The University of Western Australia
Achieve International Excellence

The UWA Oceans Institute

RESEARCH HIGHLIGHTS 2011

ACHIEVE INTERNATIONAL EXCELLENCE

> "The oceans have the potential to supply the resources to meet the food, water and energy needs of more than nine billion people — the predicted global population by 2050. But we need to do much more than simply denounce the current problems we face. We need to both alert society to the problems, and drive and guide society through to the solutions."
>
> ***Winthrop Professor Carlos Duarte, Director of The UWA Oceans Institute***

Ocean solutions
for humanity's grand challenges

Advancing knowledge to safely and sustainably deliver water, food, energy and bioresources from our oceans

Strategy

The UWA Oceans Institute is focusing on the sustainable and innovative management of ocean resources to create wealth.

We aim to develop untapped opportunities to generate ocean-based solutions to safely and sustainably provide critical resources for human development, including water, food, energy and bioresources.

At the same time, we are committed to reconcile the delivery of wealth from the oceans with the conservation of the biodiversity and ecosystems that support these resources.

Underpinned by excellence in research, the deliberate exploration of ocean solutions can generate great opportunities for innovation, providing a competitive advantage to the industry partners collaborating with us to deliver this vision.

A maritime nation

Australia is a maritime nation with more territory in the ocean than on land and an economy that heavily relies on its oceans, through fisheries, oil and gas and tourism.

Australia has the potential to lead the world in the development of safe and sustainable uses of our ocean resources, opening a pathway of wealth and well-being through what is, in effect, our last frontier.

IMAGE / CORAL REEF
(PHOTO: BEN PIEK)

Highlights

Researchers at The UWA Oceans Institute made significant discoveries across a range of disciplines in 2011, shedding light on important issues surrounding our oceans. Our top research highlights are showcased in the following pages. (See page 23 for a full list of the Institute's scientific publications.)

New insights
into the history of an ancient seagrass

One of the most ancient genera of seagrasses, *Posidonia*, may have a radically different evolutionary history than previously thought, according to an international study.

Posidonia is one of Australia's most important genera of seagrass, covering some 5000 square kilometres of ocean floor, and providing food and shelter to countless marine organisms.

New research involving Professors Gary Kendrick, Di Walker and Carlos Duarte from The UWA Oceans Institute suggests that the genus — comprised of one recognised species in the Mediterranean and seven in the waters around Australia — evolved very differently than what we previously thought.

Comprehensive DNA studies indicate that the Mediterranean and Australian groups split from each other around 65 million years ago — 50 million years earlier than suggested in other recent studies.

The new estimate for the split coincides with the mass extinction event that wiped out the dinosaurs. This catastrophic episode might have been responsible for the extinctions of *Posidonia* ancestors, which explains the long period of separation between the existing Mediterranean and Australian groups.

Another major finding was that despite differences in appearance, four of the Australian species are genetically indistinguishable. In other words, they in fact appear to be a single species — perhaps only morphologically distinct because they grow in different environments. Another possibility is that the four lineages, which make up the *Posidonia ostenfeldii* complex, have only recently diversified and are still undergoing speciation.

Whichever the case, the remarkable lack of species diversity in *Posidonia* shows it has among the slowest DNA evolutionary rates reported for any herbaceous plant. The research is continuing but with a different focus: the genetics of populations across Australia.

The fieldwork in Australia was supported by a Fisheries Research and Development Corporation grant and an ARC Discovery grant.

Aires T, Marbá N, Cunha RL, **Kendrick GA**, **Walker DI**, Serrao EA, **Duarte CM**, Arnaud-Haond S (2011). Evolutionary history of the seagrass genus *Posidonia*. *Marine Ecology Progress Series* **421**: 117-130.

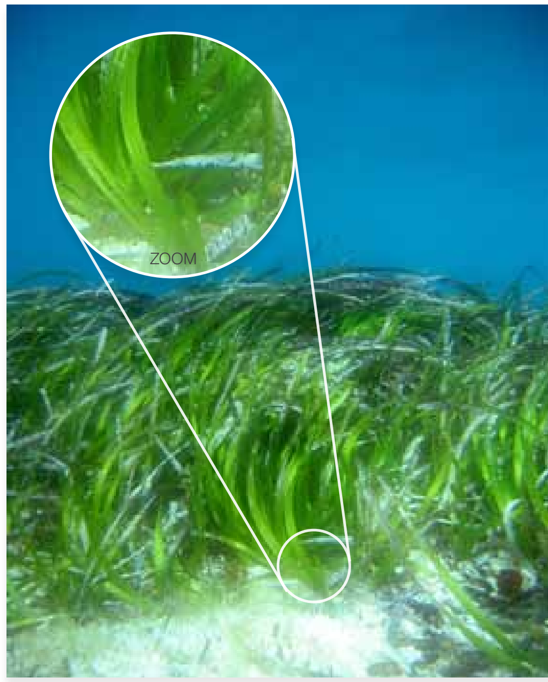


IMAGE ABOVE/ THE RESEARCH SHOWS THAT AUSTRALIAN *POSIDONIA* SPECIES SPLIT FROM THEIR MEDITERRANEAN ANCESTORS AROUND 50 MILLION YEARS EARLIER THAN PREVIOUSLY THOUGHT. (PHOTO: GARY KENDRICK)

IMAGE LEFT/ WEEDY SEADRAGON – MARMION MARINE PARK. (PHOTO JACQUI MCGHIE)

Marine life
off Australia most at risk

Marine life in the areas to the north of Australia and elsewhere along the Equator, as well as the waters off Australia's east coast, have emerged as being at particular risk from temperature changes due to climate change, according to a study published in *Science*.

The researchers analysed global temperatures from 1960 to 2009 to determine the velocity of climate change on land and at sea over the past 50 years, which sets the pace at which marine life must shift their distribution to keep within the same temperature regime.

They found that the velocity of climate change is pronounced in the biodiversity hotspot of the 'Coral Triangle' off Australia, which includes the waters of New Guinea, Indonesia and the Solomon Islands.

The paper's authors include Winthrop Professor Carlos Duarte, Director of The UWA Oceans Institute. Professor Duarte was one of several Australian researchers among the 19 co-authors, with lead researcher Dr Mike Burrows of the Scottish Association of Marine Science.

They also studied seasonal shifts, such as spring arriving earlier due to the effects of climate change. Such changes mean that organisms may have to move to areas where temperatures are conducive to their seasonal activities such as reproduction and migrations.

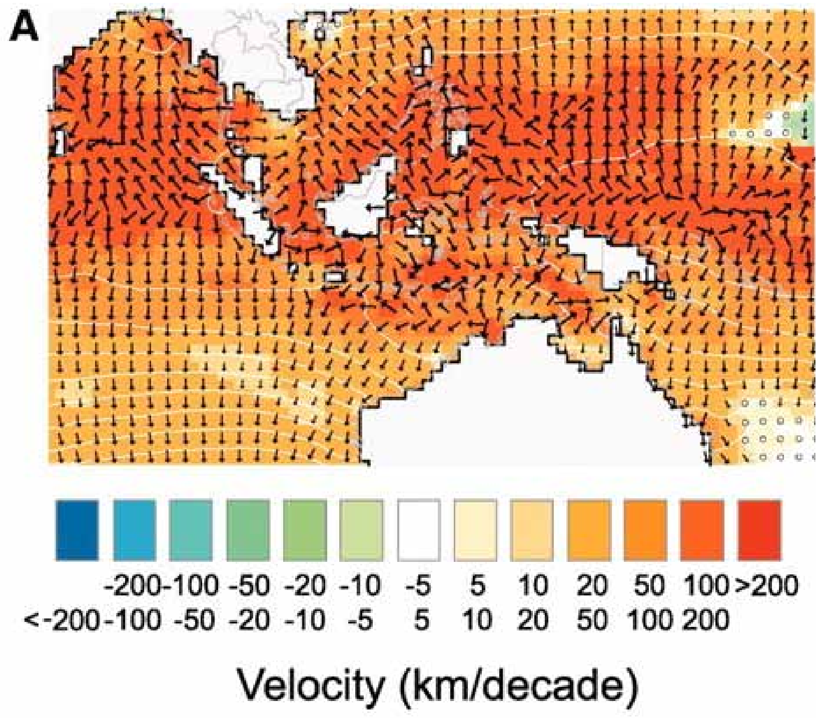


DIAGRAM ABOVE/ TEMPERATURE REGIMES ARE SHIFTING RAPIDLY IN THE 'CORAL TRIANGLE' OFF AUSTRALIA, WHICH INCLUDES THE WATERS OF NEW GUINEA, INDONESIA AND THE SOLOMON ISLANDS. (IMAGE: *SCIENCE*)

Professor Duarte said the challenge for marine organisms is to either move to areas so they remain within their temperature 'comfort zone', adapt to the new conditions, or face extinction.

