# IAEA BULLETIN

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## PROTECTING OUR MARINE ENVIRONMENT

**Kelp and Harbour Seals**

The cover photograph by Kyle McBurnie of a California Harbour seal (Phoca vitulina) in a kelp forest at Cortes bank, near San Diego, California, was honoured with Best Overall award in the 2013 Underwater Photography Contest of the University of Miami's Rosenstiel School of Marine and Atmospheric Science.

Harbour seals are the most common seal species and live in temperate and subarctic coastal areas on both sides of the north Atlantic and north Pacific Oceans and consumes fish, squid and crustaceans.

Kelp forests are one of the most ecologically dynamic and biologically diverse habitats on the planet. They play an important role is sustaining marine productivity in flora, fauna, fish and birds. Kelp are anchored by holdfasts that grip rocky substrates. From the sea floor, kelp plants grow toward the water's surface. Gas bladders called pneumatocysts, keep the upper portions of the algae afloat. These forests represent one of the 'keystone species', which affect the survival and abundance of many other species in the ecosystem.

Kelp beds host a rich variety of mobile invertebrates, which in turn support the diet of fish species. Birds forage in kelp forests, roost in drift kelp, and find food among kelp washed ashore. Some fish and invertebrate species attach eggs to kelp plants, which extend into deeper waters and thus provide shelter and nurseries for fish. Sea lions, harbour seals, sea otters, and whales may feed in the kelp or escape storms or predators in the shelter of kelp. The kelp also helps to weaken currents and waves thus protecting species and preventing coastline erosion.

Kyle McBurnie is a scuba instructor, ocean expedition leader, and underwater photographer, based in southern California, where his company, SD Expeditions, partners with the leading organizations in marine research.

The University of Miami's Rosenstiel School of Marine and Atmospheric Science, Virginia Key, Florida, was founded in the 1940s and has developed into one of the leading academic oceanographic and atmospheric research institutions in the world.

**The IAEA's Environment Laboratories**

In 1961, the IAEA concluded with the Principality of Monaco and the Oceanographic Institute, then directed by Jacques Cousteau, an agreement on a research project on the effects of radioactivity in the sea. That same year the IAEA opened a laboratory in Monaco, with the generous support of the Principality. The IAEA's Environment Laboratories now collaborate with international and regional organizations, as well as national laboratories. The unique data derived from the application of nuclear and isotopic techniques improve scientists' knowledge of the seas and oceans and help to assess pollution, climate change and ocean acidification. These studies support the conservation and sustainable development of the ocean.

The research is buttressed by strategic partnerships with UN agencies such as the United Nations Educational, Scientific and Cultural Organization - Intergovernmental Oceanographic Commission, the United Nations Environment Programme, the United Nations Development Programme, and the International Maritime Organization.

Many Member States' national laboratories rely upon the Laboratories' accurate analyses of sea water, sediment and marine life samples. Reference materials and methods produced by the laboratories have helped to improve the quality and reliability of analytical data in Member State laboratories for over 50 years. IAEA-supplied reference materials are used for instance to quantify ocean circulation, and contaminants in seafood. The Laboratories promoted the use of a nuclear-based technique to detect toxic algal blooms, a threat to human health. And the Laboratories provided the essential scientific and analytical support for landmark studies of radioactive and non-radioactive pollutant levels in all principal seas. The laboratories also serve to train scientists from developing countries.

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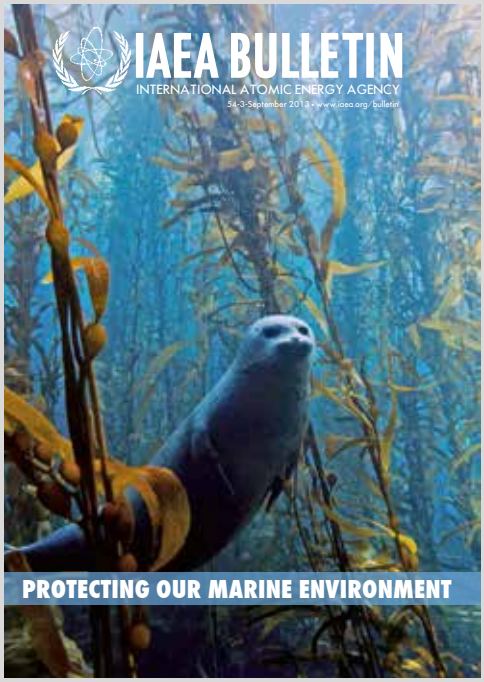



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Cover Photo:
Kyle McBurnie

# PROTECTING OUR MARINE ENVIRONMENT

Human well-being and prosperity depend upon healthy oceans and seas. Much of the oxygen we breathe is generated by marine life, while ocean currents transfer heat, playing an important role in maintaining a moderate climate.

**Nuclear and isotopic techniques make an important contribution to improving our understanding of the challenges that threaten the health of our oceans.**

However, the marine ecosystems that keep the oceans healthy are subject to increasing stress. Many of the stress factors are either caused, or worsened, by human activities on land. As we burn more fossil fuels, more carbon dioxide is emitted, trapping heat that warms the oceans. Ocean waters absorb about a quarter of that carbon dioxide, which dissolves and increases ocean water acidity.

Physical and biological conditions in the oceans are deteriorating due to pollution. Coastal habitats are under threat from unsustainable development and resource exploitation.

Nuclear and isotopic techniques make an important contribution to improving our understanding of the challenges that threaten the health of our oceans. This issue of the IAEA Bulletin is published in conjunction with the 2013 IAEA Scientific Forum, entitled The Blue Planet — Nuclear Applications for a Sustainable Marine Environment.

The Scientific Forum focuses on the IAEA's work with Member States and international partners in monitoring and evaluating the challenges facing our oceans, and in seeking solutions.

Scientists at the IAEA Environment Laboratories in Monaco study biological processes to understand how marine organisms react to acidification and warming. They use isotopes to track the sources of pollution and its dispersion. The IAEA trains researchers from developing countries to use nuclear techniques to monitor pressures on the marine environment. It makes available precise and cost-effective tools to help both developed and developing countries to acquire the data needed to adapt strategies that mitigate pressures on the oceans.

I hope that the 2013 IAEA Scientific Forum will help to strengthen new cooperation between experts and policy-makers to protect and preserve the ecological balance that is vital for the survival of the marine environment.

Yukiya Amano, IAEA Director General

# AN ADVOCATE FOR OCEAN PROTECTION

*Prince Albert II of Monaco discusses his passion for the oceans and his ongoing support of the IAEA's ocean protection activities. The Principality is home to the IAEA Environment Laboratories, which were founded in 1961 with the support of Monaco.*

### Where does your passion for marine protection come from?

There's obviously some family heritage here. My great-grandfather, Prince Albert I, had an incredible vision for sciences in general but for oceanography in particular. His wonderful work in this field left us with his legacy in the form of the Monaco Oceanographic Museum. But of course this interest also comes from my father, Prince Rainer III, and the many marine protection initiatives he led, primarily in the Mediterranean Sea.

### Did growing up next to the sea encourage you to protect it?

Obviously, the more you know the ocean or our sea here, the Mediterranean Sea, the more you want to protect it. Living near the sea and being exposed to it at a very young age can only entice you to learn more about it and find innovative ways of protecting it. Also the exceptional geographic situation of my country encouraged me to take a keen interest in the field of marine protection.

### A year after your accession, in 2006 you founded your own foundation. What led you to this?

I was exposed to different environmental issues at a young age, but I think one of the turning points was the Earth Summit in Rio in 1992 where I accompanied my father. Through attending this event, I became more aware of different environmental issues, not only concerning oceans but climate change, greenhouse gases and deforestation. Then I tried at my level and with our different organizations based here in Monaco to try to work more closely on these issues. But way before 2006, I wanted to create some kind of foundation, something more personal. I suppose after this Rio summit I finally got the sense of urgency to do this, which had been building up over the years.

Prince Albert II of Monaco (left) is a committed environmentalist, and supporter of the IAEA's Environment Laboratories and its work; taking part in Arctic marine expeditions, and even conducting mollusc dissections with IAEA scientists.
(Photo: Jean Jaubert)

### What is the main focus of the foundation?

The three main pillars are biodiversity, water and climate change. The three main regional areas that we've been trying to concentrate on are the Mediterranean Basin, the least developed countries, this group includes a lot of African countries, and the polar regions. I'm very happy to see the way the foundation has developed over the last seven years. We've now been a part of over 230 projects in 40 different countries and have partnerships with many organizations, such as the UN Foundation, The Climate Group and the WWF.

### You don't just use your name and your title to draw attention to these issues, you actually get first-hand experience of them. How important is this for you?

I think it's extremely important. Not only to get a better knowledge of the different issues on the ground, but also to be able to meet the local populations we're trying to help through these different programmes, whether they are on land or sea. I don't do it for myself. I do it because I'm interested and because I'm passionate about what I'm trying to achieve. But it's also for the foundation, to get better visibility and to show that we're following these different programmes with all the attention they deserve.

## How does your government support the work of the IAEA?

There is a long-standing collaboration between Monaco and the IAEA dating back to the early 1960s. We were collaborating through our scientific centre, the Centre Scientifique de Monaco, and it was decided that this cooperation could become even closer by establishing an IAEA marine laboratory. It's now the IAEA Environment Laboratories that is here in Monaco. The research done there is absolutely tremendous and we're very proud and honoured to have this close partnership and it's only going to develop even further in the future.

