twas

Institute of Marine Sciences

ZANZIBAR, TANZANIA

IMS

EXCELLENCE IN SCIENCE

Profiles of Research Institutions in Developing Countries

PUBLISHED IN COLLABORATION WITH

SIG
Science Initiative Group
Institute for Advanced Study

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Published by TWAS, the academy of sciences for the developing world

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Foreword

For more than a decade, TWAS, the academy of sciences for the developing world, in collaboration with several other organizations and funding agencies – including the United Nations Development Programme's Special Unit for South-South Cooperation (UNDP-SSC), the Global Environment Facility (GEF) and the Packard Foundation – has developed a large number of profiles of scientific institutions of excellence in the developing world. The profiles have been published as books (by Harvard University Press and Kluwer Academic Publishers), as articles (in *Environment Magazine*) and as news stories (in the *TWAS Newsletter*).

To date, more than 150 institutions have been examined. Each profile details how the institutions have developed and how their research programmes are organized. Each explores the institutions' strengths, probes their weaknesses – and, most importantly – describes how their experience can offer valuable lessons for other institutions seeking to build scientific capacity.

A major goal of this decade-long initiative has been to showcase the high level of scientific excellence taking place in the developing world and to illustrate how science is being put to work to address critical social needs in the South. In this way, we hope that our expanding series of 'best practices in the applications of science and technology' can serve as a valuable blueprint for policy-makers and those involved in the administration and management of national policies and programmes.

The case study that follows examines the work of the Institute of Marine Sciences in Zanzibar, Tanzania, one such successful scientific institution in sub-Saharan Africa.

Dismal statistics abound about the state of science and society in sub-Saharan Africa. There are also numerous publications detailing the difficult circumstances faced by the people of the region.

Yet, encouraging signs of progress are also emerging. Over the past decade, six of the world's 10 fastest growing economies have been in sub-Saharan Africa. These countries have been led by Angola, which has experienced an annual growth rate of more than 11% and also include Nigeria, Ethiopia, Chad, Mozambique and Rwanda, each of which grew at annual rate exceeding 8%.

Yet, much of this economic growth has been commodity-based and due in no small measure to China's insatiable appetite for the continent's treasure trove of metals and minerals.

While investments in science and technology have also grown, this growth has been at a far slower pace. Indeed Rwanda is the only country in sub-Saharan Africa that spends more than 1% of its gross domestic product on science and technology.

Nevertheless, it would wrong to ignore the increasing emphasis that countries throughout sub-Saharan Africa are placing on science and technology as primary engines of sustainable growth. The trend is discernible, in part, in the increasing number of scientific institutions of excellence that are making significant contributions to their societies.

Investments, no doubt, remain too small, and the number of scientific institutions of excellence too few in number. Progress, moreover, has been uneven and fragile. And reversals in fortune are not uncommon. Moreover, the global economic crisis, which began in mid-2008, has placed the future at risk even for those African countries that have made significant strides forward. Yet, it should also be noted that many countries in sub-Saharan Africa have not only weathered the economic crisis better, but have also rebounded more quickly, than have the United States or the majority of countries in Europe.

In short, what has been happening in sub-Saharan over the past decade is encouraging, and science and technology have become important tools in helping to advance these positive trends.

TWAS is dedicated to exploring these developments by profiling scientific institutions of excellence that are leading the way for a better future on the continent – institutions like the Institute of Marine Sciences in Zanzibar. We are delighted that the Science Initiative Group at the Institute for Advanced Study in Princeton, New Jersey, USA, is joining us as an invaluable partner in this effort.

Daniel Schaffer
TWAS Public Information Officer
Trieste, Italy

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Introduction and Issues

Physically, the aging structure of the Institute of Marine Sciences (IMS) in Zanzibar, Tanzania, is not imposing. The building is wedged between the gently lapping waves of Zanzibar Harbour and the bustling byways of Mizingani Road, where surging crowds of traders and hagglers have little notion of the mindful activity inside. The paint on the small, white harbour-side building is faded and chipped after more than half a century of the Indian Ocean's damp air and seasonal downpours. Aside from the occasional departure and return of the SUVs that ferry students and faculty to their study sites, there are few hints that this is home to East Africa's leading research institute of marine sciences.

Zanzibar, since ancient times an exotic way station for explorers seeking a sea route to the Far East or the source of the Nile River, has always beckoned to the ambitious and the powerful. A few steps away from the IMS building is the heart of Zanzibar Town, or Stone Town, which hums with activity today much as it has for centuries, a maze of alleys, bazaars, mosques and once-grand townhouses built by Arab traders.

Many buildings are distinguished by their famous hand-carved, brass-studded 'Zanzibar doors', imported from India to signify the wealth of the owners. Some of the grandest houses are now attractive hotels, signs of the island's growing stream of tourists who have discovered the white beaches, blue waters and intriguing historical past of the 'Spice Islands'.

Driven by a rising tide of Western visitors, the archipelago is moving quickly to catch the rhythms of the 21st century, some of which can be heard literally next door to IMS at Mercury's restaurant and bar. Mercury's is named after Freddie Mercury, a Zanzibar native who gained international fame as the lead singer and songwriter for the rock band Queen.

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Like the archipelago itself, IMS has not ignored the changing needs of Zanzibar, most of whose people are among the world's poorest. Despite the institute's low local profile, in the past decade, its small but close-knit academic community has leapt ahead not only in its professional capacities, but also in the concern for its neighbours who can benefit from science in many ways. At the level of academic research, IMS has no peer in the region, claiming expertise across the spectrum of geology, oceanography, chemistry, biology and information technologies. Equally important, it has made a strategic decision not to be satisfied with scientific knowledge, but to share its insights and expertise with the community and local partners in Zanzibar, on the mainland of Tanzania, and throughout the Western Indian Ocean community.

A telling mark of maturity for IMS is that the parent University of Dar es Salaam (UDSM) has given the institute approval to award most postgraduate degrees on its own. As of 2010, IMS has been able to offer MSc and PhD degrees by virtue of students having successfully completed a thesis, and as of 2011 it has gained the right to award an MSc through the successful completion of coursework and a thesis. IMS faculty will now be able to train the next generation of researchers more effectively, awaiting only the ability to award PhD degrees by coursework and thesis.

In fact, the progress of IMS faithfully reflects the motto of UDSM as it celebrates its 50th anniversary in 2011: *Advancing knowledge, creating futures*. The academic staff of IMS, most of whom arrived on the island within a few years of one another in the late 1980s, seem equally motivated to pursue their own research careers and to create better futures for others. Indeed some of the staff and students are familiar figures in the most remote villages of Zanzibar and the mainland coast, where they enlist local residents as partners in developing new forms of aquaculture that provide both food and livelihoods for more people.

> *"Zanzibar has always beckoned to the ambitious and the powerful."*

Recent History

IMS is located in Zanzibar for the same reason humans have settled there for millennia: it provides a safe and strategic location amid an appealing climate and attractive coral reefs.

Zanzibar, which actually consists of multiple islands – the main island of Unguja, the island of Pemba, and several smaller islands – is only 40 kilometers (km) from the mainland. Yet its human history and natural character are its own.

After some 50,000 years of human habitation, it became part of the historical record when Persian traders discovered the value of its protected harbour as a trading base for voyages throughout the Indian Ocean. During the Age of Exploration, it was appropriated by the Portuguese in the late 1400s and became known for its exports of cloves, pepper,

nutmeg, cinnamon and vanilla. Two centuries later, it was seized by the Sultans of Oman, who developed an economy of trade and cash crops ruled by an Arab elite. By the late 1800s, the Sultanate controlled a Zanzibar empire stretching from Somalia to Mozambique, along with extensive inland trading routes. Many of the most elaborate buildings were built then, and most of them still stand, including the house where Dr. David Livingston (of Livingston and Stanley fame) lived. The sultans grew wealthy trading not only spices, but also elephant tusks from the mainland and slaves bound for cities on the coast of the Indian Ocean.

The region gradually came under British control with part of the motivation being a desire to abolish slavery. In 1890, following the succession of a sultan of whom the British did not approve, British warships shelled the sultan's palace for about 40 minutes and assumed control of Zanzibar, marking what many historians believe to be the shortest war in history.

During the era of African independence, the island gained freedom from Britain, and in 1963 became a constitutional monarchy under yet another sultan. A month later, old scores were settled during the bloody Zanzibar revolution, in which several thousand Zanzibaris of Arab descent and South Asians were killed. Thousands more were expelled.

