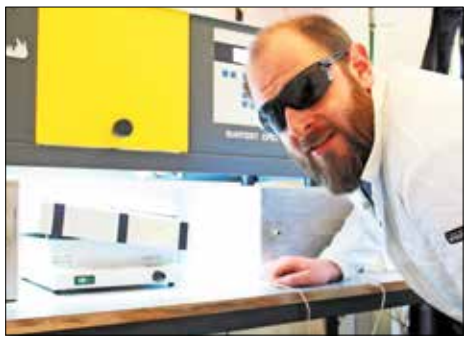
Every set of tyres releases 6kg of toxic plastic into the environment

'Globally, we are increasingly concerned about microplastic and nanoplastic pollution in the ocean, because if a particle of this size is ingested by fish, it might be small enough to transfer across the walls of the digestive system and into the organism, possibly accumulating in organs such as the brain, liver and kidneys," said Dr Andy Booth, senior research scientist in the environmental technology department at one of Europe's largest independent research institutes, Sintef Ocean, in Norway.

Speaking at the Sanocean conference at Nelson Mandela University in March 2019, he explained that microplastic particles are less than 5mm in size and nanoplastic particles are less than 100 nanometres — they are so small you wouldn't be able to see them. "Estimates are that what we see is only about 10% of the total marine plastic pollution. What this means is that about 90% of plastic litter is already on the sea floor."

Research is being conducted by the Fortran project (factors influencing the formation, fate and transport of microplastic in marine coastal ecosystems). It's a partnership between Sintef Ocean, Stellenbosch University, the University of the Western Cape and Wildoceans — a programme of the Wildtrust in KwaZulu-Natal.

"Very importantly, different plastics and polymers contain a broad range of chemicals, some of which are added specifically to make



the polymers more resistant to degradation. Some chemicals are very toxic, and this is a big unknown at the moment. What we need to identify, as part of coming up with solutions for plastic pollution, is which are the benign and which are the toxic materials.

Toxic tyres

"We know, for example, that vehicle tyres are not benign. Not only are they one of the highest volume emitters of microplastic particles, which are continuously released when the tyre comes into contact with the road surface, but they have some of the most toxic chemical additives in their composition," said Booth.

He said that the average car tyre loses 1.5kg in its lifetime in the form of micro- and nanoplastic tyre wear particles that are released directly into the environment. Therefore, every car with four wheels releases 6kg of micro- and nano-

Above: Green sea turtle with a plastic bag, which can be confused with jellyfish. The bag was removed by the photographer before the turtle had a chance to eat it. Photo: © Troy Mayne / WWF

Left: Dr Andy Booth simulating UV degradation of microplastic in freshwater and seawater. Photo supplied.

Right: Plastic pollution on a Cape Town beach. Photo supplied by WWF-SA.

plastic into the environment — into the land, freshwater sources and oceans. Scale up to the number of cars in the world and this may be one the main sources of micro- and nanoplastic particles polluting the ocean.

To determine their toxicity, microplastic tyre particles were added to fresh and seawater and the Fortran research team analysed the metals and chemicals that came out. "We found that they are really toxic," says Booth. "We are now looking at the transport route and toxicity effect of tyre wear particles on test organisms in the ocean, including microalgae, zooplankton and small sediment crustaceans.

"Obviously you can't ban car tyres, but what can be done is to assist, guide and regulate tyre manufacturers and other producers of plastic to better manage their plastic footprint, to develop products with reduced plastic particle pollution and to replace the toxic chemicals in plastics with non-toxic counterparts.

"What we can also do is to look at the points of origin of high flows of macro and microplastic into the environment. A good example is wastewater treatment plants — these are ideal points for targeted management," concluded Booth.

For more information:
https://www.sintef.no/en/
http://wildtrust.co.za/wildoceans/

Ocean Sciences

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Painting by Maggie Newman reflecting the lives of humans on the southern Cape Coast dating back 164 000 years. Photo: Maggie Newman.

ACCP member Dr Jan De Vynck who recently graduated with his PhD in Ocean Science from Nelson Mandela University, taking notes during an ethnographic study of marine intertidal foraging. Photo: ACCP

Coastal link in the origins of human awareness

Shells and shellfish were used for decoration and nutrition by early humans

The cognitive revolution of humans took place when we evolved not only anatomically but also cognitively. For signs of human development into sentient, conscious beings, we look to the first indications of planning, invention, art and adornment, which, in turn, reflect an awareness of self, others and the world.

Scientists from Nelson Mandela University's African Centre for Coastal Palaeoscience (ACCP) are collaborating on research into this phase of human evolution. The team includes Professor Richard Cowling, Dr Alastair Potts and Professor Curtis Marean from the School of Human Evolution and Social Change at Arizona State University.

At Pinnacle Point Cave in Mossel Bay on the southern Cape coast, they have found sandblasted shells collected by humans 164 000 years ago. During his SANOCEAN presentation Dr Potts explained that they know the shells weren't collected fresh for food because they were sandblasted, so had already been lying on the beach. These shells would have been used for adornment, such as necklaces.