## Why do you think it's beneficial for the IAEA to have its Environment Laboratories here in Monaco?

We have a long history in marine sciences, so this makes us as credible as other locations that also do scientific research in this field. Because of this history and our teams of scientists at the Centre Scientifique de Monaco, we were able to establish this working cooperation with the IAEA. Also, Monaco is a small country directly concerned by marine environmental problems, due to its position. Its size is an asset in testing out new environmental practices and implementing them. Furthermore, my country is apolitical. So, when we organize debates or conferences, we look to promote just a single interest, that of environmental protection. This is fundamental and lends credibility to our environmental approach on the international stage.

## You also support the IAEA's work in the field of research into ocean acidification. You led the Monaco Declaration on Ocean Acidification in 2008. What was the purpose of this?

We wanted to draw international attention to ocean acidification. Increased $CO_2$ emissions due to human activities represent a major threat to the marine environment. 50% of $CO_2$ produced by humans over the last 200 years has been absorbed by the oceans. The higher the level of $CO_2$ absorbed, the higher the level of ocean acidity. This acidification will upset the ocean balance and have a negative impact on biodiversity hotspots, the coral reef ecosystems for instance.

## What was achieved by the Declaration, have we moved on with our understanding of the issue?

I think the Declaration and the meeting that lead to the Declaration were of paramount importance — not only to raise awareness of the issue, which very few people outside of the scientific community knew about, but also for us to get the stamp of approval from scientists from 26 different countries as to what the dangers are, to better identify the issues and to direct the research towards a better understanding of the dynamics of ocean acidification. I'm very happy to see that the Declaration is considered to be a very important stepping stone towards a better awareness not only by the scientific community but by the general public as well.

## Despite your efforts the seas are still being abused. Do you think this situation can really improve?

I think we are at a crossroads now and we have very little time to try to reverse these different trends that are affecting our seas and oceans — from ocean acidification to overfishing, excessive pollution and the non-treatment of different wastewaters. Pressures on marine ecosystems are constantly growing, and the sustainable management of marine resources is now a major global issue. As global populations increase and most people live in urban areas that are on the coast, there is more and more pressure on the oceans. The consequences of climate change and ocean acidification further exacerbate the fragile balance of ocean ecosystems and biodiversity. My personal commitment and my Government's policy are to work towards improving the situation.

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Interview by Louise Potterton, IAEA Division of Public Information

# HEALTHY OCEAN, HAPPY PLANET

Scientists use nuclear techniques to get a better understanding of the El Niño, a phenomenon in which the changing sea surface temperatures of the Pacific Ocean can cause disastrous effects. In 1972 Peru's anchoveta fishery collapsed, at the time the world's largest, partly due to El Niño.
(Photo: iStockphoto)

Looking down at our planet from space, we are enchanted by a veritable 'sea' of blue, because most of our planet is made up of water, and most of its surface area is ocean. The world's saltwater bodies influence the planet's climate, and provide a home to millions of the world's plants, which also produce the oxygen we breathe.

Since the oceans and seas are so critical to human survival, scientists continue to study and attempt to fully understand the processes and mechanisms that control them. Nuclear techniques are some of the most precise research methods that are being employed in this endeavour. By monitoring stable isotopes in different locations and measuring the decay of radioisotopes, scientists can better understand how marine environments are changing, and how they changed in the past.

This kind of understanding improves humanity's ability to keep the marine environment healthy.

## Ocean Acidification

One sign of an unhealthy marine environment is ocean acidification. This is the name given to the disruption of the sea's normal acid/alkaline balance, an imbalance that can cause some marine species to die off, because they are incapable of adapting to a more acidic environment, thereby disrupting the entire ecosystem and food webs.

## Time Travel

"Understanding the effects of ocean acidification on marine organisms and ecosystems is critical if we are to identify where these systems are vulnerable and evaluate the potential impact on fisheries, aquaculture and ecosystems," says David Osborn, Director of the IAEA Environment Laboratories in Monaco.

To do this, researchers need accurate models that will help predict future conditions and thus help governments develop the appropriate strategies.

Marine radioisotopes provide a powerful tool both to help diagnose problems in ocean models and to help orient the development of new models.

## Beneath the Surface

"We see only the surface of the ocean. But it is so much more extensive in mass and function than we initially perceive. Marine life produces between 50% and 85% of the earth's oxygen and is a key element in the global climate system," says Michail Angelidis, Head

of the IAEA's Marine Environmental Studies Laboratory in Monaco.

To understand ocean acidification, harmful algal blooms (HABs), El Niño or La Niña events, or any number of dangerous phenomena occurring in the marine environment, we must first understand how the ocean itself works; understand how it acts as a heat sink and as a carbon sink; how it moves, when and why; how it transports plants, animals, soil, gases and heat from one part of the globe to another; and how it interacts with the wind and sun, regulating weather and climate.

For example, scientists use nuclear techniques to pinpoint the age of sediment at the bottom of the ocean and date coral skeletons, which give them accurate data about the state of the oceans hundreds of thousands, even millions of years ago.

This kind of information is invaluable when attempting to forecast the effect that current conditions will have on the oceans. And this information is used to extrapolate what will most probably happen to our planet decades and even centuries from now.

Occasionally, very warm ocean water temperatures will cross over from the western Pacific and stop the upwelling of cold and nutrient-rich water off the western coast of South America and influence climatic changes around the world. This is called the El Niño event, which has wide ranging effects, as it may cause e.g. enhanced melting of polar ice, reduced production in fish in Peru, decreased growth of maize in Africa and increased rainfall and flood in Florida. El Niño's intensity and characteristics in terms of salinity and temperature vary widely, thus making its impact hard to predict. So scientists have collected radionuclide, stable isotope and trace element records in corals and ocean sediments in order to reconstruct the patterns left by past El Niños going back several hundred years. These studies enable scientists to predict the sea surface temperature and salinity, and the frequency and intensity of future El Niños with much greater accuracy.

## Radionuclides

Since the amount of time it takes for radionuclides to lose half of their radioactivity (known as half-life) is well known, scientists can use those radionuclides as a kind of clock to study how quickly or slowly ocean processes are occurring. Radionuclides are also being used to monitor the transfer of energy/mass in the food chain, providing critical information about key marine organisms, including those at the base of the marine food chain, and whose demise could very well mean the collapse of ocean ecology as we know it.

Isotopic techniques also provide information about these species' metabolism, photosynthesis, pollutant accumulation, calcification and their basic ability to survive under specific conditions.

Marine radioisotopes also contribute to the study of how rising ocean acidity together with increasing temperature disrupts the ecophysiology of coral reefs that serve as coastal protection and act as a habitat for countless marine species.

## Pollution

"Science by itself cannot save the world, but science can provide the necessary knowledge and tools that humanity needs to make the right decisions; decisions which can save the world," says Hartmut Nies, Head of the IAEA's Radiometrics Laboratory in Monaco.

Nies' team of scientists at the IAEA helps Member States use natural radioactive tracers (such as uranium and thorium and their decay chain products) and man-made ones like plutonium or radiocaesium to understand sea dynamics and monitor for toxic elements.

Also, by studying pollutants' different isotopic signatures, scientists can find out where a particular pollutant is coming from. For example, lead from gasoline and naturally occurring lead have different isotopic signatures, which can be analysed using isotopic techniques. Knowing exactly where a pollutant is coming from helps authorities stop the flow of harmful substances into the sea.

Jacques Yves Cousteau, the renowned oceanographer and former Director of Monaco's Oceanographic Institute, with which the IAEA signed an initial agreement on joint exploration and research, said "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."

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Sasha Henriques, IAEA Division of Public Information

# RADIOTRACERS: ESSENTIAL NUCLEAR TOOLS TO UNDERSTAND OCEANS

Radiotracer studies can be applied in floating or seabed tent structures called mesocosms. This valuable experimental tool allows natural environments to be studied under controlled conditions combining the benefits of lab and field work.
(Photo: Nick Cobbing)

The IAEA's work in helping understand and ultimately protect our oceans depends on nuclear research tools called 'radiotracers'. Radiotracers are chemical compounds that contain unique radioactive isotopes. Isotopes of an element all have the same number of protons in the nucleus, but varying numbers of neutrons. Isotopes are thus forms of a single element with differing mass. When the composition of a nucleus does not change over time, it is considered to be a stable isotope. Unstable, or radioactive, isotopes 'decay' over time. In other words, they transform to another element, or energy status, through a process known as transmutation, in which atomic nuclei (protons and neutrons) emit highly energetic charged and ionizing particles, and/or highly energetic electromagnetic waves, called gamma-ray emission.

Radioecologists routinely introduce tiny quantities of a 'radiotracer', a radioactive isotope, into a complex biological system, for instance, to be able to observe how cells or tissues function. Scientists can identify a radiotracer among all the other natural and almost identical compounds. The radiotracer's unique 'isotopic signature' produces a clearly visible trace as it follows nutrients, energy, or pollutants through an organism, food web or ecosystem. Radiotracers are easy to detect in minute quantities, therefore studies can be conducted without poisoning organisms or ecosystems or affecting the chemistry or fluid dynamics of the system. The IAEA applies radiotracers in both laboratory settings and in field work, each of which has its own strengths. Laboratory based experiments have the advantage of creating simplified and artificial ecosystems in which natural processes and interactions can be studied uninterrupted. Field studies tackle the complex systems of the real world, having the potential to answer questions about a compound's fate, the dynamics between different species, and how compounds attach themselves to sediments and/or are dispersed as pollutants into the environment.

During larger scale field studies, radiotracers are used primarily to reveal the transport processes, dispersion and settling of chemicals

in the natural environment. These studies are applied to coastal environments where the extent and effect of sewage and other effluent disposal has been evaluated and scrutinized. In the 1970s, a series of experimental studies conducted on Canadian lake systems, using heavy metal radiotracers (cadmium-109, zinc-65, mercury-203, iron-59, cobalt-60, caesium-134, and selenium-75) and nutrient radiotracers (carbon-14), revealed how tracers are absorbed into sediment and nutrients.