"Marine organisms can shift their distribution to track the temperature regime they require, but can be left behind and forced to adapt when the velocity of climate change is too fast to cope, or where land masses intersect the migration pathways," Professor Duarte said.

"This seems to be the situation in the Coral Triangle north of Australia, where temperature shifts are particularly fast and where the presence of Australia may interfere with the displacement of biological ranges."

Burrows MT, Schoeman, DS, Buckley LB, Moore P, Poloczanska ES, Brander KM, Brown C, Bruno JF, **Duarte CM**, Halpern, BS, Holding J, Kappel CV, Kiessling W, O'Connor MI, Pandolfi JM, Parmesan C, Schwing F, Sydeman WF, Richardson AF (2011). The pace of shifting climate in marine and terrestrial ecosystems. *Science* **334**: 652-655.

Sharks
may be colour blind

New research on how sharks see may help to prevent attacks on humans and assist in the design of fishing gear to reduce shark bycatch in long-line fisheries.

The joint study between researchers at The University of Western Australia and The University of Queensland looked at the potential for colour vision in a number of Australian shark species.

Associate Professor Nathan Hart and his team measured the light-sensitive cells in the sharks' eyes using a specialised instrument called a microspectrophotometer and concluded that they have only one type of cone photoreceptor in the retina.

"Humans have three cone types that are sensitive to blue, green and red light, respectively, and by comparing signals from the different cone types we get the sensation of colour vision," Professor Hart said.

"However, we found that sharks have only a single cone type and by conventional reckoning this means that they don't have colour vision."

"It has long been assumed that sharks have some sort of colour vision and indeed have a preference for certain colours.

"Our study shows that contrast against the background, rather than colour per se, may be more important for object detection by sharks, and this may help us to design long-line fishing lures that are less attractive to sharks whilst still effective for the target fish species — and thus help to reduce the massive bycatch of sharks in this industry."

One of the shark species studied by Professor Hart and his colleagues, the bull shark (*Carcharhinus leucas*), is responsible for numerous attacks on humans.

IMAGE ABOVE/ THE BULL SHARK, RESPONSIBLE FOR NUMEROUS ATTACKS ON HUMANS, WAS ONE OF THE SPECIES STUDIED.

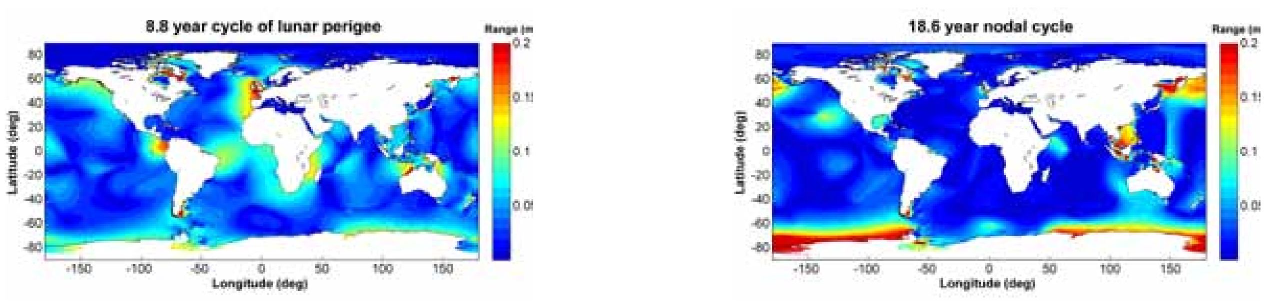
"Now we know a bit more about how such sharks see the world, it may be possible to design swimming attire and surf craft that have a lower visual contrast to sharks and, therefore, are less 'attractive' to them," he said.

"After all, most shark attacks are thought to be the result of curiosity on the part of a shark that has been attracted to an unusual stimulus, rather than some premeditated ambush."

Hart NS, Theiss SM, Harahush BK and **Collin SP** (2011). Microspectrophotometric evidence for cone monochromacy in sharks. *Naturwissenschaften* **98**: 193-201.

How lunar cycles
affect high tide levels

A deeper understanding of how the Moon's orbit influences high tides will help improve predictions of coastal flooding across different parts of the world.



DIAGRAMS ABOVE / THE INFLUENCE OF THE DIFFERENT LUNAR CYCLES VARIES DRAMATICALLY ACROSS THE GLOBE. (IMAGES: IVAN HAIGH)

Major coastal floods in the last decade, such as Hurricane Katrina and Cyclone Nargis, have highlighted the enormous damage that extreme sea level events are capable of. By understanding the factors that lead to high sea levels, such as high tides and storm surges, we can better predict the periods of increased risk — and eventually help save lives.

A study led by Dr Ivan Haigh from The UWA Oceans Institute and School of Environmental Systems Engineering assessed how two aspects of the lunar orbit, the nodal cycle and the cycle of lunar perigee, influence high tide levels all around the world.

The 18.6 year nodal cycle relates to the lunar nodes — the occasions where the apparent path of the Moon and Sun (as seen from Earth) intersect.

The 8.8 year cycle of lunar perigee relates to the Moon's elliptical orbit around the Earth. The phase is determined by the positions at which the Moon is closest (perigee) and farthest (apogee) from the Earth.

The research showed that the influence of each lunar cycle depends on where you are in the world.

The nodal cycle affects tidal range by up to 80cm in places with large daily tides, such as the South China Sea and the Gulf of Carpentaria. The shorter cycle generally has a slightly smaller affect — although up to 60cm — with the biggest impact in places with large twice-daily tides, including the Northwest Shelf of Australia.

An important finding of the study is that the phase of the nodal cycle depends on the form of the tides. At locations with daily tides, the nodal cycle last peaked in 2006 and will peak again in 2024. In contrast, at locations with large twice-daily tides the nodal cycle last peaked in 1997 and will peak again in 2015, resulting in increased likelihood of coastal flooding over this period.

The effects might sound small, but even a 10cm difference in tide range means a three times greater probability of extreme flood events in many parts of the world. So the knowledge of when and where high tides will occur in the future could be invaluable to vulnerable coastal communities.

The study was funded through the Western Australian Marine Science Institution (WAMSI).

Haigh I, **Eliot M** and **Pattiaratchi CB** (2011). Global influences of the 18.61 year nodal cycle and 8.85 year cycle of lunar perigee on high tidal levels. *Journal of Geophysical Research—Oceans* **116**: C06025.

Smallest plankton
play a big role in reef communities

New research shows that bacteria, viruses and other minute plankton are a major food source for fringing coral reef communities, such as Ningaloo Reef.

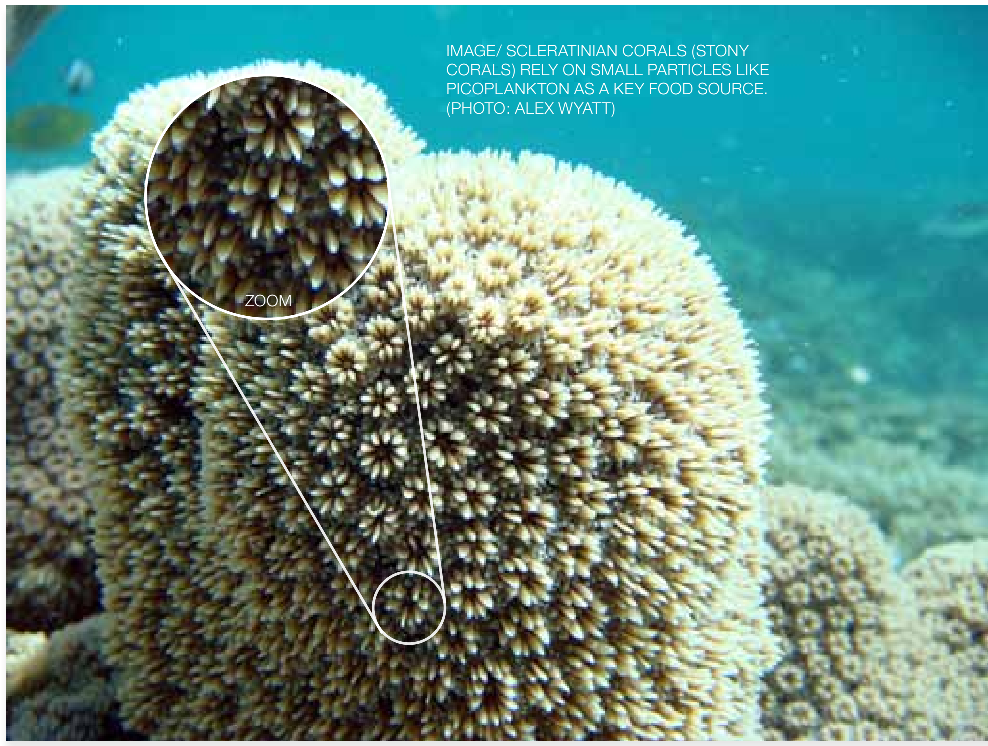
As coral reefs worldwide come under increasing pressure from threats such as climate change, it's important that we understand the factors controlling their health and productivity.