Khoe-San descendants participating in the ACCP's ethnographic study of marine intertidal foraging. They built a fire to cook the Turbo sarmaticus, or giant turban snails. Vast deposits of discarded shells were found in the middens along the coastline. Photo: Jan De Vynck.

"There were also signs of art during this period, including abalone shells with five different types of ochre in them — an artist's palette. And although we do not know whether this was used for adornment or paintings, it is a clear sign of the progression in cognitive development," said Potts.

During the same period, the team found vast deposits of discarded shells in the middens in the cave — evidence that humans had been harvesting shellfish in the intertidal zone. Shellfish and other aquatic resources are extremely rich in the specific nutrients that the brain requires to grow, such as iodine and omega3 polyunsaturated fatty acids.

"These humans also had a rich source of terrestrial plant foods, including bulbs and berries, and the region at the time was full of animals: giant zebras, wildebeest, buffalo, even giraffe," said Potts who, with his colleagues, has reconstructed what this extinct ecosystem might have looked like.

For more information:
https://www.humanorigin.co.za/

Life below water from Zanzibar

Advancing science and conservation in the West Indian Ocean

The Zanzibar-based Western Indian Ocean Marine Science Association (Wiomsa) is supporting scientists in the region to advance ocean science, ocean conservation and the associated legislation in the Western Indian Ocean (WIO) countries of Somalia, Kenya, Tanzania, Mozambique, South Africa, Comoros, Madagascar, Seychelles, Mauritius and Réunion.

Wiomsa's executive secretary, Dr Julius Francis, who lives in Zanzibar and presented at the IIOE-2 conference, said their aim is to establish a science-to-policy platform by addressing the research gaps in the WIO, including research on ocean acidification, marine litter and mining activities. They also closely engage with coastal cities and communities who depend on the ocean for their livelihoods.

"Through the Nairobi Convention (a regional Convention for the Protection, Management and Development of the Marine and Coastal Environment) the 10 countries agreed to develop a co-ordinated approach to the implementation of the Sustainable Development Goals (SDGs), with a focus on SDG 14: Life Below Water," Francis said.

"We are setting up baselines for at least four SDG 14 targets, providing management and policy recommendations, and tracking the progress of these targets over time. These include: marine pollution, with a focus on marine litter, healthy oceans, ocean acidification, and marine protected areas."

To date, Wiomsa has provided support to set up monitoring programmes for ocean acidification and marine litter as the first steps in establishing baselines against which to measure change and the degree of success of mitigation strategies.

Partnering in Wiomsa's regional marine litter monitoring programme is the Port Elizabeth-based Africa Marine Waste Network, which uses similar sampling methodologies.

Sunset over Stone Town, Zanzibar, Tanzania Photo: Oskar Henriksson

Fisherman with the day's octopus catch.
Photo: rahimsaggaf_photography

An experienced Kenya Wildlife Service ranger helps a non-swimmer experience coral reefs for the first time for the Strategic Adaptive Management (SAM) Project in Mombasa Marine Park.
Photo: Jennifer O'leary

Cities and Coasts

Francis explains that the coastal zone of the WIO region hosts major cities, harbours, industries and other development infrastructure that, while vulnerable to climate change themselves, also pose increasing threats to the integrity of coastal and marine ecosystems.

To address this, in 2018 Wiomsa launched a four-year programme called Cities and Coasts. One of the research projects supported by the programme is Cities and Climate Change in Coastal Western Indian Ocean, A Grand Challenge, led by Dr Bernadette Snow, director of the Institute for Coastal and Marine Research at the Ocean Sciences Campus of Nelson Mandela University https://cmr.mandela.ac.za/, in collaboration with the German Climate Service Centre.

Together with decision-makers and society, this three-year project is exploring and planning how coastal and marine planning can be implemented to enable better adaptation to climate change in vulnerable coastal cities of the WIO.

For more information visit:
www.wiomsa.org

Era of marine spatial planning

Humpback whale breaching. Photo: Dr Stephanie Plön, Ocean Health Unit, Earth Stewardship Science Research, Nelson Mandela University

South Africa has more ocean territory than land, and more than 40% of South Africans live on or near a coastline. In 2014, the government launched Operation Phakisa: Oceans Economy, to unlock the economic potential of the oceans, based on the principles of sustainable development. One of the key tools available to promote sustainable practices in the ocean is marine spatial planning.

Professor Mandy Lombard, who holds the DST/NRF SARChI Chair in Marine Spatial Planning at Nelson Mandela University, explained: "Marine spatial planning brings together the research, data and everyone with an interest in the oceans — government, fisheries, shipping, energy, tourism, conservation and recreation — to make co-ordinated, evidence-based decisions about how to sustainably use resources and manage our oceans. Optimising economic opportunities has to be done without compromising the environment. This is non-negotiable, because the ecosystem services the oceans deliver are essential for our survival."

> It brings together everyone who has an interest in South Africa's oceans

These services include provisioning (such as food and water production), regulating (such as climate regulating through CO2 and heat absorption), supporting (such as oxygen production), and cultural (such as recreational or spiritual activities). Despite a clear understanding of this dependency, humans continue to impact marine systems in potentially irreversible ways.