In April 1964, the Republic of Zanzibar and Pemba merged with the mainland Tanganyika to become the United Republic of Tanganyika and Zanzibar. This moniker was simplified to the United Republic of Tanzania, but local Zanzibar affairs continued to be controlled by a Zanzibar president, while foreign affairs were handled by the Tanzanian government in Dar es Salaam. To this day, Zanzibar retains its own president and a semi-autonomous government.

MARGARETH KYEWALYANGA

• ***Margareth Kyewalyanga***, *director of IMS, arrived in 1988 as part of the '1980s class' of senior researchers, who still work together. They include Jiddawi (1982), Nyandwi (1984), Shaghude and Muzuka (1986), Mmochi (1988) and Mtolera (1989). Like the others, Kyewalyanga followed a path with many twists and turns. She studied botany and chemistry at UDSM, hoping to work in marine science. But the hiring policies at UDSM, not IMS, dictated the opportunities, and UDSM was not hiring botanists at that time. So she began work at IMS as a chemist.*

A year later, she won a scholarship to Dalhousie University, in Nova Scotia, Canada, where she learned more marine science than even she had bargained for. "We had to pass programmes in four different subfields of oceanography", she recalls, "chemical, physical, biological and geological. I did it, and after two years I earned an MSc and qualified for PhD studies. But I didn't have another scholarship. So I came back to IMS. The director then was Magnus Ngoile. He had the only PhD at the institute, and the only computer, a laptop."

Ngoile soon arranged funding from his own research grant to allow Kyewalyanga to return to Dalhousie in 1992. She came back to IMS in 1997 for good with a doctorate degree in biological oceanography, turning at last to her true research interest, which focuses on the role of phytoplankton in primary productivity. She was also a key investigator in the IMS programme to develop finfish mariculture, applying her expertise in productivity. In particular, she analysed the food needs of the milkfish, determining that the simple application of chicken manure, along with low salinity, would provide optimal conditions for the development of the mat-like community of algae and zooplankton needed for the growth of fingerlings.

Kyewalyanga was appointed IMS director in 2009 after the departure of Alfonse Dubi, whose term had ended. Dubi moved to Arusha to help develop the new African Institute of Science and Technology.

> *"To this day, Zanzibar retains its own president and a semi-autonomous government."*

Evolution of an Institute

Against this backdrop, IMS has followed its own long and uneven growth path, beginning in the 1950s as part of a multi-country East African Marine Fisheries Research Organization (EAMFRO) comprising several constituent parts.

At the time, EAMFRO consisted of a small institute in Kenya, which continues in an expanded form today, and a freshwater laboratory in Uganda mandated to study the 'African Great Lakes'. EAMFRO survived the 1963 revolution in Zanzibar. The senior member of the academic staff, Salim Mohammed, recalls being hired in 1975 as a technician, when the staff consisted of just a few British, Ugandan and Tanzanian scientists, and a Ugandan director. With the collapse of the East African Community in 1977, the Ugandans and Kenyans left, and in 1978 IMS was adopted by UDSM. Its mandate was confined to

fisheries biology, along with some oceanography. Tanzania took over the existing building, but its research community did not have experience in managing an institute. Most of the scientists left except for Mohammed and Magnus Ngoine, both of whom gradually moved ahead in their academic careers. Mohammed, who completed his PhD at Stockholm University in Sweden, retired from IMS in 2010, but continues to teach there. Ngoine later served as director.

Even as IMS struggled to survive, it raised the academic bar, requiring academic staff to have college degrees and gradually adding some training activities for younger people. In 1980, two more faculty members arrived, a biologist and a botanist, and in 1982 Narriman Jiddawi came from UDSM. She was followed in 1984 by Ntahondi Ngandwi and then by Yohanna Shaghude and Alfred Muzuka. All are senior leaders today.

Most of the early group were geologists, partly because the government was promoting oil and gas development and saw little value in biology. In 1988, however, Jiddawi was joined by the current director, Margareth Kyewalyanga, a second biologist, and in the 1990s more biologists began to arrive. The research laboratories were built with the help of the Swedish International Development Agency (Sida) and the International Centre for Ocean Development of Canada. As a result of these developments, the institute's research reputation began to grow.

> *IMS has followed its own long and uneven growth path, beginning in the 1950s as part of a multi-country research organization.*

IMS began to teach postgraduates, but UDSM kept the prerogative of awarding degrees. Leadership flagged when a director was appointed in 2001 who refused to move to Zanzibar, attempting to direct the institute from Dar es Salaam. She died a year later. Throughout this difficult period, the laboratory's main focus remained on staff development and less on capacity building.

The appointment of Alfonse Dubi, a civil engineer, as director in 2002, signalled a revival of capacity building for the laboratory. By 2004, there were 16 academic staff, 13 of whom were PhD holders. In addition, there were two PhD students. The institute was now ready for a more ambitious agenda, and began to expand from fisheries into all branches of marine science. It was also ready to meet more of the obligations outlined in its mandate. These responsibilities include a broad response to the needs of local stakeholders and expanded efforts to make its research relevant to society – for example, by conducting studies on food security, tourism, climate change, poverty alleviation and environmental management. It has drawn up a detailed research agenda identifying each of these themes.

> *"IMS's responsibilities include a broad response to the needs of local stakeholders and expanded efforts to make its research relevant to society."*

Expanding the place of students

The ability of IMS to award advanced degrees remained contentious, however. In 2005, Ntahondi Nyandwi, now a deputy director, recalls that the institute requested degree-granting status but was turned down. “In 2006”, he said, “I went to the vice-chancellor at Dar and sat down with him and had a talk. They finally gave approval for us to issue our own MSc and PhD degrees by thesis only. Then, in 2009, they approved the MSc with coursework and thesis. The final step is the ability to grant a full PhD, which we eventually hope to attain.”

The first new MSc class of 12 students, from Tanzania, Mauritius and Mozambique, enrolled in 2009, supported by scholarships from Sida and the Regional Initiative in Science and Education (RISE), which is funded by Carnegie Corporation of New York. After completing their MSc course work, a portion in January and a portion in July 2010, they have begun their fieldwork with the hope of continuing to work towards their PhDs.

Margareth Kyewalyanga, who was appointed director in 2009, applauds the presence of the students. “I strongly believe that having them here makes the institute research more active”, she says. “The institute gains new energy and different points of view. This keeps us from getting stodgy.” Yohanna Shaghude, head of the Physical and Applied Sciences section, notes the faculty is taking the change seriously, dedicating considerable time to new mentoring and evaluation duties.

IMS has made the most of its limited physical space. The main building now contains fully equipped laboratories, a research aquarium and the National Oceanographic Data Center. A continuing concern is adequate internet bandwidth, with slow connections still coming to the island by microwave. An even graver concern is electrical power, which comes to the island through a 40-year-old cable that was designed for 25 years of service. Last year the cable failed, causing a power blackout that lasted three months. The lab had to provide power with its own generator.

Concern for community

Despite widespread challenges, research and teaching at IMS have become steadily more diverse and productive. Indeed, additional human resources and better laboratory equipment have led to higher research output. Publications are on the rise. Research focuses largely on the needs of island and mainland coastal residents. "We have a new community emphasis", says Salim Mohammed. "Part of our mission is development, which requires us to deal with the coastal people and to encourage them to work on projects with us. Our environmental awareness programmes have been successful. We meet with people in schools, community centers and market places. We coordinate our programmatic agendas with the policy agendas of the government."

For example, the IMS geology group in the Physical and Applied Sciences section not only studies such basic research issues as climate change and sea level fluctuations, but also examines such applied, policy-oriented issues as coastal erosion. Their work has proven to be valuable not only for the scientific community but also for broad segments of society interested in development – most notably the tourism industry, which is a mainstay of the economy.

Shaghude points out that some erosion is natural, as shorelines evolve and sand migrates to new locations. For example, an ancient baobab tree near the fishing community of Fumba Chaleni is being undermined by wave action. No one, however, is certain whether human activities, notably intensive fishing and shellfish gathering offshore, have played a role. What is certain is that local communities like to build near the

beach for any number of reasons: for example, they use the shoreline to weave long ropes from palm fronds, to make lime for concrete, to lay out their seaweed farms, and to launch dugout fishing boats. For the majority who have no indoor plumbing, the beach has long provided a convenient substitute for bathroom facilities. Today, many of Zanzibar's near-shore communities are at risk.