They also showed how contaminants transfer from water and sediments to organisms. From there they enter and move through the food chain. More recently, concerns have been raised over the possible radiological impact such field studies may have had on the environment.

**The latest reports on the state of our oceans are worrying at best. The exploitation of their limited resources, the increase in marine pollution, and destruction of their service providing habitats, is placing a great strain on their organisms.**

A non-human biota dose assessment (ERICA assessment tool)[1] of one lake study focused on whether the concentrations of radiotracers used were high enough to have a negative effect on the ecosystem; the results confirmed that doses were below the reference levels established by the International Commission on Radiological Protection. This suggests that it is feasible for radiotracers to be used safely in ecosystem scale studies.

With their limited environmental impact, radiotracers have the potential to be used in a variety of new applications to create a wider awareness of the environment and the challenges it faces. By using carbon-14 or phosphorus-32, it is possible to study nutrient dynamics and acquire a better understanding of the foundations of an ecosystem. Using short-lived analogues of nuclear industry products like caesium-134 and strontium-85, or heavy metal isotopes, radioecologists can examine contaminant accumulation in marine organisms and biomagnification (the cumulative increase in concentration of substances in organisms at successively higher levels of the food chain).

Biomagnification is an important aspect of marine pollution that is particularly worrying for longer living animals like humans. Potential further applications for radiotracers include using them on the nanoscale and labelling organic molecules, such as drugs, to track their behaviour as these molecules interact with organisms, after they are excreted by the human body and pass through sewage systems.

Despite their potential extensive uses, radiotracers do have their limitations, primarily the fact that in order to study some processes the tracers need to be absorbed and dispersed in the environment for several days or longer. In open water environments this can result in a very wide dispersion due to currents, wave action, and migratory animals removing the tracers far from the study area. However, studying some of our most vital marine habitats is not limited by this disruption. Coastal embayment areas, aquaculture farms, coral reefs, and floating or seabed tent structures, may all be used to constrain the movement of organisms and tracers, making them very viable environments for such studies using state-of-the-art nuclear technology.

The latest reports on the state of our oceans are worrying at best. The exploitation of their limited resources, the increase in marine pollution, and destruction of their service providing habitats, is placing a great strain on their organisms. Radiotracers are unique nuclear tools that can be used to study pollution and its transport in coasts and oceans. The IAEA and its partners are striving to make available these nuclear technologies to improve understanding of the health of the oceans, encouraging countries to take practical steps to prevent any further deterioration.

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Cath Hughes, Australian Nuclear Science and Technology Organisation

[1]Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA)—www.erica-tool.com

# OUR CHANGING OCEANS
## ALL ABOUT OCEAN ACIDIFICATION

*If all the world were paper,*
*And all the sea were ink,*
*If all the trees were bread and cheese,*
*How should we do for drink?*
*— Anon*

Centuries have passed since the notion of the sea becoming ink appeared in a child's rhyme. Yet, in the 21st century the seas are changing — their acidity is increasing.

Since the start of the industrial revolution in the 18th century, carbon emissions have been taken up by the oceans, increasing their acidity by 30% — part of the unfolding global change resulting from human activity.

The oceans play an essential role in reducing the amount of carbon in the atmosphere. They take up 25% of man-made carbon dioxide ($CO_2$), every day. When $CO_2$ is absorbed, it dissolves in ocean water to form carbonic acid. Unless carbon emissions are reduced, acidity in the oceans is expected to continue to increase by 150% by the end of the 21st century as ever more $CO_2$ is absorbed.

There are already signs that rising ocean acidity is affecting fisheries and marine organisms. "The world's coasts and oceans, which make up around 70% of the earth's surface, face serious man-made threats from pollution, unsustainable extraction of resources and climate change. Nuclear and isotopic techniques help us to understand the pressures on the marine environment and to find more effective responses," said Yukiya Amano, the IAEA's Director General, in introducing the 2013 Scientific Forum that focuses on preserving marine environments.

The IAEA Environment Laboratories based in Monaco host the Ocean Acidification International Coordination Centre (OA-ICC). Its research is contributing to greater understanding of the phenomenon.

Radioactive isotopes, such as calcium-45, are used by IAEA scientists as radioactive tracers to examine the growth rates in calcifiers, such as corals, mussels, limpets and other molluscs, whose skeletons are composed of calcium. Tracers are used extensively at the IAEA to determine how ocean acidification is affecting the eggs and juveniles of vertebrate fish species, such as finfish, and among cephalopods, such as squid, octopus and cuttlefish.

As ocean water acidity increases, the consequences for marine life may be severe. Scenarios for ocean acidification include far-reaching impacts on shellfish harvests, such as oysters, mussels and abalone. Coral reefs, a diverse interlinked habitat and nursery for many marine species, are expected to deteriorate, setting in motion a series of negative consequences resulting from reduced biodiversity and shrinking sanctuaries for fish. Changes to marine food webs will have effects, among others, on marine fish health and harvests. Globally, as of 2012, fish provide 3 billion people with 20% of their animal protein intake. Artisanal fishing communities, seafood-related employment, commerce and trade, tourism and those whose subsistence is linked to seafood availability are all confronted with falling revenues, fewer jobs and less seafood.

The consequences of ocean acidification are global in scale. More research into ocean acidification and its consequences is needed. It is already known, for example, that there are regional differences in the vulnerability of fisheries to acidification. The combination of other factors, such as global warming, the destruction of habitats, overfishing and pollution, need to be taken into account when developing strategies to increase the marine environment's resilience. Among steps that can be taken to reduce the impact is better protection of marine coastal ecosystems, such as mangrove swamps and seagrass meadows, which will help protect fisheries. This recommendation was one of the conclusions of a three-day workshop attended by economists and scientists and organized by the IAEA and the Centre Scientifique de Monaco in November 2012. In their recommendations the workshop also stressed that the impact of increasing ocean acidity must be taken into account in the management of fisheries, particularly where seafood is a main dietary source.

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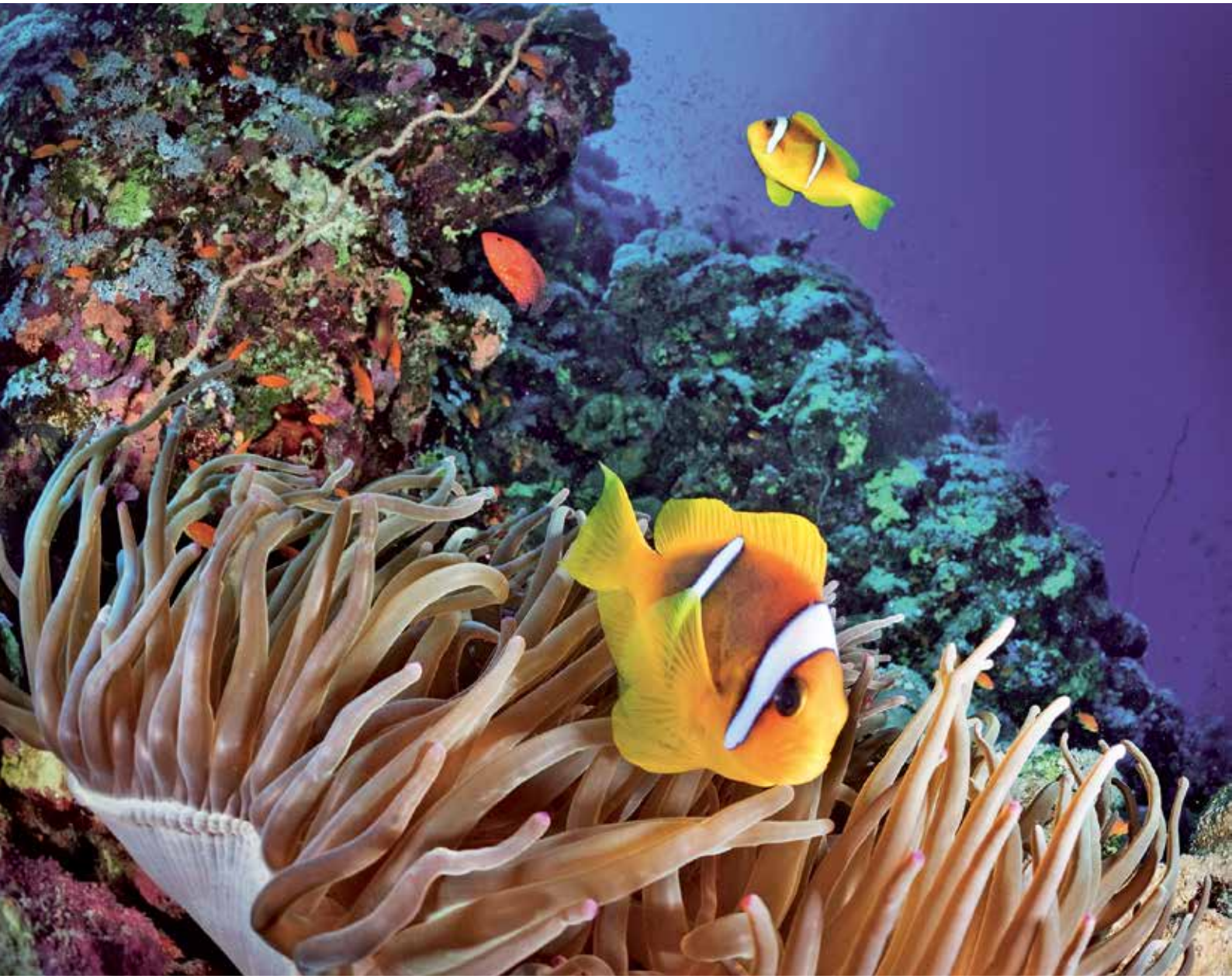
Peter Rickwood, IAEA Division of Public Information

# WAKE-UP CALL

## IAEA PROMOTES GLOBAL ACTION ON OCEAN ACIDIFICATION



Ocean acidification is already affecting marine ecosystems and their services to humankind. (Photo: iStockphoto)

The IAEA is fostering scientific collaboration to provide the sound, fact-based understanding needed to be able to assess human impact on coastal and marine environments.