"Unfortunately, South Africa's national policies tend to be fragmented and sector-specific and include decision-support tools that address only components of marine systems," says Lombard. "These tools are all represented in South Africa's legislative toolbox, the most recent addition being the draft Marine Spatial Planning Bill, and our 20 new marine protected areas. The big move required is towards integrated ocean management at local and regional levels, based on matching policy and management strategies at a national level in our Exclusive Economic Zone (EEZ), which extends 200 nautical miles out to the sea (just under 400km), as well as in the high seas (areas beyond national jurisdiction)."

Lombard explained their research projects include researchers from the physical, social and economic sciences, and law. "We work with academics, government scientists, managers and communities. We work across habitats (from deep water corals, through marine canyons, to shallower reefs and estuaries), oceans (Indian, Atlantic, Southern) and countries (from Angola to Western Indian Ocean Islands). Using a Systems Thinking approach, we build spatial and temporal models, and are working out how best to couple them with policy and decision-making."

Tackling the ocean plastics problem now

A key focus at the IIOE-2 and SANOCEAN conferences was the issue of marine plastics.

Professor Andy Cundy, School of Ocean and Earth Science, University of Southampton

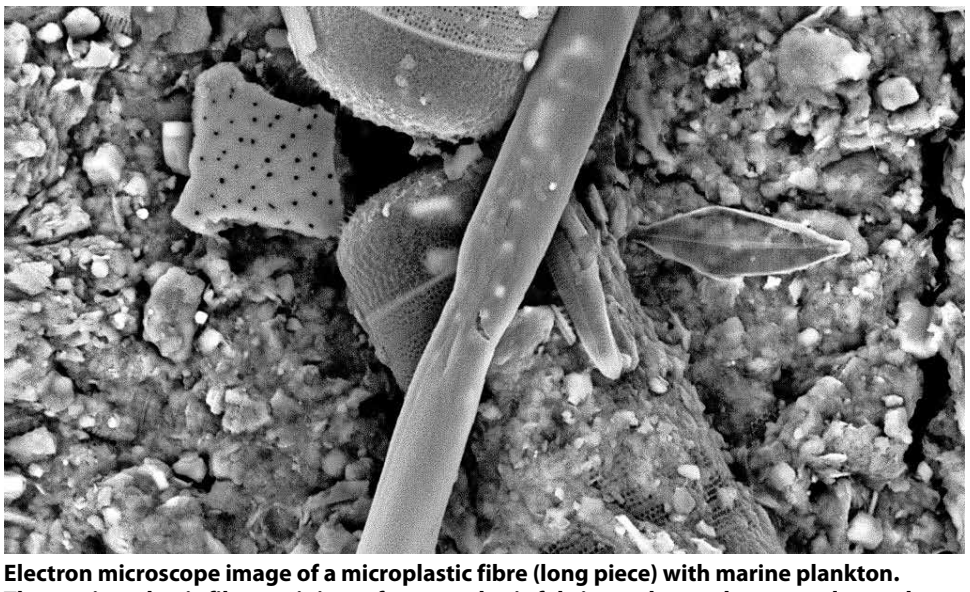
Over 100 million tonnes of plastic may now be present in the oceans and the amount is increasing year on year. Estimates suggest that by 2050 there may be more plastics (by weight) than fish in the sea.

Multiple types of plastic are now found well beyond our coastal seas, from remote mid-ocean surface waters to the deepest ocean trenches. Once plastics enter the ocean they are difficult and costly to remove.

Tackling the source of the plastics problem is critical. Interventions include reuse, recycling and replacement with alternative materials, enhanced management of wastewater treatment works, banning of microbead plastics in, for example, cosmetics, and communities worldwide coming together to collaborate in a proposed Integrated Marine Debris Observing System (IMDOS).

There is real value and huge potential in scientists, policymakers, industry and the public working together:
(a) To better understand the amount of plastics entering the sea, and their pathways and distribution between land, the coastal ocean and the deep sea to assess the risks to people and fisheries; and
(b) To tackle the plastics problem at source by developing local, regional and national policies to reduce the amount of plastic debris entering the sea and impacting marine ecosystems.

Several nations have already put in place measures to limit the amount of plastics pollution entering the environment and our seas, ranging from bans on certain plastic products to reducing the use of single-use "throwaway" plastics and plastic packaging. There are so many opportunities to build on this, collaborate, and learn from each others' experiences.



Electron microscope image of a microplastic fibre (long piece) with marine plankton. These microplastic fibres originate from synthetic fabrics such as polyester, nylon and acrylics, and are released into wastewater every time we wash our clothes, from where they can enter estuaries and the marine environment through wastewater treatment works and storm water outflows. Photo: Prof Andy Cundy

Ocean Sciences

NELSON MANDELA UNIVERSITY

Institute for Coastal & Marine Research (CMR)

The SARChI Chair in the Law of the Sea and Development in Africa is one of several trans-disciplinary Chairs in the Institute for Coastal and Marine Research CMR, Nelson Mandela University. The CMR is situated at the Ocean Science's Campus with membership from all seven faculties and includes 50 staff members and over 100 postgraduate students, doctoral candidates and postdoctoral researchers.