According to Nyandwi, the daily actions of the waves and tides have little effect on the coast. Virtually all shoreline damage occurs during a few extreme storms each year, especially when the moon is full or new. A growing concern is that extreme storms have become more common in recent decades. The damage has been exacerbated by a range of human activities that low-income people use to support themselves – for example, the mining of sand along riverbanks for use in construction, the collection of sea grass, drag-fishing along the coral reefs, and the cutting of mangrove trees that are essential for protecting tropical shores. Shaghude adds that hotels and other commercial activities may also accelerate erosion, often unwittingly, when sea walls are built to protect shorelines. He and his colleagues spend considerable time consulting with hotel proprietors and others about restricting new construction near beaches and using more effective but less intrusive shoreline defenses, such as sloping embankments that absorb and deflect wave energy.

In addition to its research and public outreach programmes, IMS has sought to broaden discussions of shoreline issues through a series of publications derived from joint meetings with communities. The first publication, coordinated by Nyandwi, was released in early 2011. Titled *Jambiani: Managing Our Coasts: The Participatory Approach to Coastal Management at Jambiani, Zanzibar*, the publication provides comprehensive information on 'decision support tools' based on discussions with 34 village leaders and governmental officials.

> *"Research and teaching at IMS have become steadily more diverse and productive."*

NARRIMAN JIDDAWI

• ***Narriman Jiddawi***, *section head of Marine Biology and Resources Management, is known around the lab as a whirlwind of activity – not only for leading her section, performing research, and mentoring a large number of graduate students, but also for teaching many local women new techniques to enhance their livelihoods. She has been a driving force in the effort to help women create half-pearls in* Pteria *oysters by working the pearls and shells into jewelry and then marketing the jewelry in Tanzania and other countries. She is also active in teaching environmental principles to fishermen, and has set up a self-driven system for monitoring their catch in Uroa and Matemwe. "We train them how to collect data", she said. "They understand the purpose of conservation as well as we do. We both want to conserve fish for the future of the community." Jiddawi's interest in conservation extends in many directions, including programmes to preserve green and hawksbill turtles, better educate dolphin tour guides, and prevent the loss of humpback whales that become entangled in fishermen's nets.*

> *"There is a serious paucity of data on the ocean topography, coastal dynamics and other physico-chemical conditions of Tanzania waters."*

Another successful effort to work with the community was funded by the International Foundation for Science (IFS) in Sweden through WIOMSA, the Western Indian Ocean Marine Science Association. The funding enabled IMS to organize a two-week workshop, consisting of 60 scientists and members of 22 local communities. The goal was to strengthen links and interactions between scientists and the public. Workshop sessions focused, for example, on the costs and benefits of tourism and the conservation of mangroves and turtles. Participants also took part in a field trip to the beach to learn about seaweed farming and to see the impacts of beach erosion.

In yet another effort to empower local communities, IMS recently completed the construction of a windmill in the Fumba Chaleni community, some 14 km south of the IMS headquarters. The project, which is funded by ReCoMaP (Regional Coastal Management Programme of the Indian Ocean Communities), aims to develop low-cost, environmentally friendly sources of energy to improve the operations of aquaculture systems in a number of villages.

Rising environmental awareness

Although the marine environment around Zanzibar is relatively undamaged compared with much of the world, a gradual degradation of the area's seawater and coral reefs is detectable, as revealed in the declining health of sand dunes, sea grass beds, coral communities, and especially mangrove forests that are cut for firewood and lumber.

Zanzibar's population density, which now stands at more than 400 people per square km, has doubled since 1978. Today, more than one million people live in the archipelago. A largely pastoral population (except for the urban dwellers of Zanzibar Town) exerts rising pressure on fish stocks, forests, coral reefs and the limited rocky farmland.

IMS scientists have begun to tackle these issues, but they find themselves faced with a dearth of basic knowledge about the physical environment. "There is a serious paucity of data on the ocean topography, coastal dynamics and other physico-chemical

conditions of Tanzania waters", says Alfred Muzuka, a geochemist in the Physical and Applied Sciences section. "For example, a lack of information on tides and currents of coastal water and on coastal geology largely explains the failed attempts to replant mangrove trees." Muzuka's research group was one of six awarded a 'TWAS Research Unit in Least Developed Countries' grant in 2003.

IMS staff is working hard to meet these challenges. One project, led by Narriman Jiddawi, involves not only monitoring fishing patterns in certain areas around the island, but also training fishermen to report on their catch. This presents opportunities for talking with local people about environmental issues and the importance of maintaining sustainable fisheries. Jiddawi has even taken local fishermen to meetings in Dar es Salaam, South Africa and India to talk with fisheries scientists. "Scientists want to hear from fishermen. In addition, the workshops include the views of both the fisheries managers and conservationists. We put them together to talk about conserving fish for the future of the community."

Leonard Chauka, a PhD student, is working with fishermen along Tanzania's mainland coast, from Tanga southward, trying to spread environmental awareness. "Bad practices have been the major factor in reducing the fish catch", he says. "This is especially true when it comes to the dragging of nets to facilitate large catches. Dynamite is another detrimental practice (dynamited fish rise to the surface where they are gathered). While it is not legal, enforcement is a problem. People don't understand why dynamiting is more harmful than other practices. And immediate concerns for an adequate catch overshadow any worries about the future health of the fish stocks."

Another problem lies in catching too many small fish before they reach reproductive age. "We know local people are doing this", Chauka says. "They are catching young sardines and rabbit fish before they are mature. We can see the fish in the market place. But when foreign fishermen do it from commercial ships and take their harvest elsewhere, no one here knows."

Closer to home, Chauka has had more success in enlisting local people to help restore coral areas, especially those severely damaged by a major bleaching event in 1988. "A large area was devastated, but the micro-algae are re-establishing themselves. The local community was eager to help during the restoration – maybe because we were serving them lunch at the same time!"

IMS is also working with hotel proprietors and managers to encourage environmentally sound practices. They cite model projects, such as the Neptune Resort and Spa on Zanzibar's east coast, which became the first corporate member of WIOMSA when it opened in 2007. The resort keeps its beach meticulously clean, treats its sewage before discharge and offers leisure and sports activities that do not harm the natural coast or its biota.

"We have made the case that tourism is essential to the economy, but if tourism-related development is not done in a sustainable manner, it will only cause economic misery", maintains Aviti Mmochi, a leader in efforts to reduce pollution and promote aquaculture. "The tourism sector, apart from earning much-needed foreign exchange, supports members of the community through employment. If the beach environment is compromised by greedy investors, our exotic islands will be ruined."

IMS has taken the lead in other environmental projects as well. For example, it has been instrumental in helping to save green sea turtles, which for years have been taken for food, and hawksbill turtles, which are taken for their attractive shells. Even though turtle hunting was banned in 1995, the custom has continued. IMS scientists have contacted people in every village, explaining that the species are on the brink of extinction.

> *"Bad practices have been the major factor in reducing the fish catch."*

ALFRED MUZUKA

• ***Alfred Muzuka*** *, associate professor, geochemist and member of the Physical and Applied Marine Sciences section, is a leader in deciphering the geology and ancient climate of East Africa. A primary aspect of his research is documenting past climate change by dating both marine and terrestrial environments. He uses terrestrial cores from Lake Tanganyika, Lake Victoria, and the Crater Lakes (Ngorogoro, Npakai). He retrieves marine cores from sediment beneath the Pemba Channel, Rufiji River Delta and Ruvuma River. Pemba and Ruvuma sediments are about 30,000 years old, and Rufiji sediments are about 20,000 years old. "One thing we have seen from the terrestrial samples", he says, "is decreasing precipitation over the past 5,000 years. The changing climate has altered the ecology of the region's forests and grasslands. Marine cores are indicating the same, but we don't yet have enough samples to understand the full dimensions of the transformation." One impediment to his work is the lack of a facility that can analyse stable isotopes. At present he is forced to send them abroad, which "takes forever".*

His second research emphasis is to gauge the impact of climate change on prawn fisheries at the mouth of the Rufiji River, the country's most productive fishing ground. Muzuka is collecting prawn fisheries data from the Ministry of Fisheries, villages, fisheries offices, and districts. He is also gathering rainfall, temperature, discharge and sea surface data from multiple sources. He has identified some trends showing decreased rainfall since 1922; other data go back only as far as 1950.