Well-known scientific journals have drawn attention to the impending dangers from ocean acidification and its implications for coastal zones and marine life. *Nature* in its July 2013 issue commented: "Although researcher numbers, funding and methodologies will always be limiting, we think that the field is being held back by a much bigger problem — a lack of knowledge of the overarching principles for how ocean acidification affects species and ecosystems. These will be crucial for addressing issues including shifts in biogeochemical processes, such as nitrogen fixation, and the interactions between animals, plants and bacteria.

Elaborating these unifying principles will require an interdisciplinary approach that structures research within and between multinational and national projects on ocean acidification. The Ocean Acidification International Coordination Centre, announced in June 2012, is a welcome first step.

Ocean acidification is already affecting marine ecosystems and their services to humankind.

In light of the millennia it will take to reverse changes in ocean chemistry, we believe that research should be oriented towards finding solutions, rather than to simply documenting the disaster. Ultimately, only the reduction of atmospheric $CO_2$ levels will alleviate the challenges of ocean acidification. Meanwhile, researchers can improve their understanding of the biological impacts of ocean acidification and identify the organisms and ecosystems that are most at risk. We can also buy some time through reducing human pressures such as overfishing, eutrophication and pollution."[1]

## The Mission of the OA-ICC

Over the past 10 years, international scientific research has shown the dangers that ocean acidification can pose for marine life. One of the first multinational projects on ocean acidification was the European Project on Ocean Acidification (EPOCA)[2], a four-year European project that ended in 2012. This project recognized the need to continue to develop international activities, as did the SOLAS–IMBER[3] Ocean Acidification Working Group and the International Ocean Acidification Reference User Group (IOA-RUG). These groups stressed the need for a broader international effort to coordinate, promote and facilitate ocean acidification science and related activities. The IAEA announced at Rio+20 in June 2012 the establishment of the Ocean Acidification International Coordination Centre (OA-ICC) at the IAEA Environment Laboratories in Monaco. The OA-ICC's mission is to facilitate global actions and responses to ocean acidification.

Established initially for a three-year period as a project, the work of the OA-ICC is funded and supported by several IAEA Member States through the IAEA's Peaceful Uses Initiative. It cooperates with other major national and international projects involved in ocean acidification research. An Advisory Board assists the work of the OA-ICC, and is comprised of members from UNESCO's Intergovernmental Oceanographic Commission, the United States National Oceanic and Atmospheric Administration, the Food and Agriculture Organization of the United Nations, the Prince Albert II of Monaco Foundation, the International Ocean Acidification Reference User Group, as well as distinguished scientists.

## The Work of the OA-ICC

The OA-ICC's goal is to serve as a platform for information sharing and promotion of international collaboration, training, development of best practices, access to ocean acidification data, and other collaborative actions. The OA-ICC website and its news centre provide information to various audiences, including policy- and decision-makers.

The OA-ICC also enhances awareness of the use of conventional and nuclear and isotopic techniques to understand variations in coastal and marine environments and to assist in providing a basis for effective management responses to maintain the resilience of these ecosystems. In its outreach activities, the OA-ICC demonstrates how research can be used to help ensure sustainable development and strengthen the resilience of these ecosystems.

The IAEA promotes a comprehensive approach to the study, monitoring and protection of marine, coastal and terrestrial ecosystems. The OA-ICC supports effective and global cooperation to address the threat to our oceans from ocean acidification.

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Aabha Dixit, IAEA Division of Public Information

[1]Reprinted by permission from Macmillan Publishers Ltd: *NATURE*, Vol. 498, p. 429, Dupont, S.; Poertner, H, 27 June 2013.

[2] European Project on Ocean Acidification was Europe's first large-scale research initiative devoted to studying the impacts and consequences of ocean acidification. More than 100 scientists from 27 institutes and nine countries were involved bringing their expertise to the project, resulting in a multidisciplinary and versatile consortium. The project was funded for four years (2008 to 2012) by the European Commission within its Seventh Framework Programme.

[3] SOLAS: Surface Ocean — Lower Atmosphere Study, and IMBER: Integrated Marine Biogeochemistry and Ecosystem Research.

# BUILDING PARTNERSHIPS TO PROTECT THE OCEAN

## IAEA COLLABORATES WITH INTERNATIONAL ORGANIZATIONS

The IAEA Environment Laboratories support Member States in applying nuclear and isotopic techniques to detect and monitor the impact of coastal zone pollutants on the marine life cycle and ecosystem services. These techniques are used to enhance our understanding of marine ecosystems and of the marine environment, as well as to improve environmental management and protection. For example, radiotracers help track the movement of various types of trace elements and industrial pollutants, and improve our knowledge of marine biological processes.

Like vast sponges, the oceans naturally soak up carbon dioxide from the atmosphere, helping to mitigate the effects of global warming. The amount of carbon dioxide, primarily generated by burning fossil fuels, absorbed by the oceans has steadily increased, and has now reached 9 billion tonnes per year. This change to the global carbon cycle, which has had an impact on the climate, has an additional environmental consequence — ocean acidification — with serious repercussions for human life, implications for coastal zones and marine life, and the risk of impairing the largest natural resources of the planet — the oceans.

Over the past years international agencies have been collaborating to combine resources and knowledge to address the impending ecological threat of ocean acidification. The IAEA engages closely with the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP), the International Maritime Organizations (IMO), the Food and Agriculture Organization of the United Nations (FAO), the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC/UNESCO) and the United Nations Industrial Development Organization (UNIDO) to implement effective programmes for sustainable development that include improving the 'state of health' of the oceans using nuclear and isotopic technology to monitor the impact on marine life and coastal areas.

The IAEA plays an important role in supporting international efforts to monitor changes in the ecological balance due to ocean acidification. The IAEA, along with IOC/UNESCO and the Principality of Monaco, sponsored the signing, by 155 international scientists, of the Monaco Declaration on Ocean Acidification in 2008[1]. This Declaration called for substantial reductions in $CO_2$ emissions to avoid widespread damage to marine ecosystems caused by ocean acidification. The IAEA is also an active member of UN-Oceans, an interagency coordination mechanism on ocean and coastal issues within the United Nations.

Learn more about the IAEA's leadership in the Ocean Acidification International Coordination Centre on pages 10-11.

The IAEA Environment Laboratories regularly organize training courses, proficiency tests and inter-laboratory comparisons for the UNEP Mediterranean Action Plan's Programme for the Assessment and Control of Pollution in the Mediterranean Region (MED POL). Through this collaborative effort, laboratories in the Mediterranean region are equipped with suitable instruments used to determine trace elements and organic contaminants, as well as to develop a monitoring database for pollution impact assessment.

The IAEA Environment Laboratories have helped to build the analytical capacities of numerous laboratories in participating States. For example, during 2011–2012, four regional training courses on the analysis of pollutants in marine samples were organized in Monaco with the participation of 24 scientists from 11 Mediterranean countries. The IAEA also conducted four proficiency tests for the Mediterranean countries as well as for other regions.

Regional inter-laboratory studies are organized to offer expert advice on the quality of measurement results and to develop action plans to deal with the risks that pollutants have on marine and coastal zones[2]. Under this project, IAEA experts provided detailed information on the use of nuclear isotopes in monitoring the deterioration taking place in the marine ecosystem.

The IAEA takes an active part in the work of the Regional Organization for the Protection of the Marine Environment (ROPME) of the Gulf region, which serves as the secretariat to oversee the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution and the Kuwait Action Plan[3]. The IAEA has collaborated with ROPME throughout the Gulf region and in the Gulf of Oman since the early 1980s. Notable activities involve 'contaminant screening' surveys of coastal water, sediments and fish, and analysis of inorganic and organic pollutants. The pollution assessments generated by these projects help Member States in the region acquire a clearer understanding of the deteriorating state of coastal areas and marine life. Visits to Bahrain, the Islamic Republic of Iran, Kuwait, Oman, Qatar and the United Arab Emirates under ROPME have assessed infrastructure and training needs to address the potential environmental disaster.

The IAEA has held separate training courses on analysing trace elements and organic contaminants in all the ROPME member countries, as well as organizing periodic regional laboratory studies for the ROPME laboratory network. Three proficiency tests have been carried out for the ROPME countries to improve the performance of Member States' laboratories in the analysis of radionuclides, trace elements, petroleum hydrocarbons and chlorinated compounds in marine samples.

Further to the south, the IAEA supported the UNEP project 'Addressing Land Based Activities in the Western Indian Ocean' — a four year project that commenced in 2006. It assisted eight western Indian Ocean countries (Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and United Republic of Tanzania) to evaluate key marine contaminants and establish a long term regional marine monitoring programme.

The focus of this project was to analyse major environmental problems. The assistance from the IAEA Environment Laboratories included conducting regional training courses and inter-laboratory studies to evaluate the performance of the Regional Activity Centre, a regional laboratory to monitor marine pollution for these countries. Nuclear techniques are used to determine the types of pollutants in marine samples, and these scientific tools have been developed and updated by the IAEA Environment Laboratories in conjunction with UNEP Regional Seas Programme. This programme provides Member States with an advanced mechanism by which they can evaluate the adverse impact of pollutants and take remedial steps to preserve the ecological balance.