The director of the CMR, Dr Bernadette Snow, was integral to the organisation of the IIOE-2 and and SANOCEAN conferences at Nelson Mandela University.

Two research units in the CMR are: Marine Apex Predator Research Unit (Mapru)

Mapru conducts research on marine top predators, including seabirds, seals, sharks and cetaceans, particularly in relation to global change, conservation and sustainable resource management. Geographically, most of the projects are focused on the South African coastline, in the sub-Antarctic region, but they also extend into Mozambique and Namibia.

Research Diving Unit (RDU)

The RDU provides diving support to projects registered with Nelson Mandela University. It provides scientific diver training, and ensures that all health and safety requirements for diving-related activities are met through its Safety, Health, Environment and Quality (SHEQ) programme in accordance with national legislation and international best practice.

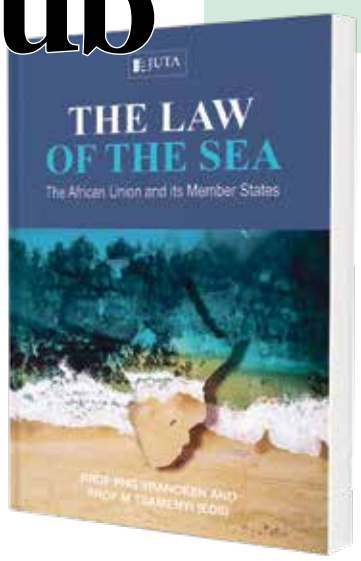
Research Chairs in the CMR include:

Shallow Water Ecosystems (Chair holder: Professor Janine Adams), **Marine Spatial Planning** (Chair holder: Professor Mandy Lombard), **Law of the Sea and Development in Africa** and **Ocean Science and Marine Food Security** (Chair holder: Professor Mike Roberts).

For more information: ***cmr.mandela.ac.za***

One Ocean Hub

Integrating research across disciplines and sectors, and at different scales



Nelson Mandela University is part of an ambitious new £20-million UK Government Research and Innovation Global Challenges Research Fund (GCRF) programme aimed at tackling threats to the world's oceans and addressing the challenges faced by developing countries. From plastic pollution to rising sea levels, acidification to over-fishing, the threats facing our oceans are well documented.

Called the One Ocean Hub, it is led by the University of Strathclyde's Professor Elisa Morgera, director of the Strathclyde Centre for Environmental Law & Governance within the Law School, who said: "The One Ocean Hub will bridge the current disconnects across law, science and policy to empower local communities, woman and youth — who are particularly impacted by decision-making — to co-develop research and solutions."

Nelson Mandela University's deputy vice chancellor for Research and Engagement, Professor Andrew Leitch, said: "The One Ocean Hub integrates research across disciplines in different sectors and at different scales (global-local). It speaks directly to Sustainable Development Goal 14 — the conservation and sustainable use of the oceans — but also to other goals, including blue economies and vulnerable communities."

He explained that one of the five focus areas in the One Ocean Hub is transformative governance for an inclusive, innovative and responsible blue society, which examines socioeconomic decision-making for ocean management. The project team includes lawyers, economists, social scientists, biophysical scientists and postgraduate students who are using Port Elizabeth and Algoa Bay as the project area, and are looking at everything from the dynamics and ocean economy of this coastal city and community to marine genetics.

Law of the sea and development in Africa

The SARChI Chair in the Law of the Sea and Development in Africa is one of the One Ocean Hub members. Its focus is the law of the sea in South Africa, and other parts of Africa, namely the east coast of Africa and the Indian Ocean; the west coast of Africa and the Atlantic Ocean; and the Southern Ocean and Antarctica.

Chair holder Professor Patrick Vrancken is the co-editor of a seminal 800-page book published in 2017, titled *The Law of the Sea — The African Union and its Member States.*

Professor Vrancken explained: "The sea is divided into maritime zones with different rules in different zones," he explains. "You have laws governing the internal waters such as our bays; then you have laws governing the territorial sea extending 12 nautical miles (1 nautical mile = 1.852km). Beyond this is the exclusive economic zone (EEZ) which extends as far as 200 nautical miles from the coastal baselines. The law treats the resources here as if they were part of the territory of the coastal state but for all other purposes the zone is subjected to the same laws as the high seas." This book is the first work to attempt to systematically collate the legal aspects of ocean governance in African countries. Before this, Africans had to rely to a much greater extent on what was written outside of Africa, which was often unreliable, biased and incomplete.

The marine plastic pollution crisis

The cost in damage to marine ecosystems is $13-billion each year

Peter Manyara is the South Africa-based regional project co-ordinator for the International Union for Conservation of Nature's (IUCN) Marine Plastics and Coastal Communities (Marplasticcs) programme for southern and east Africa

Plastic Pollution: The Facts

- Globally, over 300 million tons of plastic is produced every year.
- Between 8—10 million tons of this plastic flows into our oceans every year.
- Plastic kills an estimated one million seabirds and 100 000 marine mammals each year.
- Plastic pollution costs a minimum of $13-billion annually in damage to marine ecosystems.