Traditionally, research into the key food sources for reef organisms like corals and sponges has focused on large particles, such as zooplankton and microplankton. In recent years, oceanographers have also confirmed the importance of picoplankton (tiny cells between 0.2 and 2 μm).

But a new study at Ningaloo Reef — led by Dr Nicole Patten from The UWA Oceans Institute and School of Environmental Systems Engineering — was the first to measure how a reef community collectively removed bacteria, viruses, and picophytoplankton from seawater as it flowed across the reef.

It was also the first study to measure picoplankton and viruses within a coral reef system inside the East Indian Ocean Rim.

The results show that the reef community relies heavily on these tiny organisms. As they flowed across the reef from the ocean toward the shore, levels of bacteria and picophytoplankton (picoplankton that photosynthesise) were depleted, on average, to about 40 per cent. Viruses, which are the most abundant cell type in coral reef waters, were depleted also, but to a more variable degree.



IMAGE/ SCLERATINIAN CORALS (STONY CORALS) RELY ON SMALL PARTICLES LIKE PICOPLANKTON AS A KEY FOOD SOURCE. (PHOTO: ALEX WYATT)

It is unclear which organisms comprising the Ningaloo Reef community are the dominant consumers of these plankton, and how minute plankton and other microbes are being assimilated into the coral reef food web. What the study shows, however, is that remotely produced bacteria, viruses and picophytoplankton are highly important for the healthy function of fringing coral reef communities.

Patten NL, **Lowe RJ**, **Wyatt ASJ** and **Waite AM** (2011). Uptake of picophytoplankton, bacterioplankton and virioplankton by a fringing coral reef community (Ningaloo Reef, Australia). *Coral Reefs* **30**(3): 555-567. doi: 10.1007/s00338-011-0777-8

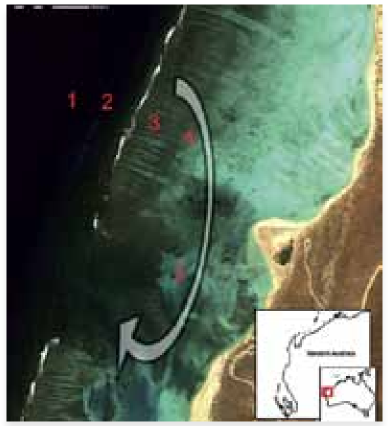


IMAGE ABOVE/ THE RESEARCHERS MEASURED THE ABUNDANCE OF BACTERIA, VIRUSES AND PICOPLANKTON AT FIVE STATIONS ACROSS THE REEF. (PHOTO: NICOLE PATTEN)

Coral geochemistry
reveals built-in resistance to ocean acidification

New insights into how corals can adjust to changes in water chemistry reveal a 'built-in' resilience to ocean acidification.

The future of many marine calcifiers is under threat from increasing CO_2, not only due to global warming, but also from the process of ocean acidification. Much of the CO_2 released from human activities is being taken up by the oceans, reducing seawater pH. This in turn affects the ability of marine species such as corals and molluscs to calcify their skeletons.

A major concern is how marine biota will be affected by this process, with some recent predictions suggesting the wholesale demise of coral reef ecosystems within decades if CO_2 emissions remain unabated.

These predictions however assume that the biological fluids from which corals secrete their carbonate skeletons have a pH similar to seawater, and so are extremely sensitive to any changes in seawater pH, such as those caused by ocean acidification.

New research involving Assistant Professor Julie Trotter and Winthrop Professor Malcolm McCulloch, from The UWA Oceans Institute and the School of Earth and Environment, has provided new perspectives on this important problem.

IMAGE ABOVE/ COLONY OF *CLADOCORA CAESPITOSA*, A TEMPERATE WATER CORAL FROM THE MEDITERRANEAN. (PHOTO: SERGIO SILENZI)

Using the isotopic composition of boron found in tropical and temperate shallow water coral skeletons, it has been possible to determine the coral's pH during the calcification process.

These results have revealed that corals adjust, or up-regulate, their internal pH in constant proportion to external seawater pH. Importantly, this allows corals to continue growing their skeletons over a much wider range of pH than previously thought, providing them with some 'built–in' resilience to the effects of ocean acidification.

Palaeoseawater pH can now also be accurately calculated from boron isotope measurements of long-lived corals, which is important to determine the natural variability of seawater pH and establish the likely thresholds of coral tolerance to increasing CO_2. Continued work is also focused on determining the inherent resilience and susceptibility of other marine calcifiers to ocean acidification.

Trotter J, Montagna P, **McCulloch MT**, Sergio Silenzi S, Reynaud S, Mortimer G, Martin S, Ferrier-Pages C, Gattuso JP and Rodolfo-Metalpa R (2011). Quantifying the pH 'vital effect' in the temperate zooxanthellate coral *Cladocora caespitose*: Validation of the boron seawater pH proxy. *Earth and Planetary Science Letters* **303**: 163-73 doi: 10.1016/j.epsl.2011.01.030.

Ocean flora
retreating to the brink

A new study has found that the warming ocean climate is causing seaweed communities, on which fauna survive, to retreat towards the brink of the continent and possibly extinction.

According to research led by Assistant Professor Thomas Wernberg from The UWA Oceans Institute, modern seaweed communities to the south are becoming more similar to past communities in the north, with several temperate species contracting poleward (south).

The results published in the journal *Current Biology* predict that, given future warming, up to one quarter of species in southern Australian waters might retract towards local extinction.

The researchers studied a database of more than 20,000 herbarium records of macroalgae collected in Australia since the 1940s, and found changes in seaweed communities in both the Indian and Pacific Oceans, consistent with rapid warming over the past decades.

"We found that continued warming might drive potentially hundreds of species towards the edge of the Australian continent, beyond which there is no refuge," Professor Wernberg said.

The researchers believe while some species may be able to make adjustments to cope with natural cooling and warming cycles, the predicted rate and strength of warming in the coming decades could force many retreating species beyond the limits of available habitat.

"The potential for global extinctions is concerning because about one quarter of all macroalgal species in the world are found off Australia and these marine habitats support equally unique fish and invertebrate communities," Professor Wernberg said.

Wernberg T, Russell BD, **Thomsen MS**, Gurgel CFD, Bradshaw CJA, Poloczanska ES, and Connell SD (2011). Seaweed communities in retreat from ocean warming. *Current Biology* **21**: 1828-1832.

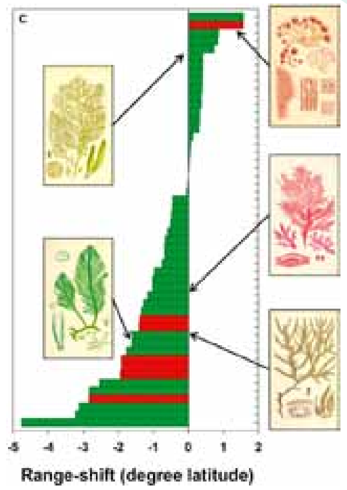


DIAGRAM ABOVE/ THE SHIFT IN NORTHERN RANGE LIMITS OF TEMPERATE SEAWEEDS ON THE WEST (GREEN) AND EAST (RED) COAST OF AUSTRALIA FROM 1940-1960 AND 1990-2009. (COLOUR PLATES OF SELECTED ALGAE FROM HENRY HARVEY'S *PHYCOLOGIA AUSTRALICA*, 1858–1863)

IMAGE BELOW/ THE STUDY LOOKED AT HOW THE DISTRIBUTION OF 52 SEAWEED SPECIES CHANGED IN AUSTRALIA SINCE THE 1940S. (IMAGE: THOMAS WERNBERG)

IMAGE/ THOMAS WERNBERG

Research Areas

The UWA Oceans Institute brings together the strength of UWA's researchers into a multidisciplinary, integrated research focus. The Institute's core research areas include:

Blue water oceanography

IMAGE/ YASHA HETZEL

The UWA Oceans Institute is a significant research provider in oceanography, with a focus on observations in biological, biogeochemical and physical oceanography, as well as the numerical modelling of coupled ocean physical-biological processes.

Biological oceanography

We are investigating the drivers of productivity and carbon flow in plankton food webs, including the regulation of settling fluxes, the role of environmental conditions in driving plankton dynamics, and the impact of global change (such as persistent organic pollutants, enhanced UV radiation, ocean warming and ocean acidification) on oceanic plankton communities. This includes coupling between physical ocean dynamics and meroplankton dynamics.

Ocean biogeochemistry

Our research is focused on carbon and nutrient fluxes in the ocean ecosystem (ranging from local to global scales), the role of micronutrients and trace elements in driving ocean production, and the exchanges of carbon and biogenic elements between the atmosphere and the mixed layer, as well as between the mixed layer and the ocean interior.