"The big problem in calculating the river's discharge", he maintains, "is that data collection has not been continuous. We also need to know more about how rainfall has affected the availability of groundwater. From the few studies I have seen, decreasing rainfall has had a major impact. Wells once used for drinking water are no longer viable because salinity has increased."

Muzuka chairs the Western Indian Ocean regional committee of the Intergovernmental Oceanographic Commission, a body that specializes in marine scientific research and transfer of marine technology.

They have also created a Turtle Preservation Committee, which has published and distributed a booklet, and have supported an aquarium in the village of Nungwi that keeps newborn turtles in tanks and then releases them to the wild when they are large enough to have a chance to survive against predators.

IMS scientists have also worked closely with promoters of dolphin tourism, which has quickly become a popular way to earn foreign exchange. The number of boats dedicated to dolphin tours has grown from two in 1992 to 55 today. At the outset, most local guides had little knowledge about tourism, offering just a 'bare' boat experience and forfeiting the bulk of their income to middlemen. In 2006, IMS established an association for the tour guides, along with an accreditation course to ensure that they can navigate carefully around the dolphins and know enough about dolphins' behaviour to provide an informative experience.

"Before", Jiddawi notes, "guides were just running after tourists, saying 'Come with me!' We showed them that tourists want life jackets, flippers and masks, boats with a cover on top, basic information. The guides are now eager to learn more about dolphin biology and ecology. It's become a community thing, and the guides enjoy the profits themselves instead of turning them over to agents and middlemen."

IMS also helps with the perennial problem of humpback whales that become tangled in fishermen's nets during their annual visits from July to November. For years, fishermen have complained that whales ruined their nets, even when they escaped or died trying. IMS held a workshop last year to educate fishermen about a different kind of net, which pops open when pulled by a whale. Staff at IMS also helped train teams of volunteers to disentangle the whales.

Seaweed farming

The first major research-and-outreach project at IMS was to introduce seaweed aquaculture, initially to Zanzibar and then to all of coastal Tanzania. Keto Mshigeni (TWAS Fellow 1987), a smiling, devout, persistent visionary from the distant Kilimanjaro district, pioneered this effort. As a professor of botany at UDSM during the 1980s, he became convinced that domesticated seaweed could offer poor coastal dwellers, especially women, a modest source of cash income and perhaps even a first step out of poverty. He remembered as a boy retrieving freshwater plants from lakes with his friends and putting the plants into river ponds to catch fish. By the time he became a professor, his experience had broadened, especially as a student at the University of Hawaii where he earned his PhD. His interest in culturing marine plants had grown, and he had gained wider experience in the traditional practices of other countries. He was convinced he could apply such knowledge and practices in his own country.

He began setting up experimental plots on the beaches of Pemba and Unguja and also near Tanga, on the northern Tanzanian mainland. He knew that seaweed does not flourish on muddy or rocky shores, or where it is windy, and found that Zanzibar's calm, broad beaches offered the best locations.

He also uncovered other features that favoured his plan: Seaweed does not compete with local crops for land, does not need fertilizers or pesticides and does not require freshwater irrigation. Best of all, there was strong global demand for seaweed compounds. For example, Mshigeni found that the carrageenans and agars were used in a wide variety of pharmaceutical and food products, from yogurt to toothpaste to shaving cream to ice cream.

CLIMATE AND CORAL

• Leonard Chauka, a PhD candidate, has a particular interest in the factors driving the decline of coral reefs, especially the stress caused by solar radiation. He has monitored the effects of radiation on the species of algae that live as partners, or symbionts, of coral, bringing to the coral the benefits of photosynthesis. Most previous researchers assumed that almost every species of coral lived in symbiosis with just one species of algae, called zoozanthellae*. But by using polymerase chain reaction (PCR) techniques to identify these algae, Chauka discovered that about half of the corals lived with as many as five species of* zoozanthellae*. This degree of flexibility suggests that corals may be able to adapt more quickly than feared to changing seawater temperatures. This is a discovery of unusual interest in Zanzibar, where IMS has recorded coastal sea water temperatures as high as 37°C. Similar studies are underway in Mauritius by two RISE graduate students, Pramod Chumun and Joseph Ravina.*

SNAPSHOT

Still, Mshigeni's plans for Zanzibar met with skepticism. In 1988 he invited a delegation of Chinese aquaculture experts to tour Zanzibar and assess the potential for a seaweed industry. To his disappointment, they told him that such a strategy would be uneconomical. But the airplane pilot was listening, and later asked Mshigeni if he could bring a technician he knew in Belgium to take a look. The technician was duly impressed and his company gave Mishigeni's idea a try. Unfortunately, the local species did not grow as rapidly as hoped.

In 1989 Mshigeni discovered that the Philippines had expertise in seaweed mariculture – the type of aquaculture for a marine environment – and he brought in several Filipino technicians carrying samples of *Eucheuma denticulatum*, a variety grown

successfully in East Asia. With just four kilograms of samples, Mshigeni was able to grow the new species more quickly than the local plant, *Kappaphycus cottonii*.

IMS scientists and others quickly learned to teach local women – typically, wives of fishermen – to try their luck. The women were taught how to tie plants to nylon lines and string the lines between stakes in the sand. Buyers began to come, offering free string and cuttings to the women in return for exclusive rights to their dried crop. The provision of farming materials became a binding factor between farmers and buyers, who established a monopoly over the producers.

By 1994, it was clear that Mshigeni's vision would become a reality. By then seaweed had become the island's leading export, valued at USD800,000, nearly twice the income derived from tourism. Seaweed farmers now produce about 5,000 to 9,000 tons per year of dried product. Women earn small but consequential amounts of cash, up to USD50 a month. Many are now their family's main breadwinner. A Zanzibari man was quoted as saying: "We no longer marry the women – they marry us!" The women pay the school fees for their children, buy new cloth for garments, purchase cooking utensils, repair their houses and can afford better food for their families. Social workers have observed that the number of children suffering from malnutrition has declined.

As the years have passed, the seaweed industry has faced additional challenges. Marine grazers (sea urchins, turtles and herbivorous fish) take their toll; diseases and epiphytes (plants that derive their nourishment from the air and water and that usually grow on another plant but are not considered parasites) sometimes reduce harvests; and processing, handling and marketing are below desirable levels. *Kappaphycus*, although it produces a more desirable gel than *Eucheuma*, is not as hardy, and die-offs have occurred in both species during the spring tides of the hot season and low salinity of the rainy season.

YOHANNA SHAGHUDE

• ***Yohanna Shaghude***, *senior lecturer and section head of Physical and Environmental Marine Science section, arrived at IMS in 1986 and was awarded a PhD in 2001 by the University of Stockholm. His primary research interests, shared with Nyandwi and Muzuka, are coastal erosion and mitigation measures, along with using remote sensing and other tools to understand sea bottom topography, coastal sediment transport and river-ocean interactions. He has relied on images taken by the Landsat satellite since 1986 to compare the outline of the delta of the Ruvuma River with sedimentation rates. He found that the delta's landmass increased by about one square km every three years. He is also trying to document past and present changes of climate and the impact of climate change. This could help determine risks to the coast due to storm surges and river flooding. It may also help the Tanzanian government decide which areas are needed for water catchment, which should not be used for habitation because of flooding risk, and which are best suited to agriculture.*

Closer to home, he is eager to help commercial and residential builders in Zanzibar reduce the danger of coastal erosion. "Our approach is multidisciplinary", he observes. "We study both the physical and socioeconomic impacts. Coastal communities may lose homes when villages are taken out by erosion. In the Bombuchi area near Dar es Salaam, some hotels have been washed away and others are placed at risk when they are built too near the beach. We are publishing a manual on the causes of shoreline changes and on mitigation efforts."

> *"By 1994, seaweed had become the island's leading export, valued at USD800,000."*

IMS has redoubled its efforts to improve seaweed production. In 2005, upon completing his PhD at UDSM, Mmochi received a grant from WIOMSA through a programme known as SUCCESS (Sustainable Coastal Communities and Ecosystems), which is funded by the US Agency for International Development (USAID). He worked in partnership with scientists from the Coastal Resources Center at the University of Rhode Island, USA, most notably with Edwin Requintina, an aquaculture expert.