Marine Plastics and Coastal Communities Project (Marplasticcs)

In 2017 the IUCN launched the Marine Plastics and Coastal Communities initiative (Marplasticcs) with the support of the Swedish International Development Co-operation Agency. This is a three-year initiative working with five countries: South Africa, Mozambique, Kenya, Thailand and Vietnam.

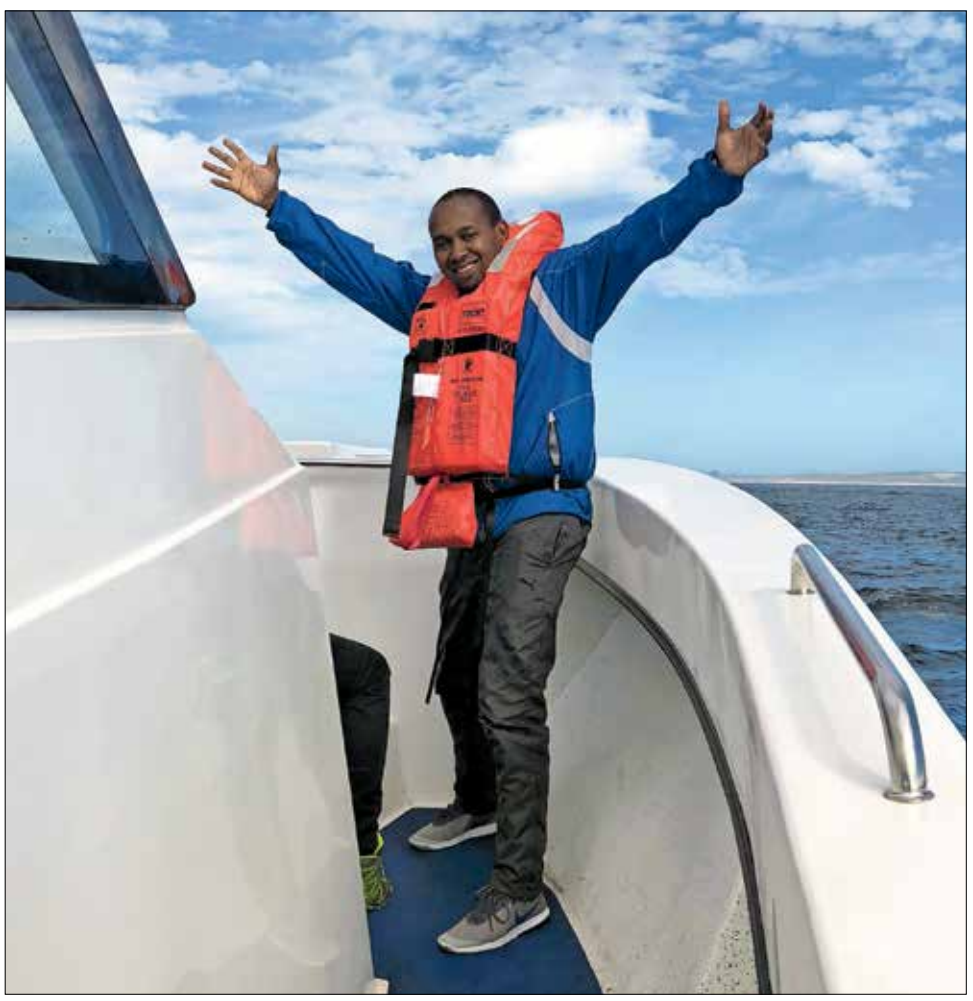
Marplasticcs assists the governments, municipalities, industry, research institutions and organisations in these countries to strengthen and effect legislative and practical measures to reduce plastic pollution from source to sea.

Working with the private sector

Plastic packaging is currently largely single use in business-to-consumer applications. It is essential that extended producer responsibility schemes should be designed and implemented to stimulate design change within the consumer goods industry.

Marplasticcs' engagement with the private sector includes supporting platforms for leadership and corporate stewardship to address the plastic problem and come up with innovative solutions and actions, as well a better understanding and assessment of the plastic footprint.

For more information ***https://www.iucn.org/theme/marine-and-polar/our-work/close-plastic-tap-programme***



Peter Manyara, the regional project co-ordinator for the IUCN's Marine Plastics and Coastal Communities (Marplasticcs) programme. Photo: Heather Dugmore

Common dolphins in Algoa Bay. Photo: Lloyd Edwards.

IUCN Marine Mammal Task Force includes SA

Chinese tour guides with Bottlenose dolphins at St Croix Island in Algoa Bay. Photo: Lloyd Edwards

In March 2019, the International Union for the Conservation of Nature's (IUCN) Marine Mammal Protected Areas Task Force (the "Task Force") completed the fifth Important Marine Mammal Area workshop in Salalah, Oman.