The Black Sea region has also benefited from IAEA cooperation with the Global Environment Facility (GEF), the Commission on the Protection of the Black Sea Against Pollution and the United Nations Office for Project Services (UNOPS) in the Black Sea Ecosystem Recovery Project, which has assisted six coastline countries (Bulgaria, Georgia, Romania, Russian Federation, Turkey and Ukraine) in enhancing facilities to better analyse key marine contaminants such as heavy metals, petrochemicals and organic pollutants.

**The IAEA plays an important role in supporting international efforts to monitor changes in the ecological balance due to ocean acidification.**

The IAEA collaborated with GEF and UNOPS on the Yellow Sea Large Marine Ecosystem project in 2010 to help China and the Republic of Korea produce reliable data on key contaminants in the marine environment. Proficiency tests in the analysis of organic pollutants and trace metals using nuclear technology in sediment and biota reference materials were carried out for marine laboratories in the Yellow Sea region. Five laboratories each from China and the Republic of Korea participated in the proficiency tests organized by the IAEA Environment Laboratories. Under the UNDP's Iraq programme from 2003 to 2004, the IAEA Environment Laboratories were called upon to coordinate an intensive pollution survey of marine sediments from around 30 shipwrecks in Iraq's waterways. A wide range of persistent and toxic pollutants (heavy metals and petroleum hydrocarbons) were examined in over 190 sediment samples. The results are currently being used to ensure that salvage operations are conducted with minimal risk to people and the marine environment.

The IAEA Environment Laboratories have also been working with the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA). IAEA staff and experts have visited countries in the region to assess national and regional capacities to undertake marine monitoring, and thereby

provide recommendations for training and capacity building.

Under the Caspian Environment Programme (CEP), an intergovernmental programme of the five Caspian littoral States, Azerbaijan, the Islamic Republic of Iran, Kazakhstan, the Russian Federation and Turkmenistan, studies have been conducted on the accumulation of pollutants in the marine environment. The IAEA Environment Laboratories support this programme through expert advice and continued technical backing to establish a regional monitoring programme for marine pollutants. Nuclear techniques were used to investigate and evaluate the impact of toxic waste on the marine ecosystem mainly from anthropogenic activities, notably mining, which has increased the heavy metal burden in the Caspian Sea's sediments.

In its close coordination with the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic[4], which was established in 1992, the IAEA Environment Laboratories provide analytical quality assurance activities in nuclear and isotopic tools to laboratories in Belgium, Denmark, France, Germany, Ireland, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. This support enhances understanding and provides advanced monitoring techniques to observe the changes occurring in aquatic areas and to reduce pollution impact.

A similar programme is conducted under the Baltic Marine Environment Protection Commission[5], in which the IAEA Environment Laboratories collaborate with the laboratories in Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, the Russian Federation and Sweden to ensure analytical quality and open internet access to Baltic marine radioactivity data. In May 2013, the third annual meeting of this group convened at the IAEA Environment Laboratories in Monaco. The Monaco meeting reviewed the latest reports on releases of radionuclides from nuclear facilities to the Baltic Sea and on environmental levels of natural and man-made radionuclides in Baltic seawater, sediment and marine organisms.

The breadth of the IAEA's global collaboration on ocean acidification and marine pollution, including marine litter and plastic, indicate that urgent cooperative action to curtail further damage to marine life, oceans and coastal zones is necessary and needs to be sustained. Therefore, partnerships with other international bodies in the use of nuclear and isotopic applications help to enhance the understanding of oceanic processes, marine ecosystems and pollution impacts.

Most importantly, the data derived from this collaboration can be used to seek the best possible solutions to environmental challenges that affect all Member States. With its experience and unique knowledge, the IAEA is a lead partner with other international organizations in working towards the sustainable use of the oceans. 'Healthy' oceans must be maintained if future generations are to continue to benefit from abundant marine life.

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[1]www.ocean-acidification.net/Symposium2008/MonacoDeclaration.pdf

[2]The accuracy of data is vital in assessing the degradation of the marine environment. IAEA quality assurance services provide Member State laboratories with the necessary training, the organization of inter-laboratory comparison exercises, and proficiency tests in nuclear and isotope techniques to evaluate the collated information. IAEA laboratory exercises and proficiency tests are based on international standards and procedures.

[3]The Regional Conference of Plenipotentiaries on the Protection and Development of the Marine Environment and the Coastal Areas of Bahrain, the Islamic Republic of Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates was convened in Kuwait from 15 to 23 April 1978. On 23 April 1978, the Conference adopted the Kuwait Action Plan, the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution, and the Protocol concerning Regional Co-operation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency.

[4]The OSPAR Convention replaced the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (Oslo Convention, 1972) and the Convention for the Prevention of Marine Pollution from Land-Based Sources (Paris Convention, 1974). For further information see: www.ospar.org

[5]Further information is provided on: www.helcom.fi

# IAEA CAPACITY BUILDING IN NUCLEAR TECHNIQUES FOR ENVIRONMENTAL SUSTAINABILITY

Sound environmental policies are needed to protect the vital ecological balance of healthy natural systems, on land and in the ocean.
(Photo: iStockphoto)

The IAEA helps Member States use nuclear technology for a broad range of applications: from generating electricity to increasing food production, from fighting cancer to managing freshwater resources and protecting coastal areas and the ocean. Assistance provided through IAEA capacity building projects addresses specific national and regional problems. Expertise in the application of nuclear technology and knowledge of good practices are transferred via training activities, information exchange, coordinated research projects and the technical cooperation programme.

Sustainable and effective environmental management is a critical global challenge in the 21st century. Countries are requesting technical cooperation support to be able to understand, monitor and mitigate the dual impacts of climate change and ocean acidification. IAEA training in advanced nuclear techniques for environmental monitoring helps policy-makers frame responses that are based on scientific evidence. Well-trained and knowledgeable national scientific personnel enable Member States to formulate sound environmental policies and feasible strategies that protect the vital ecological balance of healthy natural systems, on land and in the ocean.

In addition to these activities, the IAEA also helps to strengthen the capacity of Member States in quality assurance and quality control in their environmental laboratories to be able to provide accurate data that are comparable and based on a universally accepted system. This is especially important in regional projects involving several different countries.

The IAEA specializes in producing high-quality environmental reference materials. In fact, the IAEA is the world's largest supplier of reference materials for radionuclides in different 'matrices', such as fish, plants, soil, water or other matter. Some of these IAEA reference materials function as international measurement standards. The IAEA provides reference materials to laboratories worldwide to help them ensure that proper nuclear and non-nuclear analytical techniques are applied to achieve accurate, trustworthy and reliable results. Scientists in developing countries normally have no access to most reference materials, which are expensive to use. The IAEA, therefore, supports technology transfer to

developing countries and serves as a low cost provider of these materials for laboratories in developing economies.

**Nuclear techniques provide unique, precise tools to monitor ocean acidification. At the IAEA's radioecology facilities in Monaco, precise studies of the calcification rates of marine organisms are conducted using radiotracers.**

## IAEA Environment Laboratories Monitor Environmental Contaminants

The IAEA provides Member States with training in the use of nuclear and isotopic techniques to detect environmental contaminants and assess their impact on organisms and human health. Through this training, Member States are better able to detect environmental problems. Nuclear and isotope techniques can provide high resolution data that quantify the impact of elements and chemical processes in the environment. The IAEA Environment Laboratories use radionuclides and stable isotopes to study environmental processes, the effect of contaminants in ecosystems, atmosphere — ocean interactions, surface and groundwater systems, and the response of atmospheric, hydrological and marine systems to climate change.

Training courses conducted by the IAEA enable scientists to learn about nuclear and isotope techniques to identify and analyse the composition, migration and transport by ocean currents of contaminants and their impact on the environment. Over the years, the IAEA has conducted many regional training courses supporting capacity building in marine environmental protection in the framework of regional and interregional technical cooperation projects in different regions of the world.[1]

The threat to the environment from climate change and ocean acidification is a matter of global concern. In response, the IAEA Environment Laboratories in collaboration with Member State institutions are initiating projects to monitor, assess and forecast the impact of such change on the marine ecosystem and the coastal surroundings. At the same time, IAEA experts support Member States in developing national analytical capacities to better analyse the effects of ocean acidification on coral reefs, fisheries and marine coastal ecosystems The IAEA also assesses ocean acidification's potential negative effects on human, social and economic activities. In line with Member States' mounting concerns about the severity of these effects, the IAEA's training and research also take into account the associated ecological issues for coastal areas and marine life. The resulting data and new expertise are needed to plan actions to safeguard communities both now and in the future.

Nuclear techniques provide unique, precise tools to monitor ocean acidification. At the IAEA's radioecology facilities in Monaco, precise studies of the calcification rates of marine organisms are conducted using radiotracers. Studies in radioecology also investigate the effects of elevated levels of dissolved $CO_2$ and decreased pH of seawater on the bioaccumulation of trace metals and other pollutants in various life stages of molluscs and fish.

## IAEA Training for National Capacity Building

Activities under the IAEA's technical cooperation (TC) programme are tailored to address Member States' specific needs in meeting national development priorities and contribute to socio-economic progress. The programme is implemented in four geographical regions: Africa, Asia and the Pacific, Europe, and Latin America.

Through its TC programme, the IAEA helps Member States build expertise in using nuclear and isotopic techniques to monitor and manage the marine environment and to address the degradation of the coastal ecosystems. The IAEA facilitates the transfer of useful and tested techniques and supports training in these techniques.

