

**VLIR-UOS
International
Conference
2014**



**Sustainable use
of marine and
coastal resources
in Kenya:**

*from research
to societal benefits*

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**Kikambala, Kilifi County, Kenya
27-29 October 2014**



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BOOK OF ABSTRACTS

VLIR-UOS International Conference 2014

**Sustainable use of
marine and coastal
resources in Kenya:**
*from research to societal
benefits*

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PREFACE

Introduction

Under the Kenya Vision 2030, the long-term national planning strategy of the country, Kenya aims to be a middle-income - rapidly industrializing - nation by 2030 with a clean, secure and sustainable environment. For a country whose development is largely contingent upon the environment, this vision creates many challenges not only for the sustainability of the ecosystems and the natural resources they provide, but also for mitigating the effects of climate change starting to appear around the country.

Kenya and Flanders/Belgium share almost 30 years of collaboration in marine sciences and have built up extensive expertise in various marine research fields in Kenyan coastal areas. The Belgian partners - with complementary fields of research expertise - have collaborated in national and international frameworks and together represent a network of different universities, both in the Flemish and Belgian context. Through their link with international MSc programs (Oceans & Lakes resp. Erasmus Mundus Tropimundo, and others) they constitute entry points to a large student and alumni network. The Kenyan partners have developed their research fields in collaboration with Belgian partners. Many of the individual Kenyan researchers have received training in Belgium (Flanders) and returned to either academia or policy making and policy support in Kenya. These researchers study a wide range of subjects, including coastal ecosystem management, coastal forestry, aquaculture and fisheries and have intensive links with the Kenyan society.

To this end, this conference brings together Kenyan, Flemish and regional researchers, university teachers and students, policy makers/advisors and other key stakeholders involved or interested in marine science activities with development relevance for Kenya, to:

- provide insight in some of the most important recent and ongoing research and education projects and initiatives, including the Kenya Coastal Development Project, and in the Belgian, Kenyan and regional expertise existing in the various research fields;
- discuss critical needs, gaps and challenges identified in the Kenya Vision 2030 for the sustainable development of Kenya's coast and ocean, such as overexploitation of fisheries resources, mangrove degradation, climate change, aquaculture development and Marine Protected Area (MPA) management and put forward opportunities for future collaborations in these development relevant themes;
- establish a roadmap that defines the future marine research and education priorities in Kenya in line with the nation's development strategies and aimed at informing future policy and coordination efforts.

Main topics of the conference

The various marine and coastal ecosystems in Kenya provide extensive natural resources that constitute unique opportunities for improved livelihoods, especially for the coastal communities. However, in the coastal region of Kenya, poverty is widespread in rural areas causing people to engage in practices that are not environmentally sustainable, such as destructive fishing practices, overharvesting of mangroves and pollution. In addition, the degradation of natural resources (e.g. mangrove forest) also contributes to climate change that in turn affects natural resources, resulting in socio-economic losses. Therefore, and in the face of Kenya achieving its nationally and internationally agreed development goals (e.g. Kenya Vision 2030, Kenya's National Climate Change Action Plan, Millennium Development Goals, National Aquaculture Development Strategy), efforts need to be directed towards sustainable development and climate change mitigations. Translating this for the coastal and marine component, the following critical challenges were identified and represent the main topics during the conference:

Sustainable use of marine resources - overexploitation, pollution and climate change

Firstly, **marine and coastal fisheries resources** are facing a myriad of threats with overexploitation being one of the major challenges due to high fishing pressure in nearshore areas and the increasing use of highly efficient but non selective fishing methods which capture a high number of juveniles and non-target species. A great diversity of species are captured with demersal coral reef fish forming the majority of artisanal landings dominated by rabbitfish, emperors, parrotfish, goatfish, groupers and snappers. Considerable export earnings are also derived from the export of prawns, sea cucumbers, crabs, lobsters, live ornamental fish and invertebrates, squids and octopus. Offshore pelagic species in Kenya's Exclusive Economic Zone (EEZ) such as tuna, sailfish, swordfish and marlin remain virtually underexploited by local fleets due to limitations in appropriate gears and vessels. The EEZ is mainly exploited by distant water fishing nations. The current production levels are, however, deemed to be very low considering that Kenya's 200 nautical miles EEZ is located within the richest tuna belt in the Western Indian Ocean (WIO). These features pose enormous challenges for the **protection of biological diversity and for the sustainable development of fisheries exploitation.**