Physical oceanography

We focus on the field and numerical modelling of the physical properties of the ocean (such as ocean circulation and temperature variability). These are based on fluid mechanic principles that can be transferred across regions, as well as on coupled physical-biological models. In addition, this research examines ocean optics, particularly UV penetration and absorption in the ocean ecosystems, and the dynamics of ocean systems forced by tidal stirring.

Megafauna oceanography

This emerging field uses megafauna, such as sea lions or turtles, to sample the oceans. Instrumenting megafauna with small CTD and other oceanography sensors allows us a new opportunity to sample the oceans in the way megafauna do. Because these animals are engaged in very long range migrations, they provide data of the oceanographic structures they encounter and also sample the oceans in a deliberate way, searching the structures that conform to their requirements (feeding, reproduction, etc.).

Core members (in alphabetical order): Susana Agustí, Carlos M. Duarte, Greg Ivey, Nicole Jones, Ryan Lowe, Charitha Pattiaratchi, Anya Waite.

Coastal processes

Our researchers are investigating coastal processes, including observations, modelling and forecasts of tidal forcing of coastal environments, wave dynamics, sea level rise and sediment transport, interactions between organisms and flows, as well as transport processes across the continental shelf.

This research is complemented with an intense activity in the development and operation of coastal observing systems and remote vehicles, particularly gliders.

This research component is essential to determine risks and threats to WA coastal areas, and includes the leadership of the Australian node of the Indian Ocean Tsunami Warning System.

Core members (in alphabetical order): Marco Ghisalberti, Pauline Grierson, Nicole Jones, Ryan Lowe, Charitha Pattiaratchi, Anya Waite.

IMAGE/ YASHA HETZEL

Marine ecology

The UWA Oceans Institute conducts research on the dynamics and structure of a broad range of marine ecosystems, communities and populations, with particular emphasis of those ecosystems most important in the Indian Ocean.

Coral reef ecology

We use quantitative, process-based methods to gain an understanding of present and past reef growth, metabolism, and calcification rates in relation to environmental factors. The research addresses the functioning of the entire reef ecosystem, from the individual components, including reef fauna and symbiotic zooxanthella, to whole-system processes, such as metabolic rates.

Fish ecology

We study the demography and population dynamics of fish, habitat requirements and the evolutionary ecology of fish. Over the past 15 years, we have developed an ongoing range of non-destructive sampling techniques using stereo-video cameras to achieve this.

Marine neurobiology

Our researchers use innovative neurobiological techniques to investigate the neural basis of behaviour in marine organisms. Such techniques include molecular genetics, microspectrophotometry, bioimaging, electrophysiology and anatomy to trace the evolution of light detection and image formation, and to explore the impacts of light on biodiversity, sustainability and environmental health.

In addition to both basic and applied studies of the influences of light on animal behaviour, other sensory modalities are now being investigated, including the detection of chemosensory signals, electric fields, water borne sound and hydrodynamic disturbances.

Marine biomineralisation

We are investigating the formation of complex natural structures, such as teeth, shells and skeletons. Using a range of cutting-edge imaging and characterisation techniques, researchers investigate cellular structure-function relationships, crystal formation and growth, structure and properties of organic scaffolds, elemental uptake pathways and distributions, and the immunological properties of biomineralised tissues.

Microbial ecology

Our research aims to improve understanding of the diversity, roles and relationships of marine micro-organisms. We address the biodiversity, interactions and ecology of free-living, epiphytic and symbiotic marine bacteria.

Seagrass and macroalgal ecology

This research area centres on the production and population dynamics of seagrass ecosystems, including understanding their responses and recovery from pressures, their role in carbon cycling in the coastal zone, and the dynamics of seagrass landscapes.

Spatial ecology

We focus on the description and understanding of the drivers and patterns of both species and assemblage distribution. Some of the techniques used are continuous coverage mapping, specialising in waters too deep for spectral remote sensing, and distribution modelling.

Core members (in alphabetical order): Marion Cambridge, Peta Clode, Shaun Collin, Carlos M. Duarte, Nathan Hart, Euan Harvey, Gary Kendrick, Tim Langlois, Malcolm McCulloch, Jessica Meeuwig, Nicola Mitchell, David Sutton, Julie Trotter, Kimberly Van Niel, Thomas Wernberg.

IMAGE/ JACQUI MCGHIE

Ocean engineering

The UWA Oceans Institute conducts research to advance the safe extraction of resources in the marine environment to derive energy, food and water from the oceans and the sea floor and transport it safely to land.

Because of the growth of these activities in Western Australia, the Oceans Institute is perfectly located to build strong relationships with industry and other organisations.

The challenge of ocean engineers is to design, build and maintain the structures used to extract and transport marine resources so that they run effectively, safely and with minimal damage to the environment.

Ocean engineers not only need a combination of skills derived from the disciplines of civil, mechanical and electrical engineering; they also require a thorough understanding of other oceanographic disciplines such as marine biology, chemical and physical oceanography, marine geology and geophysics.

IMAGE/ WOODSIDE ENERGY

Offshore foundation systems

For more than twelve years the Centre for Offshore Foundation Systems (COFS) has been researching the mechanics of seabed sediments, offshore foundation systems, the stability of offshore platforms, pipeline and deep water offshore engineering and marine geohazards.

The Centre consistently produces research findings of international standard and recognition. World class facilities have allowed UWA to service the offshore oil and gas industry at a national and international level.

COFS has one of the largest teams of internationally recognised researchers and engineers in offshore geomechanics in the world.

COFS also maintains world-leading geotechnical centrifuge and soils testing equipment.

Near shore and offshore engineering

Deep sea environments can be very harsh and pose many challenges to both fixed and floating structures such as offshore oil rigs.

One of the greatest challenges in building structures that can survive these conditions is the different loads that the structures experience during installation as they are lowered to the sea floor.

UWA researchers are investigating dynamic lifting factors to determine safer practices for subsea installations and the development of installation vessels. We also study the structural fatigue from ocean currents, called vortex-induced motions, to improve designs.

Floating structures used for oil and gas production, such as large tankers moored to the sea floor, behave in an unpredictable manner when sea states get complex.

For example, the research team is studying the motion response of one of these floating structures in seas where the long-period swells and short-term seas approach from different directions, as is common in north-west WA.

In the near-shore area, we have investigated the behaviour of concrete gravity structures when in close proximity to the seabed during tow-out from casting basins, and have researched wave-breaking and run-up in coastal structures.

Core members (in alphabetical order): Mark Cassidy, Scott Draper, Christophe Gaudin.

Marine biological resources,
management, governance and conservation

Research at The UWA Oceans Institute provides a basis to inform effective policies and management frameworks, while conserving functional and diverse marine ecosystems.

This is a challenge that requires the integration of expertise — now possible under the broad collaborative and interdisciplinary platform that the Institute provides to align and articulate research capabilities in natural and social sciences and technologies.

Marine conservation
By combining natural and social sciences, we can translate existing science into policy outcomes. The Oceans Institute helps to break down barriers to effective management of the marine environment, leading to the conservation of biodiversity and cultural heritage.

Marine biotechnology
Unlocking the genome of marine organisms has opened the door to new opportunities across a range of industries, including food, cosmetic, biomedical and energy. A key focus of the Institute is the use of living marine resources — from entire organisms to molecules to genes — to solve problems and deliver key innovations.

Maritime law and governance
This area involves spatial planning in the marine environment, national and international regulatory frameworks for biodiversity conservation, the governance of economic exclusive zones and areas beyond national jurisdiction in the Indian Ocean, and the governance of new and emerging maritime sectors and activities.

Marine resource economics
We focus on the valuation of marine ecosystem resources and services in support of policy and management, and aim to shape positive public perception and attitudes toward the marine environment.

Spatial planning
Our research provides the basis for safe and sustainable human operation in the marine environment. We evaluate the risks and synergies, both positive and negative, involved in the interactions between human activities — from fishing and boating to offshore exploration and drilling — and the sensitive biological and cultural elements therein. We consider the social and psychological drivers of perceived conflicts and reluctance towards innovation; and provide governance frameworks that adequately address the complexity inherent to the continuity and connectivity of the marine environment.

Core members (in alphabetical order): Michael Burton, Carlos M. Duarte, Euan Harvey, Stuart Kaye, Jessica Meeuwig, Nicola Mitchell, Alistair Paterson, David Sutton, Erika Techera, Kimberly Van Niel.

IMAGE TOP/ ADAM CAMPBELL

IMAGE BOTTOM LEFT/ JUSTINE SANDERSON

Impacts of climate change
in the marine environment

The UWA Oceans Institute is focusing its research strengths and capacities to understand, forecast and mitigate the impacts of climate change on the marine environment.