Regional TC project RLA/7/012, 'Use of Nuclear Techniques to Address the Management Problems of Costal Zones in the Caribbean Region', supported integrated coastal zone management in the wider Caribbean region from 2008 to 2012.

Another regional capacity building project[2] was set up to assist in evaluating the toxicity of harmful algal blooms (HABs) using nuclear

techniques, as well as in designing and implementing early warning systems. This project aimed to create awareness of the dangers HABs pose for humans and marine organisms, and the damage HABs cause to ecosystems, the tourism industry and fisheries in the Caribbean region. HABs produce potent toxins that can kill fish, shellfish, marine mammals and birds, and may directly or indirectly cause illness or even death in people. This project was undertaken in collaboration with the Intergovernmental Oceanographic Commission of UNESCO[3]. The IAEA is also in the process of establishing a Caribbean Observing Network for Ocean Acidification that will focus on the use of nuclear and isotopic techniques to monitor climate change related issues affecting the coastal zone, such as ocean acidification, including their interactions with HABs.

With the support of the IAEA and other partners, the Cienfuegos Environmental Studies Centre (CEAC) laboratories were recently refurbished to provide advanced technical capacities to produce certified data for policy-makers to help them develop plans for better environment management, including nuclear techniques to solve various environmental problems in Cuba's coastal marine ecosystem. The success of this joint collaboration is illustrated in a photo essay on page 18 in this edition.

The Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA) is an intergovernmental agreement for the Asia and the Pacific region that provides a framework for Member States to intensify regional partnerships. RCA projects focus on specific shared needs for research, development and training in nuclear sciences and technologies in the region. The IAEA and RCA support activities to enhance regional capacity to effectively apply nuclear techniques evaluate and respond to pollution in coastal waters and to marine environmental problems. The small island States of the Pacific are especially dependent upon ocean resources, and therefore vulnerable to the negative impacts of multiple environmental stresses. Although not part of the RCA, they have benefitted from the nuclear technologies training being offered under the RCA project.

As threats to the environment, such as ocean acidification, become a matter of increasing concern, the IAEA continues to work closely with Member States in providing cutting edge nuclear and isotope techniques to monitor and evaluate challenging environmental problems. The IAEA Environment Laboratories transfer and disseminate nuclear and isotopic knowledge to Member State laboratories. The IAEA Environment Laboratories provide training, strategic advice, methodological harmonization and quality support for the monitoring and assessment of marine contaminants. The advanced nuclear techniques offered by the IAEA are able to validate and generate wider awareness of the extent and severity of ocean acidification, HABs and other emerging conditions. The expertise and assistance of the IAEA enables Member States to prepare and implement appropriate actions to protect coastal zones and marine life to preserve valuable natural resources and services.[4]

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[1]These projects include interregional project INT/7/018, 'Supporting Capacity Building in Marine Environmental Protection', as well as regional projects in Africa, Asia and the Pacific, and Latin America.

[2]TC project ,'Designing and Implementing Systems for Early Warning and Evaluation of the Toxicity of Harmful Algal Blooms in the Caribbean Region, Applying Advanced Nuclear Techniques, Radioecotoxicological Evaluations and Bioassays (ARCAL CXVI) (2009–2013).

[3]A guide for field monitoring of harmful microalgae has been produced by the IOC-UNESCO, in collaboration with the IAEA (available in Spanish at ioc-unesco.org/hab); a manual of methods for the detection of harmful algal toxins using radioligand receptor binding assays is being prepared under the interregional TC project INT/7/017 by the IAEA in collaboration with US National Oceanic and Atmospheric Administration and IOC-UNESCO.

[4]For more information on IAEA's ocean acidification related activities, visit the Ocean Acidification International Coordination Centre (OA-ICC) website at www.iaea.org/nael/OA-ICC

# PROTECTING THE MARINE

1 The Cienfuegos Environmental Studies Centre (CEAC) in Cuba is a marine environmental research centre with expertise in nuclear and isotopic technologies. Cuba's food security, transportation and tourism depend upon a healthy marine environment. CEAC scientists master resource challenges to produce the validated data needed for better environmental management.

2 The refurbished CEAC laboratory is able to perform complex analysis using donated equipment, including some procured through IAEA technical cooperation support, such as gas chromatography, high-resolution gamma spectrometry and microwave digestion systems. CEAC scientists undertake research, advise on environmental management, engineer solutions for environmental challenges, and monitor pollution.

3 Miguel Gómez Batista, a CEAC scientist and IAEA technical cooperation (TC) fellow at the IAEA Environment Laboratories in Monaco, studies how arsenic accumulates in Cienfuegos oysters. Carlos Alonso Hernandez, CEAC's lead researcher, said, "Thanks to the IAEA's TC programme, CEAC uses nuclear techniques to solve environmental problems in its marine ecosystems and coastal areas."

4 Without scientifically validated monitoring data, Cuban policy-makers found it difficult to take action against marine pollution. Now, CEAC scientists use gamma spectrometry to detect radioisotopes like lead-210 that help register in great detail pollution accumulation in sediment over several decades. This insight helps policy-makers develop and assess effective prevention and remediation strategies.

# ENVIRONMENT IN CUBA

5 A scientist analyses toxins released by 'red tides', or harmful algal blooms (HABs), which accumulate in seafood, posing a risk to human consumers. Michel Warnau, Head of the IAEA's Radioecology Laboratory said, "Through the commitment of its staff CEAC became a regional centre of excellence, supporting other countries in the region."

6 CEAC participates in regional TC projects in Latin America. Through a bio-monitoring network that cooperates with the IAEA, ARCAL (a regional cooperation agreement), UNEP and GEF, CEAC and Cuba help determine the impact of chemical contamination, HABs, climate change and ocean acidification on communities and marine ecosystems' sustainability throughout the region.

7 Regional projects helped CEAC expand its expertise to investigate marine environmental processes. CEAC's scientists now mentor peers in the region, conduct IAEA TC training courses and undertake expert missions throughout the region. CEAC serves as a resource centre for the Caribbean region, e.g. by providing analytical services.

8 CEAC participates in the IAEA's coordinated research projects, which bring together researchers from around the world to address a shared problem. CEAC anticipates increased cooperation with the IAEA, UNEP, GEF and the International Centre for Theoretical Physics, as well as regional collaboration to enable coordinated and effective action on regional environmental issues.

Photos and Text: Alexandra Sasa Gorisek, IAEA Department of Nuclear Sciences and Applications

# FACTS ABOUT OCEANS

## Where We Live

Today, about 60% of the world's population lives within 60 km of the coast.

By 2030, this proportion is expected to rise to 75% .

## The Great Unknown

95% of the ocean is still unexplored.
We know more about the dark side of the Moon than the oceans.

## Toxic Chemicals

Industrial activity releases about 300-400 million tons of heavy metals, solvents, toxic sludge, and other waste into the world's waters each year.

## What Goes In

Over 80% of marine pollution comes from land-based activities.

## Plastic Debris

Ocean gyres accumulate debris creating enormous ocean garbage patches, like the 'Great Pacific Garbage Patch', with litter concentrations of up to 1 million plastic particles per square kilometre.

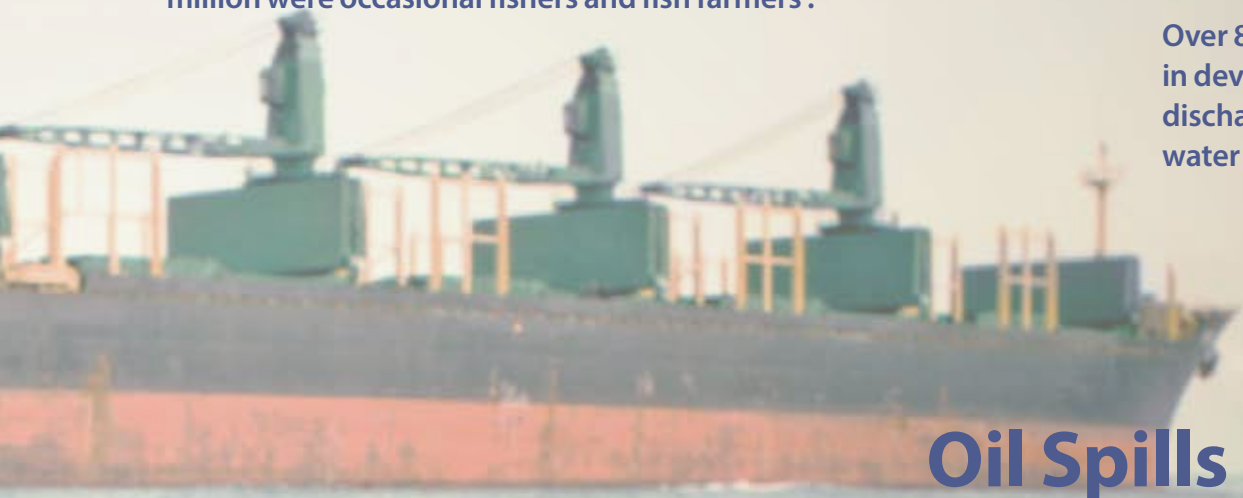
70% of marine litter sinks to the sea floor, where as many as 690 000 pieces of plastic per square kilometre accumulate.