SUCCESS helps scientists better understand the factors impeding more bountiful seaweed cultivation, especially the environmental conditions affecting yields for farms where seaweed is cultured on the beach in the intertidal zone. They found that during the high spring tides, the water retreats, leaving the seaweed exposed to the dry air. At other times, winds bring in wild seaweeds that cover the crop. Flower Msuya, who was a student of Mshigeni at UDSM and now works closely with Mmochi, has concluded that rising seawater temperatures are probably just one of multiple causes of the seaweed problems.

> *SUCCESS helps scientists understand the factors impeding more bountiful seaweed yields.*

"We've been conducting research on seaweed since 1992", she notes. "In the early years, the water temperature was always below 30°C. Now it reaches 37°C for long periods; it even exceeded 38°C on an island off the mainland. That is one factor. But we are looking at other factors as well." For example, Msuya and her colleagues are studying such potential impediments to yields as nutrient imbalances and diseases. And, they are also testing another genus, *Gracillaria*, which appears to grow well in Zanzibar.

Msuya is a facilitator of the Zanzibar Seaweed Cluster Initiative (ZSCI). Founded in 2005, ZSCI promotes an alternative to the intertidal technique. By hanging *Kappaphycus* plants from floats in deeper water of one to three metres just off the beach, the plants avoid the excess heat and drying of the spring tides. The technique also yields higher quality seaweed that contains less dirt and debris from the beach.

In addition, ZSCI has helped researchers develop new, more effective drying techniques. Traditionally, seaweed was placed on palm fronds or other branches directly on the beach, where it was impacted by blowing sand and the presence of domestic animals and children playing. In contrast, ZSCI relies on drying racks above the sand or even in the villages.

Msuya now teaches this technique to local growers in 10 villages in Zanzibar and one in the mainland town of Bagamoyo. Altogether, ZSCI reaches about 3,000 seaweed farmers with advice, new techniques, and help in negotiating with buyers and exporters.

DESIDERIUS MASALU

• ***Desiderius Masalu*** *, associate professor and marine geophysicist, has a dual role at IMS, as a researcher in the Physical and Applied Sciences section and also section head of Information and Communications Technology (ICT). His primary professional interest is the tectonics of mid-ocean ridges, especially the triple junction of the Indian tectonic plate and the tectonics of the Pacific plate. His focus is on new data on the Hawaiian 'hot spot', a conduit of hot magma from the mantle to the crust. The conventional view is that this hot spot has been stationary for tens of millions of years, and created the volcanic Hawaiian Islands as the Pacific crust moved over it.*

According to Masalu, there is now strong evidence that the spot has not been stationary, but has migrated. For his work in the Indian Ocean, he says, "a major problem is that I'm the only person at the institute doing this, and I can only work when I get an opportunity to join cruises sponsored by other countries. Since I did my studies in Japan, this usually means going on a Japanese research vessel."

Masalu, as section leader for ICT, also directs IMS's information and communication activities, as well as a separate geographic information system (GIS) laboratory. An important aspect of the section's work is done by the Marine Educational Extension and Development unit (MEED), which produces educational programmes on environmental issues, coral reefs, fishing and other topics for the public. The programmes are shown on television stations, in schools, on the Dar-Zanzibar ferry and at other venues. Masalu is also national coordinator of UNESCO's International Oceanographic Data and Information Exchange, which facilitates the exchange of data and information among participating member states.

> *"Thousands of independent fishermen using dugout boats have plied Tanzania's shallow coastal waters."*

Fish hunting to fish farming

Traditionally, thousands of independent fishermen using dugout boats have plied Tanzania's shallow coastal waters. The dugouts, which have been romanticized on postcards and tourist brochures, are propelled by oars, poles and sails. For centuries, this artisanal fishing has been the dominant occupation for most coastal men, a demanding, often dangerous way of life that yields scant economic returns. Today, these independent fishermen face rising competition from large, foreign-owned commercial firms. Artisanal fishing also carries environmental costs. Large trees from dwindling forests serve as the raw material used to construct the dugouts.

On the mainland, a revolutionary change in fishing began half a century ago when a small group of pioneers learned to take the first steps from hunting fish to farming fish. Almost all of this early fish farming was a freshwater activity devoted to various species of tilapia. Since the 1950s, some 14,000 fishponds have been constructed throughout the country. Today, Tanzania's fish farmers produce about 1,500 tons of tilapia a year, in addition to smaller amounts of African catfish and rainbow trout.

Many IMS staff and students are involved in what promises to be the next major wave of fish aquaculture for the region – the development of fish mariculture. These farmed fish may be raised in a variety of salt or brackish environments, including deep water, shallow water, estuaries, cages, tanks or tidal ponds. IMS has discovered the value of the many flat, shallow, seaside ponds originally dug to produce salt by flooding the



ponds with seawater and allowing it to evaporate. The salt industry does not provide a high economic return, and many practitioners have expressed a strong interest in replacing their salt with fish.

The first mariculture experiments that Mmochi heard about in Zanzibar were conducted not by scientists, but by villagers, in 1986. One villager had the idea of raising milkfish, and was doing so on a small scale near Uroa on the island of Unguja. Another man started to do the same on the island of Pemba, almost simultaneously. Mmochi said that neither pioneer knew about the other's efforts, and both had come up with the same idea independently at about the same time. "It was like Darwin and Wallace", he said, referring to the two pioneering scientists who separately proposed the theory of evolution by natural selection.

A decade later, Matern Mtolera, a plant physiologist at IMS, received support from the Canadian International Development Agency (CIDA) to work with communities in planning an aquaculture strategy for Tanzania. "Our experiments with growing fish began in 1996", he recalls, "when no one was yet familiar with mariculture in this area. I remember when a new director came to IMS in 2001, and said we would do 'no fish farming' at IMS. 'It doesn't work in Africa.'"

> *"Many IMS staff and students are involved in what promises to be the next major wave of fish aquaculture for the region – the development of fish mariculture."*

From his experience, however, Mtolera was convinced that mariculture could work – and not only with finfish. He believed that Tanzania, with its numerous deltas, estuaries and mangrove swamps, had great potential for mariculture of prawns, crabs, oysters and other bivalves, as well as seaweeds and fishes. But the local people lacked awareness of mariculture techniques, and had virtually no models to emulate.

When Alfonse Dubi was appointed director, the staff at IMS redoubled its efforts to prove the potential of mariculture. In 2001, WIOMSA provided a crucial grant to launch the initiative. "With this money", Mmochi says, "our activities really came into significance." WIOMSA pressed the staff for "hard scientific work" backed by publications and reports. "Margareth in particular completed a large number of publications", Mmochi notes, referring to the current director, who focused on the nutritional requirements of cultured finfish. The institute worked steadily between 1996 and 2004 to develop an integrated mariculture pond system of finfish, shellfish and seaweed at Makoba, Zanzibar, and began to understand more fully the challenges and potential benefits of mariculture.

The programme accelerated rapidly with the award of the SUCCESS grant in 2004, which included finfish mariculture as one of its primary initiatives. Mtolera and others were joined by Mmochi. Additional partners were found abroad, including the Nature Conservancy and World Wildlife Fund. On-site planning support arrived from the Coastal Resources Center of the University of Rhode Island, USA, in the persons of Michael Rice and Edwin Requintina.

"Tanzania has tremendous potential for sustainable mariculture development", writes Requintina. "This is particularly the case for milkfish farming. However, we must not repeat the mistakes of Southeast Asia. Doing it right necessitates that you don't cut down your mangrove forests. Instead, you site ponds in appropriate areas. In Tanzania, this means the salt flats and abandoned salt ponds that are found all along the coast. If done correctly, mariculture can become a significant source of employment and income in many coastal areas of Tanzania where options other than fishing are limited."

MANGROVES AND ANTI-CANCER AGENTS

• Musa Chacha, a chemist who pursues a professional interest in marine natural products, has the demanding day job of coordinating and overseeing a number of IMS graduate students. In his 'off' hours, he has discovered new evidence that the leaves, stem buds and roots of local mangrove trees contain chemical compounds that may be useful in combating certain forms of cancer.

One of the objectives of natural products research is to hunt for bioactive agents in natural organisms. For IMS, these may be sponges, tunicates, plankton, mangroves and other marine organisms. "When you're looking for something like this, it has to be done systematically", he says. "We examine every kind of activity: antimalarial, anticancer, antibacterial, antifungal, anti-oxidation. We start with the traditional healers in the community, who already use these things. They have knowledge about efficacy and toxicity. We consider the mangroves and others because they need defences against pathogens, so they have chemical defenders. The healers understand that and are trying to use those same defences against human diseases."