Climate change is arguably one of the greatest challenges affecting the functionality and health of our oceans, as well as the safety of our operations at or near the marine environment. Since the trajectories and impacts of climate change are strongly dependent on societal and technological factors, the Institute's strong interdisciplinary capacity positions us as a key resource to provide knowledge to guide society and policy to address this important problem.

Sea level rise, coastal flooding and surges
Climate change is forecast to accelerate sea level rise, but the impact of this rise will vary greatly along the world's coasts. Rising water levels are compounded by long-term cycles and a range of other factors — such as changes in precipitation patterns, land use and coastal erosion — that need be considered in predictions of regional sea level rise and to assess the risk of coastal floods.

Impacts of climate change on marine ecosystems
We are building an understanding of the responses of marine organisms, communities and ecosystems to climate change. The goal is to forecast trajectories in biodiversity conservation and ecosystem function, and to intervene through management strategies and policies aimed at maintaining healthy ecosystems.

Carbon pools, cycling and sequestration in the marine environment
The capacity of the oceans to remove CO_2 from the atmosphere is one of the key buffers to climate change. We are researching and quantifying the capacity of marine ecosystems to act as carbon sinks, which is of fundamental importance for climate forecasting. Similarly, the increased CO_2 in seawater is causing ocean acidification, which may adversely affect marine organisms such as calcifiers — the essential components of our valuable coral reefs.

Multiple stressors
Climate change trajectories occur in parallel to major changes in other important components of the Earth System. We are investigating the compounding effects of changes in UV radiation; changes in the cycles of nitrogen, phosphorus, water and other key elements; and changes in the loads and range of pollutants reaching the marine environment.

Adaptation and mitigation of climate change
The deep understanding of the marine environment, delivered through an interdisciplinary approach, offers multiple opportunities to deploy strategies to mitigate climate change. We can achieve this by increasing the supply of energy from marine renewable sources or enhancing natural marine carbon sinks. And we can adapt to climate change through the use of ecosystems to dissipate energy, reduce coastal flooding and erosion, and by adaptively managing marine resources to accommodate their trajectories with climate change.

Core members (in alphabetical order): Susana Agustí, Bryan Boruff, Marion Cambridge, Peta Clode, Carlos M. Duarte, Euan Harvey, Greg Ivey, Nicole Jones, Gary Kendrick, Tim Langlois, Ryan Lowe, Malcolm McCulloch, Jessica Meeuwig, Nicola Mitchell, Charitha Pattiaratchi, David Sutton, Julie Trotter, Kimberly Van Niel, Anya Waite, Thomas Wernberg.

IMAGE TOP RIGHT/ YASHA HETZEL

IMAGE TOP LEFT/ ALEX WYATT

Marine observation,
monitoring and risk management

The UWA Oceans Institute is committed to the need to observe and monitor the marine environment. Our researchers deliver the knowledge and data required to detect changes, identify their drivers, and manage the risks associated with natural changes or those resulting from the increased scale of human operation in the marine environment.

Marine observation

Observing the oceans is critical for all of the Institute's goals. We observe the oceans through an array of technologies, including advanced gliders — hosting the National Glider Facility, part of the Australian Integrated Marine Observing System (IMOS) — mooring systems, surveys using towed videos, baited video arrays, investigating changes in the carbon chemistry of our coastal and marine systems, and the reconstruction of past conditions through records extracted from corals and other biological structures.

Marine forecast

We are generating capabilities in operational oceanography and in the development of models able to forecast changes in the marine environment and the response of the marine ecosystem.

Tsunami alert systems

Oceans Institute researchers are leading participants in the Coordinating Group for the Indian Ocean Tsunami Warning and Mitigation System, and are active in modelling tsunamis to better assess risks and defence strategies.

IMAGE TOP RIGHT/ JOAN COSTA

IMAGE RIGHT/ GARY KENDRICK

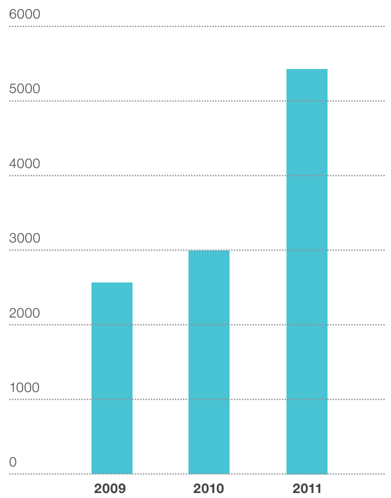
Risk management

We study the impacts — on both individuals and communities — of extreme natural events, human-induced hazards and changes to our climate, and use our expertise to inform policies and strategies to minimise the impacts from these risks. Our goal is to help build resilience and the adaptive capacity of coastal populations despite increased interactions between societies and the oceans.

Core members (in alphabetical order): Bryan Boruff, Peta Clode, Carlos M. Duarte, Euan Harvey, Greg Ivey, Nicole Jones, Tim Langlois, Ryan Lowe, Malcolm McCulloch, Jessica Meeuwig, Nicola Mitchell, Charitha Pattiaratchi.

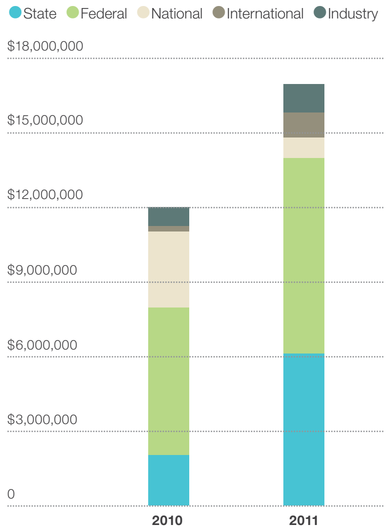
Impact

Total citations[1]



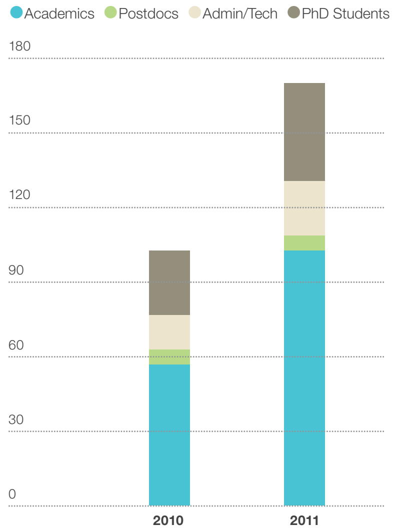
[1] Total citations for peer-reviewed journal articles by Oceans Institute members

Funding sources[2]



[2] Sources of funding for the Oceans Institue over 2010 and 2011 and total funding for that year.

Members and students[3]



[3] Total number of members and students in 2010 and 2011

Citations

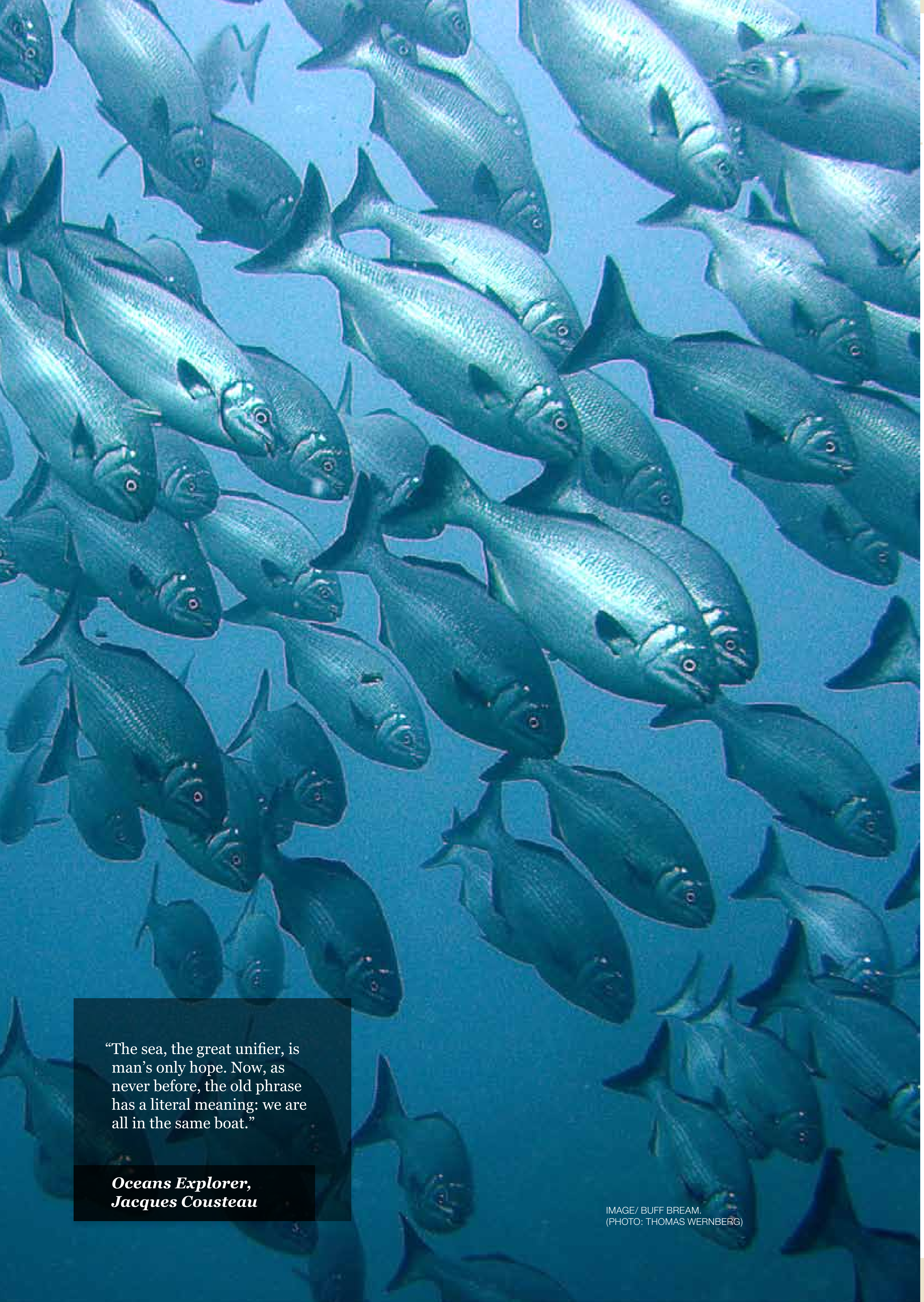
Members of The UWA Oceans Institute have had a growing impact in the marine science and engineering environment, reflected in the marked increase in citations of member papers in 2011. The past year saw the appointment of nine new members in a targeted effort to attract high impact researchers and academics, contributing to the growth in citations.