# Oceans and Economics

**90% of world trade is carried by the sea.**
**Fisheries and aquaculture provided livelihoods and income for an estimated 54.8 million people engaged in the primary sector of fish production in 2010, of which an estimated seven million were occasional fishers and fish farmers .**

# Effluent

**Over 80% of the sewage in developing countries is discharged untreated into water bodies.**



# Oil Spills

**Oil spills are responsible for only around 12% of the oil entering the seas each year. 36% of the oil entering the seas comes from runoff that originates in cities and industry. Accidental oil spills have devastating consequences, as was seen in the 2010 Deepwater Horizon oil well blowout in the Gulf of Mexico.**

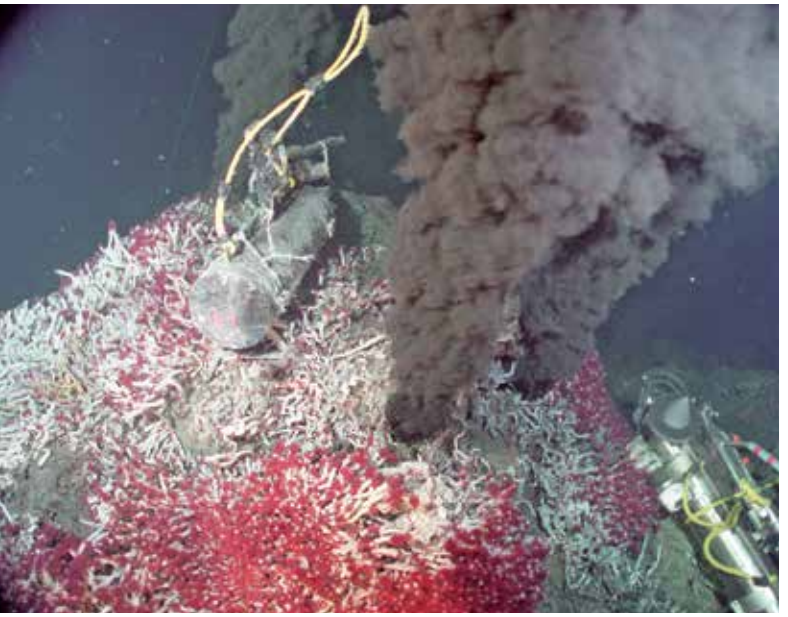
# Coral Reefs in Danger

**Approximately 20% of the world's coral reefs have been lost. An additional 20% of the coral reefs and about 35% of the mangroves have been degraded in the last few decades.**

**Text: Michael Madsen, IAEA Division of Public Information; Photo: istockphoto**

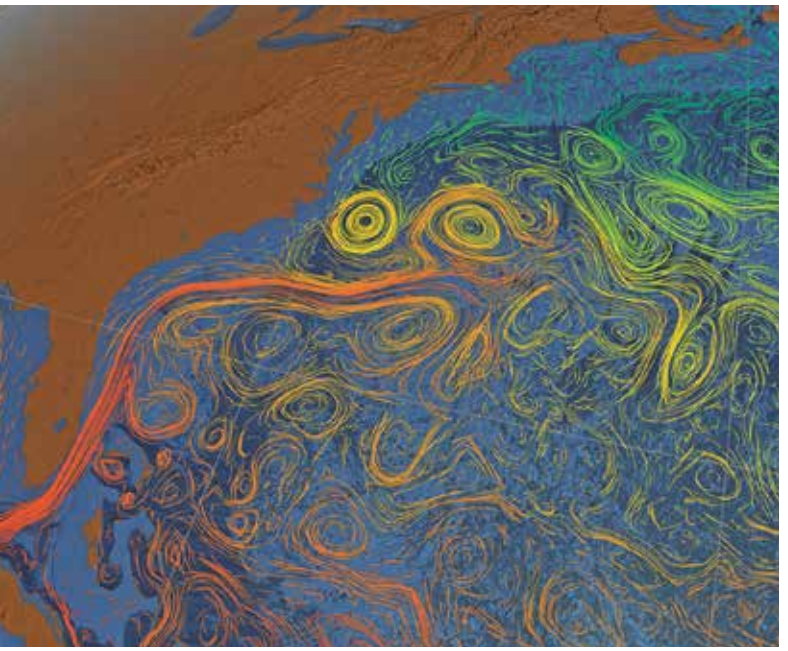
Sources: National Oceanic and Atmospheric Administration; UN Atlas of the Oceans; FAO: The State of World Fisheries and Aquaculture, 2012, www.fao.org/docrep/016/i2727e/i2727e.pdf; www.un.org/Depts/los/reference_files/wod2011-pessoa-oceans_and_the_environment.ppt; US National Research Council: 'Oil in the Sea'; http://www.nap.edu/openbook.php?record_id=314&page=R1; An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico (2013); http://worldoceanreview.com/en/wor-1/pollution/oil/; UN WWAP 2009, "Clearing the Waters A focus on water quality solutions"; www.unwater.org/Clearing_the_Waters.pdf; Ibid; (World Ocean Review, 2010); www.un.org/Depts/los/reference_files/wod2011-pessoa-oceans_and_the_environment.ppt

# WHAT THE OCEANS



1 Cradle of life — According to current scientific understanding, life on earth began in the oceans. At hydrothermal vents on the ocean's floor we can see how 'extremophiles' are able to adapt and evolve even in the most extreme temperatures and pressures.

2 Oxygen for Life — Although the Amazon rainforest is considered to be the 'lungs of the world', its oxygen production is dwarfed by the oxygen produced by ocean life. Marine phytoplankton and algae produce between 50% and 85% of the global oxygen supply by photosynthesis.



3 Weather Maker — The oceans and its currents are responsible for roughly 50% of global heat transfer. Without the transfer of warm tropical waters to the poles and vice versa, equatorial waters would be 14°C warmer and polar waters 25°C colder. This transfer grants Edinburgh warmer temperatures than Moscow, despite their location at the same latitude.

4 Recycling Powerhouse — The high biological productivity of the ocean is due to a complex food web consisting of microscopic organisms in a so-called 'microbial loop'. The loop is essential in recycling organic matter and nutrients. These organisms also serve as a powerful 'carbon sink' by capturing carbon dioxide, then mineralizing and depositing it on the ocean floor.

# GIVE US

5 Biodiversity — Over 90% of the world's living biomass resides in the ocean; estimates suggest this is made up of around a million different species. High biodiversity stabilizes an ecosystem, protecting it from other pressures and allowing complex relationships to evolve like that between clownfish and sea anemones.

6 Food Security — The oceans give us abundant food. Up to 1.4 billion people depend upon fish for a fifth of their animal protein. To meet the demand of growing populations, more fish are being harvested from fish farms and mariculture.

7 Busy nurseries — Much more than a photogenic subject, coral reefs serve as critically important nurseries for oceanic fish. Oases in what are often nutrient poor shallow waters, coral reefs have evolved symbiotic relationships that recycle and capture limited resources to sustain its communities.

8 Coastal defence — Few ecosystems are as beneficial to society as mangrove forests. They stand as physical barriers to storms, act as nurseries for fish, offer habitats for birds, trap sediment, and stop land erosion.

Text: M. Madsen, IAEA Division of Public Information;
Photos: NOAA PMEL Vents Program; NASA/Goddard Space Flight Center Scientific Visualization Studio, iStockphoto

# POLLUTION EFFECTS ON OCEANS AND MARINE LIFE

Marine pollutants are more easily defined by impact: any substance introduced into the oceans that has undesired effects. (photo: iStockphoto)

In addition to ocean acidification, our seas and their wildlife are facing a grave threat from the increased dumping and release of toxic pollutants into the marine environment. What are these pollutants and how do they affect the seas? How is the IAEA involved with monitoring these pollutants?

## Which pollutants are affecting the seas?

Defining what a pollutant is can be challenging since the term applies to many substances in addition to toxic industrial by-products. Marine pollutants are more easily defined by impact: any substance introduced into the oceans that has undesired effects. This broad definition includes heavy metals, such as lead and mercury, and synthetic organic compounds like chlorinated pesticides, flame retardants and polychlorinated biphenyls (PCBs), but also some of life's building blocks, such as nitrogen and phosphorous compounds. These pollutants can enter our oceans through illegal direct dumping of toxic industrial waste, or through harder-to-control natural processes such as wind, rain runoff and polluted rivers. Through careful monitoring and strict regulations governments hope to control the harmful pollutants that enter the seas.

## How do heavy metals affect organisms?

Although heavy metals like lead and mercury can kill an organism if a significant quantity is ingested in a short period of time, most heavy metal poisoning affects sea life by generally reducing organisms' longevity and their 'recruitment', or the organisms' ability

to produce surviving offspring. Shortened life spans and reduced recruitment in key organisms significantly weakens the ecosystem, making it more vulnerable to other threats such as overfishing, climate change or ocean acidification. Degradation of the marine environment is often attributed to the combination of these stressors rather than any single cause.

## How do nitrogen and phosphorous compounds affect organisms?

Essential in supporting plants' life and growth, the natural elements nitrogen and phosphorous are key components of fertilizers. When too much fertilizer is applied to fields, rainwater can wash excess nitrogen and phosphorous into river systems and onwards to the sea. There, these nutrients can cause phytoplankton populations to explode, an event called a population 'bloom'". Toxic algal blooms can then transfer toxins to fish that in turn can be consumed as seafood. Sometimes this overfeeding, or 'eutrophication', can boost the population of some species to the detriment of others.

Increased algal blooms can produce oxygen deficiencies in areas due to decomposition of the planktonic biomass, and create so called 'dead zones', anaerobic zones where normal sea life cannot survive.

## Where do pollutants go?

When organisms ingest and retain more pollutants and toxins than they can excrete, 'bioaccumulation' occurs. Through the food chain, pollutant concentrations tend to increase in the bodies of top predators (biomagnification). Humans, at the top of the food chain, run a great risk of accumulating high concentrations of pollutants in their body tissues. Research conducted on top predators in the marine environment (large fish, seals and seabirds) helps us in understanding the biomagnification process and to assess seafood safety.