The week-long workshop hosted 38 marine mammal scientists and observers from 15 countries to map the important habitats for 130 species of marine mammals in the western Indian Ocean and Arabian seas, namely cetaceans (whales, dolphins and porpoises), pinnipeds, sirenians, otters and the polar bear — across the world oceans.

The delegates from South Africa were Dr Stephanie Plön (who heads the Ocean Health Unit at the Earth Stewardship Science Research Institute, Nelson Mandela University), Dr Vic Cockcroft (Nelson Mandela University) and Professor Ken Findlay (Cape Peninsula University of Technology, Cape Town).

"A record 55 candidate important marine mammal areas, or IMMAs, were identified," said Plön. This includes five for South African waters, which encompass all of South African coastal and shelf waters, including:

- The inshore waters along the southern Cape coast — False Bay to Algoa Bay — where southern right whales come to mate and give birth between June and November every year;
- East coast waters within 15km from shore that are known for migrating humpback whales. They migrate from their feeding grounds in the Antarctica to the Indian Ocean/Mozambique/Madagascar to give birth between June and November each year, and back to the Antarctic from about September/October to November;
- Southern coast inshore and shelf waters where the inshore Bryde's whale is found. It was declared as "vulnerable" in the last South African Red List assessment;
- The south coast inshore Indian Ocean humpback dolphin habitat where South Africa's only "endangered" marine mammal is found; and
- The southeast coast seasonal sardine run area, where marine apex predators, such as common dolphins, Indo-Pacific bottlenose dolphins, Bryde's whales, Cape fur seals and killer whales can be seen following the annual migration in May/June every year.

The candidate IMMAs are currently being assessed through a rigorous scientific process. Once approved (towards the end of 2019), they will be placed on the IMMA e-Atlas and can be used for conservation planning.

"South Africa's marine environment is a global biodiversity hotspot," said Plön.

"Algoa Bay in Port Elizabeth, for example, has an abundance of dolphins and whales and is an ideal place for marine scientists to do research. It's known as the 'dolphin capital of the world' as there are unusually large group sizes of common and bottlenose dolphins; we see groups ranging from 10 to 15 bottlenose dolphins to several hundred common dolphins, often associated with bait balls or large schools of sardines or red eyes (part of the herring family). Sometimes these bait balls are a kilometre in diameter."

> Five important marine mammal areas identified locally

South Africa's first boat-based whale-watching study

Over the past two decades boat-based whale-watching has developed into an important, growing tourist industry, with new and established operators in marine tourism hotspots such as False Bay, Hermanus, Gansbaai, Knysna, Plettenberg Bay and Port Elizabeth.

In partnership with the Nature's Valley Trust, a WWF Nedbank Green Trust project is currently assessing the impact of South Africa's boat-based whale-watching industry on the dolphins and whales, as well as the socioeconomic impact of the industry on the towns where the operators are based. Research started in September 2018 and the findings will be released in 2020.

"Using Plettenberg Bay for our case study, we are looking at the key areas the dolphins and whales use in the bay; where they rest, feed and socialise and where the whale-watching boats operate in these areas," explained project leader Dr Gwenith Penry, a postdoctoral researcher at Nelson Mandela University's Institute for Coastal and Marine Research, focusing on the "data deficient" Bryde's whale.

"If there are too many operators in one area, the animals could leave. We need to safeguard the animals, develop a spatial plan, and offer feedback to the department of environmental affairs on which parts of the existing regulations need updating and the rate of transgressions in the industry, as there are ethical and less ethical operators."

On the socioeconomic side the team is looking at the direct and indirect benefits of marine tourism activities for the communities and towns that offer these. They will also assess the contribution of marine tourism to employment and hospitality, such as how many accommodation establishments, restaurants and shops depend on it.

Raggy Charters Whale-Watching

One of the most established whale-watching cruises is Raggy Charters in Algoa Bay, national winner of the 2018 Lilizela Tourism Award for Best Marine Adventures in South Africa. The founder and owner of Raggy Charters, Lloyd Edwards, led SANOCEAN participants on a cruise around Algoa Bay and St Croix Island, home to 22 000 breeding pairs of African Penguins, the largest breeding colony in Africa.

Algoa Bay is rich in marine wildlife, including bottlenose dolphins, common dolphins, humpback dolphins, Bryde's whales, minke whales, humpback whales (June to December), southern right whales (July to September), Cape fur seals, various species of sharks, Cape gannets and various species of pelagic birds including terns, petrels, skuas, shearwaters and albatrosses.

Algoa Bay is the furthest place east where southern right whales give birth in large numbers. They nurse their calves in the sheltered waters of the bay. Common dolphins are found further offshore here in schools of between 1 000 and 3 000 individuals throughout the year.

Purity Khosa, a marine guide with Raggy Charters, accompanied the SANOCEAN cruise. She had never seen the sea until 2014, when she started her Diploma in Tourism Management at Nelson Mandela University in Port Elizabeth.

"I'm from Bushbuckridge, Mpumalanga, and if you want to go to the beach you had to go to Mozambique or Durban, but we just didn't have the finances to do this," she said. "When I first saw the sea I could not believe there could be such an expanse of water."