Funding sources

Funding of research projects for marine science and engineering at UWA has grown by 36 per cent since the launch of the Oceans Institute in 2011. The emerging international profile of the Institute is strengthened by an increase in funding from international sources.

Members and students

Total membership to the Oceans Institute has grown by 38 per cent. There has also been a notable rise in the number of PhD students supervised by academic members — a result of the Institute attracting multiple sources of funding for research and research personnel.



“The sea, the great unifier, is man’s only hope. Now, as never before, the old phrase has a literal meaning: we are all in the same boat.”

Oceans Explorer, Jacques Cousteau

IMAGE/ BUFF BREAM.
(PHOTO: THOMAS WERNBERG)

International
and national collaborations

Collaborative research both within the University and with our national and international partners is a key tenet of The UWA Oceans Institute.

In a world where no single person or even organisation boasts the sum of knowledge in a given research field, collaboration has become more crucial than ever. By strengthening and expanding our collaborative network we are addressing gaps in our own research capacities, increasing the quality and impact of research outcomes and setting the Institute on a path of future growth.

Some of the Ocean Institute’s key collaborative partners include:

- Australian Institute of Marine Science (AIMS)
- British Antarctic Survey, Natural Environment Research Council
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Consejo Superior de Investigaciones Cientificas (CSIC)
- Curtin University
- Department of Sustainability, Environment, Water, Population and Communities
- Environmental Research Institute Denmark
- Florida International University
- French Research Institute for Exploration of the Sea
- James Cook University
- Intergovernmental Oceanographic Commission
- Mediterranean Institute for Advanced Studies
- Murdoch University
- Oceanographic Department at the Hydrographic Institute of the Republic of Croatia
- Plymouth Marine Laboratory
- Scripps Institution of Oceanography
- Stanford University
- State Herbarium of South Australia
- Universidad Las Palmas de Gran Canaria
- Universidad Rey Juan Carlos
- University of Adelaide
- University of Bergen
- University of British Columbia
- University of Cape Town
- University of Hawaii
- University of New South Wales
- University of Queensland
- University of Siegen
- University of Southampton
- University of Southern Denmark
- University of Tasmania
- University of Washington
- Western Australian Department of Environment and Conservation
- Western Australian Department of Fisheries
- Western Australian Department of Planning and Infrastructure
- Western Australian Museum
- Wildlife Conservation Society, Fiji Islands, Suva

IOMRC
The Indian Ocean Marine Research Centre

The Indian Ocean Marine Research Centre (IOMRC) is a collaboration that brings together four of Australia's leading research organisations working in and around the Indian Ocean. These are the Australian Institute of Marine Science (AIMS), CSIRO, The UWA Oceans Institute, and the Department of Fisheries.

Through the IOMRC, the partner organisations are developing new multi-disciplinary research teams and creating a graduate training environment that will significantly advance Australia's marine science capacity, capability and profile.

By integrating the research strengths of the partners, the IOMRC will be able to address greater challenges, risks and opportunities in the sustainable and safe use of marine resources, and in the conservation of the Indian Ocean's biodiversity.

The IOMRC will build Australia's potential for international competitiveness through stimulating innovative research and the teaching and training of next generation researchers and will be the largest marine research institution in the Southern Hemisphere and the largest marine research capability in the Indian Ocean Rim.

Partners

Australian Institute of Marine Science

The Australian Institute of Marine Science (AIMS) is committed to the protection and sustainable use of Australia's marine resources. The IOMRC component has a primary focus on the pristine Ningaloo Marine Park in WA and northwest Australia.
aims.gov.au

CSIRO

CSIRO is Australia's national science agency. CSIRO manages the Marine National Facility – *RV Southern Surveyor*, and a number of marine and atmospheric collections. The research effort at CSIRO Marine and Atmospheric Research is delivered largely through CSIRO's Wealth from Oceans Flagship, and with the Bureau of Meteorology through The Centre for Australian Weather and Climate Research. The Wealth from Oceans Flagship focuses on understanding Australia's oceans and their biodiversity, resources and relationships with the climate system and provides CSIRO's contribution towards national challenges where oceans play a central role.
csiro.au/oceans

The University of Western Australia

The UWA Oceans Institute brings together the strength of marine researchers at UWA into a multi-disciplinary, integrated research focus. The goal is to capitalise on UWA's existing research strengths — in areas such as oceanography, ecology, engineering, resource management, and governance — to deliver Ocean Solutions for Humanity's Grand Challenges.
oceans.uwa.edu.au

Department of Fisheries

The Department of Fisheries in Western Australia manages the state's fish, marine and aquatic resources to world-class standards to conserve, develop and share the fish and other living aquatic resources of WA — for the benefit of present and future generations.
fish.wa.gov.au

Infrastructure

As part of the collaboration, the partners are developing new marine research facilities. This major development consists of two projects: the construction of a new $52 million IOMRC facility on UWA's Crawley campus, and an $11 million upgrade of the Department of Fisheries' Waterman Marine Research Facility, at Watermans Bay, Western Australia.

Funding support for the development of the new facilities comes from the Australian Government, through the Commonwealth Education Investment Fund ($32m), and from the partner organisations ($12m from UWA, $10m from CSIRO, $6m from AIMS and $4m from the Department of Fisheries).

The University of Western Australia will become the home for the world-class, purpose-built IOMRC and will bring together more than 240 researchers working across a broad range of subjects, extending from oceanography to marine ecology, to fisheries, geochemistry, law, marine technologies and engineering, among others.