## How can nuclear techniques mitigate pollution?

Domestic wastewater and the solids it produces after treatment can be dangerous to human health and the environment if not managed properly. At the same time, wastewater solids contain valuable organic matter and nutrients, which can enrich soil and may emerge as important resources provided they can be adequately treated to avoid risks and are used safely in accordance with good practice.

Sewage sludge can now be treated with gamma rays from a cobalt-60 source or with an electron accelerator, which can kill the pathogenic (disease-causing) agents in the sludge, such as bacteria, fungi or viruses. This nuclear application will enable the release of sludge into the environment in a safe manner. A pilot plant for sludge gamma irradiation is operating in India. The process yields pathogen-free, dried sludge that can be beneficially used as manure in agriculture. The field trials performed in Baroda confirmed that the manure enhances crop yield and improves soil conditions

**The IAEA Environment Laboratories use radioisotopes to track and trace the sources of pollutants and in that way help countries control their environmental impact.**

## How does the IAEA help?

The IAEA helps its Member States use nuclear technologies to monitor pollution on land and in the sea. The IAEA Environment Laboratories use radioisotopes to track and trace the sources of pollutants and in that way help countries control their environmental impact. For example, the IAEA supported a study of the effects of trace amounts of cadmium (a toxic metal) on local fish and shellfish in Chile[1]. Experiments were designed to use the radiotracer cadmium-109 to measure how quickly the cadmium in mussels was released in order to understand the bioaccumulation of this hazardous metal.

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[1]Investigations of marine ecotoxicological impacts using nuclear-based techniques. www.iaea.org/monaco/page.php?page=2221

# IAEA MONITORS MARINE RADIOACTIVITY

On 10 March 1961, the IAEA concluded with the Principality of Monaco and the Oceanographic Institute, then directed by Jacques Cousteau, an agreement on a research project on the effects of radioactivity in the sea. The opening of the IAEA's marine laboratories in Monaco that same year marked the start of a new era for research into the marine environment.

**Determining pollution sources is one of the biggest issues in evaluating the incidence and severity of contaminants in the marine environment.**

**Isotopic studies are a powerful and unique diagnostic tool to investigate various types, levels and effects of pollution and radioactive contaminants in the marine environment.**

In providing comprehensive information on nuclear and isotopic techniques, the IAEA assists Member States in using scientific tools to precisely identify and track nuclear and non-nuclear contaminants, as well as to investigate their biological effects. Determining pollution sources is one of the biggest issues in evaluating the incidence and severity of contaminants in the marine environment. Isotopic studies are a powerful and unique diagnostic tool to investigate various types, levels and effects of pollution and radioactive contaminants in the marine environment.

The laboratories have since provided essential scientific and analytical support for a landmark study of radioactive and non-radioactive pollutant levels in all principal seas. This includes worldwide radioactivity baseline studies of the Atlantic, North and South Pacific, Indian, Arctic and Antarctic Oceans and the Far Eastern, Mediterranean and Black Seas. Regional studies have also been conducted in the Gulf, the Irish, Kara and Caspian Seas, New Caledonia and the Mururoa and Fangataufa Atolls.

Radioactive substances entered the Pacific Ocean following the 2011 Fukushima Daiichi nuclear accident. Countries throughout the region initiated an IAEA technical cooperation project to harmonize measurements of various radioisotopes in marine waters, biota, sediments and suspended matter to determine the impact on the marine environment. The uniform measurement of the radioisotopes in the ocean will ensure that any impact assessment is comparable and verifiable across the enormous volume of the Pacific Ocean. The project will enhance national capacities, which in turn will improve the exchange of data gathered from ocean measurements, as well as the information about the potential impact of these radioisotopes and risks to marine biota and to humans through marine food consumption. Twenty-one IAEA Member States and three non-Member States are participating in the project.

The project was approved by the IAEA Board of Governors at its meeting in June 2011 as a prompt response to the request of the Member States in the region; implementation of the project started on 1 July 2011 and is planned to be finalized in 2015. Extrabudgetary funding for the project was provided by the USA, New Zealand, Australia and Japan. Australia is serving as the lead country in the project.

The majority of countries participating in the project are collaborating under the Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA)[1]. Additional countries participating include Cambodia, Cook Islands, Fiji, Nepal, Palau, Marshall Islands and Solomon Islands.

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[1]Established in 1972, the RCA is an intergovernmental network of policy-makers and scientists, with the IAEA acting as its Secretariat. RCA countries participating in the project are Australia, Bangladesh, China, India, Indonesia, Japan, Republic of Korea, Malaysia, Mongolia, Myanmar, New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam.

# BETWEEN SEA AND EARTH — PROTECTING AN ESSENTIAL BUFFER

Neither ocean nor land, coastal zones are ecologically and economically important. Making up a fifth of the earth's surface, coastlines are experiencing the swiftest population growth on earth. Livelihoods in tourism, industry, fishing and trade, as well as revenues worth hundreds of billions of dollars are generated on and in these coastal waters.

## Food for Growing Populations

Wild fish caught in coastal zones serve as an essential source of feed for aquaculture, the world's fastest growing food production system that depends heavily on marine fisheries. The OECD–FAO Agricultural Outlook 2013–2022 projects that aquaculture will surpass 'capture' fishing as the main source of fish for human consumption by 2015. The total world production of farmed fish production now exceeds beef production[1].

## Irreplaceable Protection

Since healthy coastal zones are powerful contributors to sustainable ecosystems and economies, they need to be preserved. They serve as natural coastal protection in the form of mangrove forests, sand banks, corals and salt marshes, moderating the full impact of floods and ever more powerful storm surges, which are expected to be more frequent with warming waters and rising sea levels. Coral reefs, for instance, break surf and prevent damage to coastlines and their natural defences. But these natural protections are themselves under threat, making coasts even more vulnerable. Coral, for example, is sensitive to rising ocean temperatures and higher acidity and is increasingly threatened. According to the UNEP, as much as 7% of mangroves, salt marsh plants and seagrasses are lost every year.

## Carbon Sink

These weakening, natural protective barriers play a dual role in moderating climate disruptions. 'Blue' carbon sinks, like mangroves, saltmarsh plants and seagrasses, capture more than half of the naturally captured carbon emissions. The UNEP estimates that the earth's 'blue' carbon capture capacity is equal to half the annual emissions from the global transport sector.

Coastal zones serve as natural coastal protection in the form of mangrove forests, sand banks, corals and salt marshes, moderating the full impact of floods and ever more powerful storm surges, which are expected to be more frequent with warming waters and rising sea levels. (Photo: iStockphoto)

## Threats

Beyond threats to coasts' natural protection, there are several other reversible threats burdening these ecological treasures.

## Run-off

Agricultural run-off triggers algal blooms in coastal zones, which can lead to toxic seafood contamination and later to oxygen-depleted dead zones (see 'Pollution Effects on Oceans and Marine Life', pages 24-25). Herbicides in run-off can kill mangroves, reducing biodiversity since the mangroves serve as fish nurseries.

## Dredging and dumping

Deeper harbour channels are needed to handle ever deeper draught cargo ships, but the dredged sediment carries pollutants that are then dumped in concentrated form in an otherwise undisturbed area. Life forms that cannot escape are buried and the pollutants contaminate that ecosystem. Annually, hundreds of millions of cubic metres of sediments are dumped worldwide.

**Industrial effluent can be treated using radiation without adding any other chemical substances or generating radioactivity. This technique can be used to clean wastewater and reclaim water for use in industry and agriculture.**

## Wastewater

Municipal sewage increases the 'turbidity', or cloudiness, of water, which cuts the amount of light reaching organisms like seaweed, seagrasses and corals. Solids bury marine life that lives on the seabed. Pathogens are also transported by untreated sewage that can cause diseases like typhoid, hepatitis and cholera. Nitrogen in sewage is difficult and expensive to remove and when released in the sea can trigger or extend dead zones and increase turbidity. In developing countries, the UNEP estimates that up to 90% of municipal wastewater entering rivers, lakes and coastal zones is untreated.

## Weakening Resilience

These combined threats push coastal marine environments' resilience to a tipping point, beyond which these environments may no longer recover. According to the UNEP's Blue Carbon report, the carbon sinks and fisheries in coastal zones can be reinvigorated, if measures are taken to regulate the activities that cause damage, such as coastal reclamation, mangrove removal, fertilizer overuse, silting caused by deforestation, overfishing and unsustainable coastal development.

## Solutions

Radioactive isotopes, or 'radiotracers', are used to precisely measure the purification efficiency of wastewater facilities and drinkable water production facilities, aiding their design and improving their performance. Minute quantities of radiotracers can be reliably detected in large-scale processing, such as treatment plants handling millions of litres of effluent daily. (Learn more about radiotracers on page 7)

Sewage sludge, which normally would be released into waterways, can be irradiated to produce both fertilizer and sterile water for agriculture, improving crop yields, food safety and reducing the demand for fresh water. Isotopic techniques are used to map how sediment moves, ensuring that dredged material can be released in an area where it cannot migrate into ecologically sensitive regions or return to the dredged harbour.

Industrial effluent can be treated using radiation without adding any other chemical substances or generating radioactivity. This technique can be used to clean wastewater and reclaim water for use in industry and agriculture. Irradiation removes persistent organic pesticides and toxic compounds. An electron beam can irradiate wastewater containing chemicals that resist being broken down with heat, such as those used in manufacturing textile dyes. After irradiation these chemicals are either rendered harmless or converted to substances that are easily removed by using conventional treatment techniques.

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[1]Earth Policy Institute, Plan B Updates; June 12, 2013; Farmed Fish Production Overtakes Beef; Janet Larsen and J. Matthew Roney.

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