She started working with Raggy Charters in 2017 for the experiential component required in her final year. "That was when I fell in love with the sea and in January 2019 I joined as a full-time staff member," said Khosa, who is pursuing a marine guiding qualification with the Field Guides Association of Southern Africa.

www.raggycharters.co.za, www.thebaywatchproject.com, www.facebook.com/raggy-charters

Why the Indian Ocean?

By Heather Dugmore and Professor Peter Burkill, Co-Chair of the Second International Indian Ocean Expedition (IIOE-2) Steering Committee and Past President of the Scientific Committee on Oceanic Research (SCOR), Emeritus Professor, University of Plymouth, UK.

The Indian Ocean remains the least known of all the global oceans, and the least scientifically studied. A strong contributing factor for this is that from the 1990s, the global economic recession resulted in the West turning its back on the Indian Ocean due to the cost of operating in far waters, and the resurgence of piracy in the region.

In the last few years, however, this has changed, as the West begins to realise the impact that this ocean has on the world's marine and the terrestrial environment.

Prof Peter Burkill and Dr Satheesh Shenoi, Co-Chairs of the IIOE-2 steering committee, at the IIOE-2 conference at Nelson Mandela University in March this year.

The monsoons

The Indian Ocean is bounded in the north by countries that include Somalia, Oman, Pakistan, Bangladesh, India and Indonesia, a region of monsoonal weather systems. Because of this there is huge upwelling of deep nutrient-rich water in the ocean during the monsoon months of June, July and August, only subsiding when the winds die down in September. This seasonal upwelling enhances the productivity of the surface waters of the ocean, and species such as migratory tuna are attracted to the area, while residents such as squid grow profusely due to the abundance of food.

One of the questions that scientists are grappling with is whether the pattern of monsoons is changing. To monitor this, data is collected over the northern Indian Ocean basins using satellites and oceanographic moorings and fed into climate models to establish changes.

Indian Ocean is warming faster

Research reveals that the surface waters of the Indian Ocean south of the equator seem to be warming faster than in any other ocean region. The regional warming pattern in the Indian Ocean is globally significant as it accounts for a large proportion of the heat assimilated by the ocean as a whole. This effect may be a crucial aspect of the ocean's role in global climate regulation. It will also have profound local effects. These include a rise in sea levels, flooding or even submerging coastal land, severe damage to coral reefs — and the effects may even extend to widespread changes in rainfall patterns.

Tipping point

The best scientific research, data and prediction models are needed if countries are to manage the impact of climate change and to avoid reaching an environmental "tipping point", beyond which it may be impossible to recover.

Sea levels are already rising at a rate of 30 to 40cm per century, with predictions that this will increase significantly in the future. About 500 million people live on land that will be submerged or exposed to chronic flooding by 2100. This will affect all low-lying countries bordering the Indian Ocean, with the Maldives, Seychelles and Bangladesh most at risk: the Maldives could be submerged within the next two decades.

The Indian Ocean is surrounded by countries in which artisanal fisheries are of significant importance for income and food, yet we know little about the impact of ocean warming and marine pollution on this critical coastal community resource. Tourism is another resource of great importance to the Indian Ocean countries. And coral reefs, a vital asset to both fishing and tourism, are bleaching and dying as a result of ocean warming.

Blue economy rapid development

Responsible stewardship of ocean resources for the blue economy depends critically on knowing what resources are where and what governs their sustainability. Since 1957, SCOR see: *https://scor-int.org/* — the Scientific Committee on Ocean Research — has been bringing together ocean scientists from all parts of the world to advance our understanding of the ocean.

SCOR sponsors the Second International Indian Ocean Expedition programme together with UN Educational, Scientific and Cultural Organisation's Intergovernmental Oceanographic and the Indian Ocean Global Ocean Observing System.

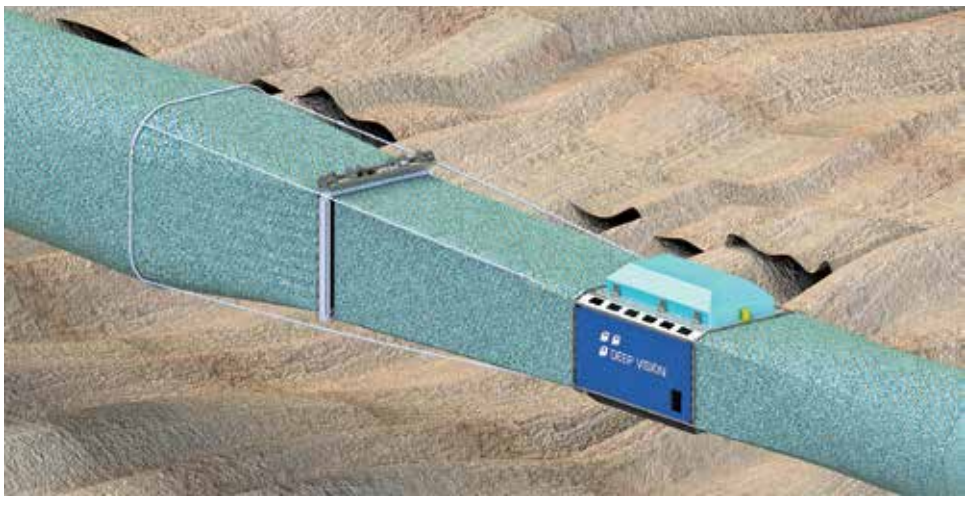
Such collaborations are essential to working out what can be done for the environment and who should be doing it. Despite what President Trump may think, human-driven climate change is a reality.