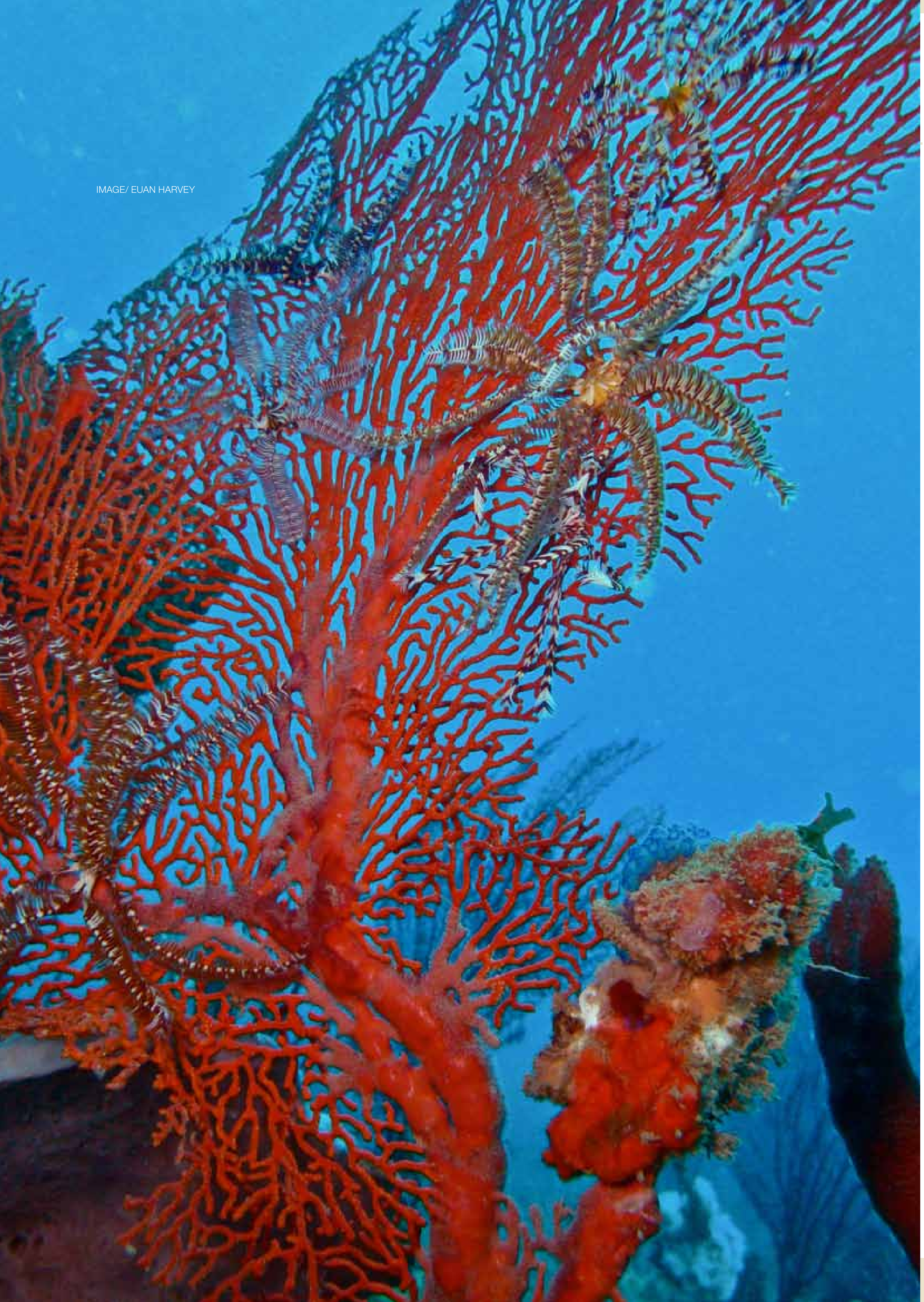
IMAGE ABOVE / ARTIST IMPRESSION OF PROPOSED NEW IOMRC FACILITY TO BE CONSTRUCTED AT UWA'S CRAWLEY CAMPUS.

The partners will not only be co-located within the same facility, laboratories and capacities will be integrated by function, enhancing the culture of collaboration and, in doing so, everyone's capability and the efficient use of public resources.

The site of the existing Waterman Marine Research facility will undergo significant refurbishment including upgrades to the internal laboratories, offices and marine cultural facilities with direct access to good quality sea water.

The upgrade and refurbishment to the existing Waterman Marine Research facility is expected to be completed by the end of 2012, with occupancy by early 2013. The completion date for the new Crawley facility is expected by the end of 2014. Upon completion the IOMRC will be set to lead the scientific exploration of the Indian Ocean.

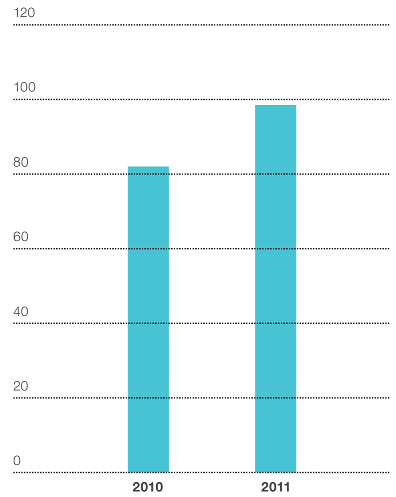
Information specific to the construction and development of these facilities can be located at:
uwa.edu.au/campusdevelopment/current-projects/iomrc



IMAGE/ EUAN HARVEY

Publications

Peer-reviewed journal articles❶



❶ Total number of peer-reviewed journal articles published by The UWA Oceans Institute members.

Oceans Institute members published 98 articles in peer-reviewed scientific journals in 2011, a 20 per cent increase from 2010. Two papers appeared in the top international journal *Science*: one on the pace of shifting climate in marine and terrestrial ecosystems (see page 4), the other which proposes a new international system to ensure the fair use of marine genetic resources.

Peer-reviewed scientific journals

1. Agawin NSR, Tovar-Sanchez A, Alvarez M, **Agustí S**, Stal LJ and **Duarte CM** (2011). Low water column nitrogen fixation in the Mediterranean Sea (Basin-wide experimental evidence). *Aquatic Microbial Ecology* **64**: 135-147.

2. Aires T, Marbá N, Cunha RL, **Kendrick GA**, Walker DI, Serrao EA, **Duarte CM** and Arnaud-Haond S (2011). Evolutionary history of the seagrass genus Posidonia. *Marine Ecology Progress Series* **421**: 117-130.

3. Arnaud-Haond S, Arrieta JM and **Duarte CM** (2011). Marine biodiversity and gene patents. *Science* **331**: 1521-1522.

4. Baird ME, Suthers IM, Griffin DA, **Hollings B**, **Pattiaratchi CB**, Everett JD, Roughan M, Oubelkheir K and Doblin M (2011). The effect of surface flooding on the physical-biogeochemical dynamics of a warm-core eddy off southeast Australia. *Deep Sea Research II: Topical Studies in Oceanography* **58**: 592-605.

5. **Barrington DJ**, **Ghadouani A** and **Ivey GN** (2011). Environmental factors and the application of hydrogen peroxide for the removal of toxic cyanobacteria from waste stabilization ponds. *Journal of Environmental Engineering, ASCE* **137**(10): 952-960. doi:10.1061/(ASCE)EE.1943-7870.0000401.

6. Bellchambers LM, **Meeuwig JJ**, Evans SN and Legendre P (2011). Modelling habitat associations of the common spider conch Lambis lambis in the Cocos (Keeling) Islands. *Marine Ecology Progress Series* **432**: 83-90.

7. Bellchambers LM, **Meeuwig JJ**, Evans SN and Legendre P (2011). Modelling habitat associations of 14 species of holothurians from an unfished coral atoll: implications for fisheries management. *Aquatic Biology* **14**: 57-66.

8. Black R, Johnson MS, **Prince J**, **Brearley A** and Bond T (2011). Evidence of large, local variations in recruitment and mortality in the small giant clam, *Tridacna maxima*, at Ningaloo Marine Park, Western Australia. *Marine and Freshwater Research* **62**: 1318-1326.

9. **Bluteau CE**, **Jones NL** and **Ivey GN** (2011). Dynamics of a tidally-forced stratified shear flow on the continental slope. *Journal of Geophysical Research—Oceans* **116**: C11017. doi:10.1029/2011JC007214.

10. **Bluteau CE**, **Jones NL** and **Ivey GN** (2011). Estimating turbulent kinetic energy dissipation using the inertial subrange method in environmental flows. *Limnology and Oceanography: Methods* **9**: 302-321. doi: 10.4319/lom.2011.9.302.

11. **Bosserelle C**, **Pattiaratchi C**, and **Haigh ID** (2011). Inter-annual variability and longer-term changes in the wave climate of Western Australia between 1970 and 2009. *Ocean Dynamics* doi: 10.1007/s10236-011-0487-3.

12. Brown CJ , DS Schoeman, Sydeman W, Brander K, Buckley L, Burrows M, **Duarte CM**, Moore PJ, Pandolfi JM, Poloczanska E, Venables W and Richardson AW (2011). Quantitative approaches in climate change ecology. *Global Change Biology* **17**: 3697-3713.

13. Burrows MT, Schoeman, DS, Buckley LB, Moore P, Poloczanska ES, Brander KM, Brown C, Bruno JF, **Duarte CM**, Halpern, BS, Holding J, Kappel CV, Kiessling W, O'Connor MI, Pandolfi JM, Parmesan C, Schwing F, Sydeman WF and Richardson AF (2011). The pace of shifting climate in marine and terrestrial ecosystems. *Science* **334**: 652-655.

14. Cahyarini Y, Pfeiffer M, Dullo W-C, **Zinke J**, Hetzinger S, Kasper S, Grove CA and Garbe-Schönberg D (2011). Comment on 'A snapshot of climate variability at Tahiti at 9.5 ka using a fossil coral from IODP Expedition 310,' by KL Delong, TM Quinn, Chuan-Chou Shen and Ke Lin (2010). *Geochemistry, Geophysics, Geosystems* **12**. doi:10.1029/2010GC003377.