He notes that healers are often distrustful of outsiders and their motives. "We hired a local as an IMS technician who serves as 'my

SNAPSHOT

> *IMS staff decided that mariculture would be appropriate at two scales: small-scale backyard farming and larger-scale commercial farming.*

eyes and ears' in gathering information about what the healers are doing."

Chacha began this project in 2008-09, when he discovered anti-cancer, antibacterial and antioxidant activity in mangrove stems and roots. He first did the characterization, bioassay and phyto-chemical studies, and isolated the active agent in crystalline, pow-dered and oil form. Then he went to the University of Botswana, where he had done his PhD work, to use the university's MRI, mass spectrometer and other advanced instruments to establish the structure of each component.

He has recently received funding from WIOMSA to continue his work, and his one graduate student, supported by RISE, will soon be joined by two more RISE students.

He is especially interested in caspase 3*, a protein that interrupts the normal programmed death of the body's cells. Normal cells have a finite lifetime, whereas cancer cells proliferate unchecked. He says that his "fantasy" is to find a chemical that blocks the activity of* caspase 3*. In his search, he plans to examine all nine species of mangrove that live in Tanzania – all of which are present in Zanzibar.*

SNAPSHOT

A pivotal opportunity to follow Requintina's advice came in 2006, when IMS acquired a group of salt ponds near Tanga, on the northern coast, from the Department of Prisons. The ponds soon became the long-term focal point for mariculture initiative. IMS also continued to make use of ponds in Zanzibar, near Bagamoyo, and at other locations.

First came the essential question of what kind of fish to raise. After testing rabbit fish, mullet, tilapia and milkfish, the researchers settled on the milkfish (*Chanos chanos*) for its many positive attributes: it is hardy, feeds happily on cost-free algae, tolerates a wide range of salinity, grows faster than other herbivorous fish, resists disease,

RISE STUDENTS RISE

Grace Mutia *of Kenya, a member of the first round of students in the WIO-RISE network, studies Zanzibar's coastal seaweeds as well as the seaweed industry that has helped increase the standard of living for thousands of women and their families. She learned early in her investigations that coastal fishermen, many married to women who sold seaweed to the food and pharmaceutical industries, did not cultivate seaweed as a crop but used it as bait to catch fish. The fisherman discovered that the crushed leaves lured the common parrotfish and they developed techniques for placing the leaves in hand-woven fish traps. Mutia is currently determining which species the fishermen use, why they use them, and how they can be cultured. As she comes to know the species better, her next step will be to do additional chemical analysis of the leaves, identifying the proteins, amino acids, minerals and other nutritional qualities that may lead to additional applications. She also hopes to explore new techniques of aquaculture and mariculture that may provide larger and more reliable harvests.*

As a master's student at the University of Dar es Salaam from 2004 to 2008, ***Siajali Pamba*** *was interested in preventing marine pollution, specifically through the ability of mangrove trees to filter and clean wastewater before it returns to the ocean. His focus was on the large tourist hotels near the shore that emit a steady discharge of sewage water. He proposed the use of settling ponds inhabited by mangroves, which can take up suspended particulate matter in a self-sustaining system of water purification. For his PhD studies, he has expanded his range considerably, investigating one of the major water systems of Tanzania, the Pangani River and its estuary. His goals include monitoring and measuring sediments suspended in the water, as well as the river flow, tides, waves and salinity. More than 70% of the flow of the five major rivers is pumped out for irrigation before it reaches the ocean. As the economy grows, more water will be needed for industry and power generation. "A lot of water is extracted without considering the impact on the estuary", he says. "If the river flow is too low when it reaches the coast, it does not supply the necessary nutrients and sediment that make the estuary productive. This affects many different fisheries, most notably the prawn fishery. It also impacts navigation." Pamba's goal is to construct a scientific basis for the strategic management of the nation's few large estuaries.*

Pramod Chumun *came to IMS to work on a question of urgent concern to both Zanzibar and his native Mauritius: the survival of coral reefs. He has focused on the symbiotic relationship between the coral animals and the micro-algae that produce food by photo-*

synthesis. This symbiosis of corals and zooxanthellae*, as the algae are called, is vital for the survival and ecology of reef-building coral. Chumun has found, using polymerase chain reaction (PCR) techniques, that some* zooxanthellae *are more common in Mauritius than Zanzibar. The difference in populations may be due to varying environmental factors, such as temperature and light, or to stress from abrupt climatic changes resulting in coral bleaching. His findings could pave the way for a better understanding of* zooxanthellae *shuffling among corals in the region and thus contribute to the long-term management of coral reefs.*

***Joseph Ravina**, like his compatriot Chumun, is working on reef-building corals that are threatened by an increase in the frequency and severity of coral bleaching caused by such environmental stresses as more intense light and higher temperatures. A current concern is whether the reef-building corals will be able to adapt to the environmental changes over the next century that are being forecast by sea surface temperature models. His studies have examined the responses to temperature and light stress of four coral species common to the Changuu Reefs in Tanzania and the Trou au Biches Reefs in Mauritius. Corals in each area have shown a significant drop in photosynthetic efficiency in response to both stresses, with some species reacting more strongly than others. Understanding these responses is essential in predicting the occurrence, frequency and severity of bleaching among different coral species.*

*Mozambique Channel is the name given to the section of the Indian Ocean between the island of Madagascar and Mozambique on the mainland. The huge eddies swirling throughout the channel have received extensive study because of their importance to ocean circulation and the production of phytoplankton, the primary source of the ocean food chain. While most studies have focused on the channel's southern and central segments, **Avelino Langa**, a native of Mozambique, has chosen to investigate the northern parts of the channel, which have received little scientific attention. Using both satellite measurements of net primary production (NPP) and measurements of the eddies' kinetic energy (EKE) or rate of flow, Langa has found a close correlation between the two for eddies flowing in both cyclonic and anti-cyclonic directions. He has also found that ocean water rises to the surface in the center of cyclonic eddies and at the edges of anti-cyclonic eddies. Because the eddies help determine the dispersion of phytoplankton, Langa's study is providing some key information for the future management of living marine resources in the Mozambique Channel.*

is not cannibalistic and shows great fecundity. The fingerlings can gobble up large quantities of food equal to 70% of their weight each day. Best of all, this food consists of an algal mat that forms naturally on the bottom of any shallow, flat pond that is fertilized and exposed to the sun. This mat begins with algae but soon matures into a complex community of copepods, worms, crustaceans and other organisms. It is highly nutritious and freely available for little more than the cost of some fertilizer, unlike the expensive fish foods required by many kinds of aquaculture.

IMS staff decided that mariculture would be appropriate at two scales: small-scale, 'backyard' farming and larger-scale commercial farming. A backyard pond would be only about one-tenth of a hectare in area, supplying a family with modest local sales generated by continuous small harvests of the largest fish. A commercial pond would be one or two hectares, with the entire fish population harvested at one time. In 2006, the first commercial pond of one hectare was established near Bagamoyo, using milkfish fingerlings. The first harvest, later that year, yielded one ton of fish that sold for USD2,000, a small fortune.

"In 2008, a milkfish farmer was celebrated as 'the first milkfish millionaire' earning over one million Tanzanian shillings in a year."

By 2008, Requintina, Mmochi and Msuya decided they knew enough about the subject to publish *A Guide to Milkfish Culture in the Western Indian Ocean Region* for new and potential mariculturists. They gave specific instructions for every aspect of the job. To grow the mat, they advised, a pond is first dried and the bottom enriched with dry chicken or cow manure. Then a few inches of water are allowed to flow in through small gates from a bay, estuary or even a freshwater source. Once the mat is flourishing, fingerling fish are introduced. While initial construction costs for a new pond are relatively high, a pond will generate income over several decades with only minor capital outlays.

Word about fish mariculture spread quickly. Between 2006 and 2008, the total area of ponds dedicated to milkfish farming rose from two hectares to about 150 hectares. Another grant came from a European Union (EU) project called ReCoMaP, Sustainable Management of Coastal Zones, allowing IMS to develop additional research stations in the districts of Pemba, Tanga, in the far north, and Mtwara in the far south. The scientists also trained 22 people as 'trainers of trainers' in finfish farming. Some who received that training now work as consultants for others who want to build ponds themselves, including former salt producers.