India Rapidly Gearing Up

"India has completed the mapping of this region and made a quantity assessment, but it is a question of how sustainably, safely and economically you can mine it."

"India is rapidly gearing up its blue economy and its ocean sciences research," says Hyderabad-based Dr Satheesh Shenoi, director of the Indian National Centre for Ocean Information Services, and co-chairperson of the Second International Indian Ocean Expedition (IIOE-2) steering committee.

"We are building more ports and harbours so that many more goods can be transported by ship, which is far more cost effective, with fewer carbon emissions. India is also looking at the resources in the oceans, including oil and gas and potential medicines. We recognise the critical role of our oceans in climate change, and are investing substantially in ocean research and ocean observation."



New technology such as the Scantrol Deepvision System is being used in ocean research. It takes photographs of and measures fish and invertebrates as they swim through the tunnel. There are only a few in operation at the moment and it can be modified to 3000m depth.

Monsoon winds

Sailors in the Indian Ocean have always known that the monsoon wind pattern changes twice a year, but investment in research into these winds and the many complex dynamics of the Indian Ocean is only fairly recent. With the Indian Ocean warming faster than any of the world's other oceans, the IIOE-2 is very much part of the shift towards conducting scientific research in the region.

Why the Indian Ocean is warming

Shenoi suggests two possible explanations for Indian Ocean warming that require further research:

1. The Indonesian throughflow from the Pacific has increased, bringing more of its warm water into the Indian Ocean.

2. The westerly winds over the equatorial Indian Ocean are becoming stronger, strengthening the downwelling conditions, and leading to the warming of the upper ocean.

More than 40% of the world's population lives in countries prone to cyclones, floods and droughts along the Indian Ocean, so it is important to understand how the climate affects people and their livelihoods.

A key question is how Indian Ocean warming influences the monsoons.

"We don't know the answer to this yet," Shenoi replies. "Some of the published research indicates that warming is happening more at the subsurface layers, in which case it won't immediately affect the atmosphere. But is it a matter of time before the ocean transfers the heat to the surface? Increased surface temperature is certain to affect the African and Asian monsoons; the entire regional pattern could change, with either increased or decreased rains. All this will directly affect the Indian Ocean populations and their livelihoods."

Macroeconomic level: Looking to the ocean

At a macroeconomic level, India is a major importer of oil and it is looking to the ocean for an alternative, with the discovery of solidified methane gas deposits on the ocean floor.

"India is one of the pioneer investors in future ocean technology, but it might take another decade to develop the technology to extract these deposits without losing the methane," Shenoi explains. "Another example is the technology required to mine the deposits of manganese, zinc, cobalt and several other metals at a depth of about 500 metres in the central Indian Ocean.

"India has completed the mapping of this region and made a quantity assessment, but it is a question of how sustainably, safely and economically you can mine it. These metals are used to make alloys for many purposes – from engineering to technology. Assessments predict that these will run out on land in about 30 years, so these ocean deposits will become a critical resource. In all forms of ocean management – from conservation to mining – we need to think several decades ahead. It's a very short period of time in the greater scheme of things."

http://www.incois.gov.in

Interconnected ocean power and its influence on the Earth's rotation

Massive exchanges of water between the Pacific and Indian Oceans emphasise the interconnectivity of the world's oceans, with significant climate-related implications.

Dr Satheesh Shenoi was part of a group of scientists from France and the Indian National Centre for Ocean Information Services (INCOIS) working on this research. Their findings were published in April in the journal *Nature Communications,* in a paper titled: Basin-wide Sea Level Coherency in the Tropical Indian Ocean Driven by Madden–Julian Oscillation. (**Rohith et al.** ***https://www.nature.com/articles/s41467-019-09243-5***)

Sea level rise or fall of ~4cm

Excerpts from this paper read as follows: During the months of December to April, the Indian Ocean routinely gains or loses ~three trillion tons of water from the Pacific Ocean every ~30 to 80 days accompanied by a sea level rise or fall of ~4cm, which is ~ 30% of the total sea-level change during the period. This process is driven by intense winds hovering over a very small area in the eastern Indian Ocean. This intense wind is associated with a little-known tropical weather phenomenon known as Madden-Julian Oscillation (MJO).

Effect on the GPS

The rise and fall of the sea level in the Indian Ocean leads to mass exchanges between the Indian Ocean and the Pacific Ocean. Such large mass exchanges are known to influence the polar motion of the Earth and the length of the day, the variability of which is of utmost importance to the accuracy of the Global Positioning System (GPS).