15. Carstensen J, Sánchez-Camacho M, **Duarte CM**, Krause-Jensen D and Marba N (2011). Connecting the dots: responses of coastal ecosystems to changing nutrient concentrations. *Environmental Science and Technology* **45**: 9122-9132.

16. **Cassidy MJ** (2011). Assessing the three-dimensional response of jack-up platforms in directional seas. Special Issue on *Energy Geotechnology — KSCE Journal of Civil Engineering* **15**(4): 623-634.

17. **Clode PL**, Lema K, Saunders M and Weiner S (2011). Skeletal mineralogy of newly settling *Acropora millepora* (Scleractinia) coral recruits. *Coral Reefs* doi: 10.1007/s00338-010-0673-7.

18. **Duarte CM**, Kennedy H, Marbà N and Hendriks I (2011). Assessing the capacity of seagrass meadows for carbon burial: current limitations and future strategies. *Ocean & Coastal Management* doi 10.1016/j.ocecoaman.2011.09.001.

19. **Gallop SL**, **Bosserelle C**, **Pattiaratchi C** and Eliot I (2011). Hydrodynamic and morphological response of a perched beach during sea breeze activity. *Journal of Coastal Research, Special Issue* **64**: 75-79.

20. **Gallop SL**, **Bosserelle C**, **Pattiaratchi C** and Eliot I (2011). Rock topography causes spatial variation in the wave, current and beach response to sea breeze activity. *Marine Geology* **290**: 29-40.

21. Garcías-Bonet N, Sherman TD, **Duarte CM** and Marbà N (2011). Distribution and pathogenicity of the protist *Labyrinthula* sp. in Western Mediterranean seagrass meadows. *Estuaries and Coasts* doi: 10.1007/s12237-011-9416-4.

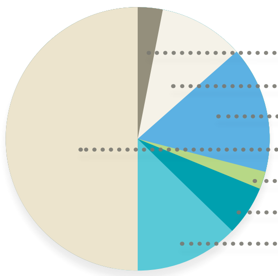
22. Gaudin C, **Cassidy MJ**, Bienen B and Hossain MS (2011). A review of the recent contribution made by geotechnical centrifuge modelling to the understanding on jack-up spudcan behavior. *Ocean Engineering* doi: 10.1016/j.oceaneng.2010.1012.1001.

23. Geertz-Hansen O, Montes C, **Duarte CM**, Sand-Jensen K and Marbà N (2011). Ecosystem metabolism in a temporary Mediterranean marsh (Doñana National Park, SW Spain). *Biogeosciences* **8**: 963-971.

24. **Ghadouani A** and **Coggins LX** (2011). Science, technology and policy for Water Pollution Control at the Watershed Scale: Current issues and future challenges. *Physics and Chemistry of the Earth* **36**(9-11): 335-341. doi:10.1016/j.pce.2011.05.011.

25. **Goetze JS**, **Langlois TJ**, Egli DP and **Harvey ES** (2011). Evidence of artisanal fishing impacts and depth refuge in assemblages of Fijian reef fish. *Coral Reefs* **30**: 507-517.

Publications by research area



	Total
Ocean engineering	5
Marine biological resources❶	10
Impacts of climate change❷	12
Marine ecology	49
Marine observation❸	1
Blue water oceanography	7
Coastal processes	14
	98

❶ Marine biological resources, management, governance and conservation
❷ Impacts of climate change in the marine environment
❸ Marine observation, monitoring and risk management

26. Gutierrez-Rodriguez A, Latasa M, **Agustí S** and **Duarte CM** (2011). Distribution and contribution of major phytoplankton groups to carbon cycling across contrasting conditions of the subtropical northeast Atlantic Ocean. *Deep-Sea Research Part I* doi:10.1016/j.dsr.2011.08.003.

27. **Haigh I**, **Eliot M** and **Pattiaratchi CB** (2011). Global influences of the 18.61 year nodal cycle and 8.85 year cycle of lunar perigee on high tidal levels. *Journal of Geophysical Research—Oceans* **116**: C06025.

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29. **Hart NS**, Coimbre JP, **Collin SP** and Westhoff G (2011). Photoreceptor types, visual pigments and topographic specializations in the retinas of hydrophiid sea snakes. *Journal of Comparative Neurology* doi: 10.1002/cne.22784.

30. **Hart NS**, Theiss SM, Harahush BK and **Collin SP** (2011). Microspectrophotometric evidence for cone monochromacy in sharks. *Naturwissenschaften* **98**: 193-201.

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32. Hernández-Mendiola E, Bernal JP, Lounejeva E, Mortimer GE and **McCulloch MT** (2011). U-series dating of carbonates using inductively coupled plasma-quadrupole mass spectrometry. *Quaternary Geochronology* **6**(6): 564–573 doi:10.1016/j.quageo.2011.09.001.

33. Hogg C, Neveu M, Stokkan KA, Folkow L, Cottril P, Douglas R, **Hunt DM** and Jeffery G (2011). Arctic reindeer extend their visual range into the ultraviolet. *Journal of Experimental Biology* **214**: 2014-2019.

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36. **Kempster RM** and **Collin SP** (2011). Electrosensory pore distribution and feeding in the megamouth shark, *Megachasma pelagios* (Lamniformes: Megachasmidae). *Aquatic Biology* **11**: 225-228.

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38. **Langlois T**, **Radford B**, **Van Niel K**, **Meeuwig JJ**, Pearce A, **Rousseaux C**, **Kendrick GA** and **Harvey ES** (2011). Consistent abundance distributions of marine fishes in an old climatically buffered infertile seascape. *Global Ecology and Biogeography* doi: 10.1111/j.1466-8238.2011.00734.x.

39. Lewis SE, Brodie JE, **McCulloch MT**, Mallela J, Jupiter SD, Stuart Williams H, Lough JM and Matson EG (2011). An assessment of an environmental gradient using coral geochemical records, Whitsunday Islands, Great Barrier Reef, Australia. *Marine Pollution Bulletin* doi:10.1016/j.marpolbul.2011.09.030.

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41. Marzullo TA, Wueringer BE, Squire Jnr. L and **Collin SP** (2011). Description of the mechanoreceptive lateral line and electroreceptive ampullary systems in the freshwater whipray, Himantura dalyensis. *Marine and Freshwater Research* **62**: 771-779.

42. Mason HE, Montagna P, Kubista L, Taviani M, **McCulloch MT** and Phillips BL (2011). Phosphate defects and apatite inclusions in coral skeletal aragonite revealed by solid-state NMR spectroscopy. *Geochimica et Cosmochimica Acta* doi: 10.1016/j.gca.2011.10.002.

43. McLean DL, **Harvey ES** and **Meeuwig JJ** (2011). Decline in the abundance of coral trout (*Plectropomus leopardus*) in areas closed to fishing at the Houtman Abrolhos Islands, Western Australia. *Journal of Experimental Marine Biology and Ecology* **406**: 71-78.

44. Mcleod E, Chmura GL, Bouillon S, Salm R, Björk M, **Duarte CM**, Lovelock CE, Schlesinger WH and Silliman B (2011). A Blueprint for Blue Carbon: Towards an improved understanding of the role of vegetated coastal habitats in sequestering CO2. *Frontiers in Ecology and the Environment* doi: 10.1890/110004.

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53. **Patten NL**, **Lowe RJ**, **Wyatt ASJ** and **Waite AM** (2011). Uptake of picophytoplankton, bacterioplankton and virioplankton by a fringing coral reef community (Ningaloo Reef, Australia). *Coral Reefs* **30**(3): 555-567. doi: 10.1007/s00338-011-0777-8.

54. **Pattiaratchi CB**, **Hollings B**, **Woo M** and **Welhena T** (2011). Dense shelf water formation along the south-west Australian inner shelf. *Geophysical Research Letters* **38**: L10609.

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56. Proietti MC, **Reisser JW**, Kinas PG, Kerr R, Monteiro DS, Marins LF, Secchi ER (2011). Green turtle Chelonia mydas mixed stocks in the western South Atlantic, as revealed by mtDNA haplotypes and drifter trajectories. *Marine Ecology Progress Series* **447**: 195-209.

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Future directions

2012 and beyond

2009

- The UWA Oceans Institute is established

2010

- The UWA Oceans Institute is formally launched

2011

- IOMRC collaboration formed with AIMS, CSIRO and the Department of Fisheries
- Memorandum of Understanding signed with Consejo Superior de Investigaciones Cientificas (CSIC)

2012

- Ocean Solutions strategic focus strengthened
- Ocean Solutions Dialogue Series launched

2013

- Opening of IOMRC Watermans facility
- Expanding network of international collaborators
- Oceans Horizons 2020 conference hosted by The UWA Oceans Institute

2014

- IOMRC Crawley building complete
- First intake of students in the Ocean Solutions Masters Program

IMAGE/ CARLOS DUARTE

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