To date, IMS researchers have published more than 15 papers on milkfish farming and its nutritional aspects. The programme was deemed important enough that Tanzania's President Jakaya Kikwete agreed to attend the inauguration of a pond near Tanga in 2008. That same year, a milkfish farmer was celebrated as "the first milkfish millionaire", earning over one million Tanzanian shillings in a year (over USD600) from his crop.

Mmochi asked all milkfish farmers to keep records of their production. In 2011, he was astonished to find that the most successful farmers were producing 15 tons a year per hectare. "That's just enormous", he says. "When I show that figure to some people they say it can't be true. Even the average yield of 1.7 tons is very good." Prices have risen as well, from USD0.40/kg to USD4/kg through improved marketing and increased farm size.

The new mariculture lands south of Tanga, in Pangani, were officially handed over to IMS in April 2010, and the institute has begun to consolidate its research and training activities for all kinds of mariculture and fisheries.

"I would say that at this time we're the leaders of mariculture in Tanzania", says Mmochi. "We are experimenting with different salinities and feeding regimens. We are also working with about 70 species of tilapia, and have found they can all interbreed." Chauka adds that once sufficient expertise is developed, IMS hopes to charge tuition for the training programme at its Tanga centre. "We're also thinking of forming a union for fishermen", he says, "to help them learn more about marketing and how to train others."

IMS staff have plans to extend their work in mariculture beyond finfish. They have begun a project for cockles, *Anadara antiquata*, a popular, high-protein bivalve common in Zanzibar. Women have traditionally picked them at low tide, but the need to transition toward mariculture is urgent because the local *Anadara* populations are now overharvested. With sponsorship from the Island Creek Oyster Foundation, in Duxbury, Massachusetts, USA, IMS scientists launched a research project several years ago.

Starting with just four adults, researchers first tried raising the young cockles in the water of Stone Town harbour in front of the laboratory. The bacteria count in the water was too high, however. So, in February 2010, the programme was moved indoors to the laboratory aquarium. Here they are reproducing well, and the young will be given to local women to grow in fenced cages in shallow water near their villages. As astounding as it sounds, it is nevertheless true that a single large female can release six million or more eggs in breeding season. They also grow rapidly. Within a month, notes Jiddawi, baby clams are big enough to transplant to the beach. Jiddawi is conducting training sessions to prepare local residents for this new opportunity.

Scientists envision many other mariculture opportunities that await trained personnel and funding. At the head of the list are prawns (especially in Tanga, where milkfish fingerlings are scarce), followed by crabs, sea cucumbers and sponges.

Value added

A significant barrier to development for many low-income countries is an economy that depends on the export of commodities at low prices without adding value. During the past decade, IMS staff has advanced from its traditional research in marine science to a strategy of value addition in marine products. For example, this has been a central strategy for the Zanzibar Seaweed Cluster Initiative (ZCSI), which emphasizes the development of finished products for sale locally as well as internationally.

"Farmers used to sell seaweed with no value added", says Mmochi. "Nor did the people here make much use of the seaweed for themselves. Now farmers are eating seaweed and, among other things, marketing it locally as a green vegetable that is very nourishing." They also use seaweed to make soap (lemongrass, lime, cinnamon, clove), body creams, massage oils, pies, cakes, puddings, cookies, biscuits, mango and tamarind juices, and are experimenting with other uses.

The programme has sponsored training workshops on seaweed soap packaging and marketing, and has demonstrated to 34 women the use of soap production machines designed by the UDSM College of Engineering. Workshops have covered many business



"IMS is the leader of mariculture in Tanzania."

topics, including how to present the products in a competitive market, how to find markets, and how to make traditional packaging materials (banana leaves, coconut husks) that are appealing to tourists.

In March 2011, SUCCESS organized a three-day 'training of trainers' course focusing on entrepreneurial skills and business management. The activity, which included participants from 14 local communities, was funded by the McKnight Foundation and led by a nongovernmental organization from Arusha, in northern Tanzania. "By getting into the business of semi-processing, beginning with grinding the dried seaweed, farmers can increase the shelf life of their product, improve the price, and bring new packaging", observes Mmochi. "Government officials are not business people, so we are reaching out to others to provide entrepreneurial training."

> *"IMS is similar to many institutions in sub-Saharan Africa in that it depends on partner institutions for much of its research support."*

ZSCI is reaching out in many other directions as well. Drying seaweed is essential, and takes from two to seven days, depending on the weather. During the rainy season, the seaweed may not dry at all, forcing farmers to cease working.

ZSCI has formed a partnership with the Chalmers School of Engineering in Sweden to construct a drying facility that can allow drying year-round. In addition, Chalmers with its partners have launched a 'seaweed tourism' initiative in which the seaweed farmers discuss the details of seaweed production before tourist groups, putting their work sites and techniques on display. After the presentation, visitors may purchase soaps, oils and other products. Thus far two shops have been set up – in the villages of Kidoti and Paje.

IMS is involved in another mariculture programme that teaches local women to make jewelry out of the shells of the oyster *Pteria*. This project, also supported by ZSCI, has transformed the lives of many local women. It has several aspects. The first is pearl farming. Traditionally, women have collected these oysters solely for the meat, walking a half-mile or more across the flat, shallow bay during the five days each month when the moon is full or new and the tide low. For many years they simply sold the meat and discarded the shells, which were used to pave roads or build walls. Soon the wild stocks of oysters were depleted, and the women tried farming the oysters in staked corrals near the beach. But this also proved too large a drain on the wild populations.

The discovery that the shells can be used to make jewelry changed the entire industry and reduced the number of oysters harvested. Women still collect some large oysters, but they also gather the young spats and cultivate them in the corrals close to home. As the oysters grow, the women insert small plastic molds of various shapes. The

oyster forms a 'half-pearl' around the insert. These half-pearls are then incorporated into designs with other parts of the shell or other jewelry elements. This involves smoothing, polishing and cutting waste shells into pleasing shapes, then drilling holes in them to make earrings, bracelets and necklaces. The work is easily done with a bench grinder and small drill. Meanwhile, a 'no-take' zone has been created next to the harvest area to ensure a sustainable population.

When this activity began, Narriman Jiddawi took a group of six pioneering women, who were residents of the tiny villages of Bweleo and Fumba Chaleni, to the Coastal Resources Center at the University of Rhode Island, USA, where they were given instruction not only on jewelry making but also on marketing, bookkeeping, pricing and environmental stewardship. She then took them to Rwanda, Nigeria, Kenya, and Dar es Salaam to attend trade shows. The project has received extensive publicity, especially after Miss Tanzania, Emmy Melau, and a leading Tanzanian designer visited Fumba Chaleni to select jewelry for the 2009 Swahili Fashion Show. The original six women continue to work together and train other women, some of whom are reported to earn up to USD400 a month from jewelry sales.

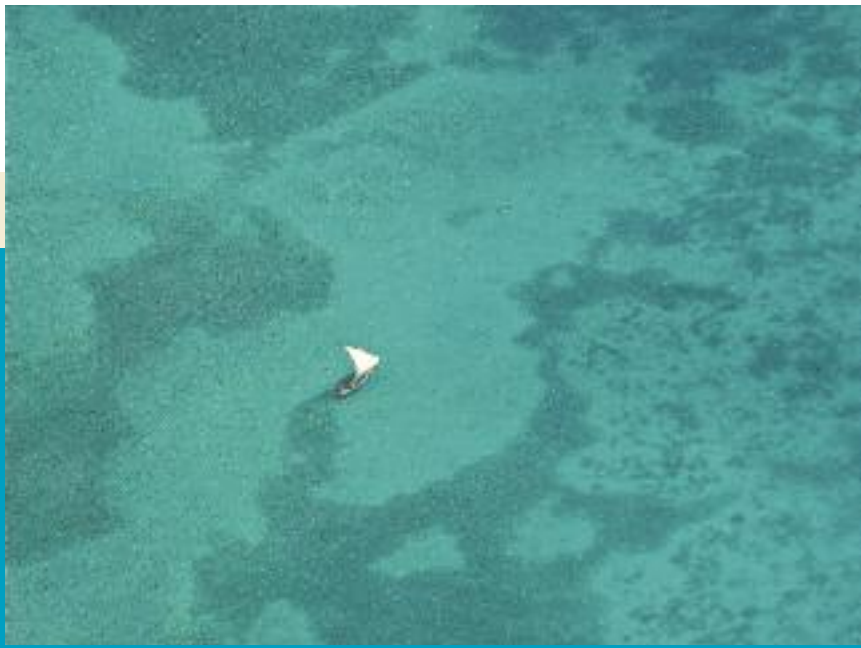
The nascent jewelry industry in Fumba Chaleni village, which had no electricity, was given a boost recently when IMS helped assemble a small windmill generator. The generator provides power for the grinder and the drill, as well as for electric lights so work can continue in the evening. When the winds are sufficiently strong, it will also drive the village water pump. Similar windmills on the mainland are already being used to pump water into or out of mariculture ponds.



Budget Matters

IMS activities are funded by two primary sources: an annual appropriation from the Tanzanian government, currently running at about USD770,000, and grants from international partners, which for the 2011 fiscal year totaled just over USD900,000.

The institute is strained to cover all of its expenses within this budget, due partly to irregularities in the public funding system. Most public funding is dedicated to salaries. What remains, covers so-called 'other charges', primarily utilities and additional overhead expenses. Unfortunately, the federal government's anticipated payment schedule is often delayed. As a result, instead of receiving the four scheduled quarterly disbursements per year, the institute often receives only three. Similarly, the actual payment for



'other charges' is often less than budgeted, and the outflows tend to be higher than budgeted – usually because of unforeseen expenses, such as the supplementary power needed during three months of electrical outage in 2010. The institute is forced to meet such irregular demands by dipping into the research portion of grant income, to the detriment of those programmes.

IMS also pays a premium for its island location. Rates for power and internet usage are higher than those on the main campus, even though service is less reliable. The institute, moreover, must keep enough standby generator power to maintain the freezers, lights and computers during times of local power failure.

Another budgetary issue is IMS's longstanding plan to build a larger laboratory just south of Zanzibar Town in Buyu. The concrete foundation for the new facility was constructed amid much optimism in 2004 – in the shape of two Zanzibar doors. A budget of USD4.4 million was drawn up for offices, laboratories, library and other facilities. A second construction phase was planned for an aquarium and shops. However, government funding was halted at the foundation stage and has yet to resume. In the intervening years, the estimated cost of the facility has tripled, and local residents have begun to scrawl graffiti on the site walls.

> *"As IMS looks toward the future, it sees a panorama of opportunities."*

International Partnerships

IMS is similar to many institutions in sub-Saharan Africa in that it depends on partner institutions for much of its research support. As it has strengthened both its training and research programmes over the past decade, external support has increased, primarily from Europe and North America. The Swedish International Development Cooperation Agency (Sida) has been a strong partner through its Bilateral Marine Science Programme. The Canadian International Development Agency (CIDA) has supported its long-term efforts, and the University of Rhode Island's Coastal Resources Center has funded its seaweed, mariculture and jewelry programmes.

An especially close partner – located literally across the street – is WIOMSA, which IMS helped create in 1992. This organization consists of members throughout the western Indian Ocean region, including IMS. It provides research funds and travel grants to facilitate collaboration. Other regional initiatives in which IMS is a partner include Eastern African Action Plan, funded largely by United Nations Environment Programme (UNEP),

and a coral reef project funded by the World Bank and Global Environmental Facility (GEF). IMS has also reached out to additional partners, including the International Oceanographic Commission of UNESCO, Vermont's School for International Training (USA), Bangor University's School of Ocean Science (Wales) , McGill University (Canada) and the Sokoine University of Agriculture (Tanzania).

A recent partner, which complements the ongoing efforts of Sida to support graduate education, is RISE, the Regional Initiative in Science and Education. RISE is funded by Carnegie Corporation of New York and administered by the Science Initiative Group (SIG) of the Institute for Advanced Study in Princeton, New Jersey, USA. The objective of RISE is to strengthen higher education in sub-Saharan Africa through multi-country networks of research and education. RISE currently supports five such networks. IMS is the lead node in the WIO-RISE network, which also includes Eduardo Mondlane University in Mozambique, the University of Botswana's Okavango Research Institute in Maun, and the University of Cape Town in South Africa. WIO-RISE supported six PhD and six MSc students during its first three-year phase, and has recently received nine additional students for its second phase.

As IMS looks toward the future, it sees a panorama of opportunities – many of which will depend on the anticipated move to the new headquarters in Buyu. Its newly granted ability to award MSc and PhD degrees has brought fresh energy to the laboratories, as well as the promise of a new generation of professional staff. Its vigorous outreach activities are creating enlightened community partners who will train others in sustainable livelihoods.

Fulfilling this vision will depend on helping to strengthen other partners as well, including better training for extension agents in aquaculture. A decade ago, the field of aquaculture was so small that IMS could do research, educate the public, and work hand-in-hand with individual villagers in Zanzibar and even in a few distant sites along the mainland. Now that the topic has reached an unforeseen level of interest and popularity – a new federal Department of Aquaculture has even been created – there is a need not only for substantial resources, but also for a new level of coordination and outreach to bring best practices to where they are needed.

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TWAS

TWAS, the academy of sciences for the developing world, is an autonomous international organization that promotes scientific capacity and excellence in the South. Founded in 1983 by a group of eminent scientists under the leadership of the late Nobel Laureate Abdus Salam, TWAS was officially launched in Trieste, Italy, in 1985, by the secretary-general of the United Nations.

TWAS has a thousand members from 90 countries, over 85% of whom live and work in developing countries. A Council of 13 members is responsible for supervising the Academy affairs. TWAS is assisted in the administration and coordination of programmes by a small secretariat, headed by the executive director. The secretariat is located on the premises of the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy. UNESCO is responsible for the administration of TWAS funds and staff. The Italian government provides a major portion of TWAS funding.

The main objectives of TWAS are to:

- recognize, support and promote excellence in scientific research in the South;
- provide promising scientists in the South with research facilities necessary for the advancement of their work;
- facilitate contacts between individual scientists and institutions in the South;
- encourage South-North cooperation between individuals and centres of scholarship.

To achieve these objectives, TWAS is involved in various activities and collaborates with a number of organizations, especially UNESCO and ICTP.

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INNOVATIVE EXPERIENCES IN SCIENCE AND TECHNOLOGY SERIES

For the past decade, TWAS – in collaboration with several other organizations and funding agencies, including the UNDP's Special Unit for South-South Cooperation (UNDP-SSC), the Global Environmental Facility (GEF) and the Packard Foundation – has published a series of profiles focusing on scientific institutions of excellence in the developing world. The case study on the Institute of Marine Sciences, which is summarized here, is the second with our new partner, the Science Initiative Group (SIG), which heads the Regional Initiative in Science and Education (RISE) with funding from the Carnegie Corporation of New York. The first case study co-sponsored with SIG profiled the Okavango Research Institute in Botswana. All case studies can be browsed online at www.twas.org. For print copies of the profiles, contact info@twas.org.

SCIENCE INITIATIVE GROUP (SIG)

The Science Initiative Group (SIG) is an international team of scientific leaders and supporters dedicated to fostering science in developing countries.

Formed in 1999 to provide scientific and administrative oversight for the Millennium Science Initiative (MSI), SIG is currently governed by a six-member board consisting of three scientists from developing countries, two US scientists and an entrepreneur. SIG is administered by a small staff based at the Institute for Advanced Study in Princeton, New Jersey, USA. The group's informal structure allows it to take advantage of opportunities quickly and with minimal bureaucracy.

Thanks to strategic partnerships with other organizations and careful stewardship of grant monies, over the last 12 years SIG has parlayed some $15 million in foundation grants into more than $100 million in project support, consisting primarily of financing from the World Bank and governments.

Since 2008, SIG's main project has been the Regional Initiative in Science and Education (RISE), funded by Carnegie Corporation of New York. RISE prepares PhD and MSc-level scientists and engineers in sub-Saharan Africa through university-based research and training networks in selected disciplines. Its primary emphases are on training new faculty to teach in African universities and on upgrading the qualifications of current faculty.

For additional information, see **www.ias.edu/sig**.

EXCELLENCE IN SCIENCE

This series of booklets – published by TWAS, the academy of sciences for the developing world – highlights successful scientific institutions in the South and explains how their research has both been sustained over a number of years and how it is helping their host nations achieve sustainable economic development.

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