Secondly, **impacts of pollution and climate change** are a major threat to Kenyan ecosystems. Events such as increasing sea surface temperatures, changes in salinity, precipitation, water circulation and mixing, river runoff, contaminants and nutrient levels may result in cascading ecological effects leading to a loss of fish breeding and nursery habitats and thus eventual fishery production. Aiming at the sustainable management of exploited offshore and inshore marine resources, the Kenya government is currently investing in crucial activities such as fisheries stock assessments, understanding the biology and ecology of key target species, understanding the socio-economic dynamics of exploitation, understanding fishing gear impacts, exploring new and alternative environment friendly fishing technologies as well as monitoring the associated environmental and ecosystem interactions. In addition, the **new oceanographic research vessel, RV Mtafiti**, provides a unique opportunity to jointly explore new areas of research towards understanding the status of fisheries resources and the associated ecosystem impacts.

Coastal resource management – blue carbon sinks, aquaculture development, integrated planning

Targeted Kenyan coastal ecosystems for exploitation are coral reefs, seagrass beds, mangroves, estuaries,... often under overlapping responsibility of various governance bodies. Besides local dependence and utilization patterns (coastal communities), there are overlapping, aligned or conflictual interests, e.g. for the tourism industry, one of the major coastal assets, and global interest, such as carbon sequestration (for which mangroves play an underestimated major role). Coastal wetlands, mangroves, salt marshes and seagrasses, sequester and store large quantities of blue carbon in both the plants above ground and in the sediment below. For example, over 95% of the carbon in seagrass meadows is stored in the soils. Mangroves on the other hand capture and store five times more carbon than terrestrial forested ecosystem. When mangroves are degraded or destroyed all that sequestered and stored carbon is released back into the atmosphere as CO₂ emissions. The emissions released through ecosystem conversion are now being recognized by the IPCC and UNFCCC as significant sources of greenhouse gasses. Therefore a third critical challenge is the effective management and conservation of coastal wetlands, aimed at **safeguarding and enhancing blue carbon sinks**.

A fourth critical challenge for the development of Kenya is the **sustainable development of coastal and marine aquaculture for food production**. Aquaculture is the fastest growing food production sector with an average annual growth of 9% over the past 20 years (FAO, 2010). Yet sub-Saharan Africa lags behind with a production level that has stagnated at about 1% of the world production. In spite of the vast freshwater and marine resources of several African countries, current aquaculture activities are largely traditional, extensive, and operate below capacity. Until recently, government aquaculture policy in most African countries was incoherent and resulted in rather scattered initiatives. Policy makers and research entities in Africa, as well as donor organizations, are now increasingly aware of this situation, especially in view of the aggravating food situation in many countries. Kenya has had unprecedented growth of aquaculture in the last few years as a result of the implementation of its National Aquaculture Development Strategy. Through the Economic Stimulus Program, aquaculture has been revamped from production of 4,000 MT in 2007 to over 22,000 MT in 2011. This growth has, however, been experienced only within the freshwater sector. The marine aquaculture sector has hardly been touched. Kenya aims at reaching fish production over 100,000 MT from aquaculture in the short and medium terms. This will be achieved by diversification of farmed fish species, genetic improvement programs, and intensification of present systems, diversifying into new more intensive culture systems, reduction of post-harvest losses and increased value addition and promotion of fish consumption. Marine and coastal aquaculture is expected to play a central role in enhancing fish production both in terms of diversification of species and culture systems owing to the vast unexplored resources of the Kenyan Coast.

Coastal ecosystems are integrated ecosystems, depending on both continental systems (in casu catchment processes) and marine systems at various scales. In practice, policy and governance and its management bodies rarely take into account this integrated nature. Since globally and this equally applies to East Africa and Kenya, coastal populations are very dense and increase faster than the demographic average, the pressure on the relatively narrow strip is disproportionately high. This pressure combined with socio-economically critical products and services offered by coastal and marine ecosystems demands **integrated planning and implementation**.

More information about the conference outputs will be available from the website:

www.vliz.be/kenya

DEDICATED TO THE MEMORY OF PROFESSOR PHILIP POLK

MARINE BIOLOGIST

(19 OCTOBER 1932 – 11 MAY 2014)



an inspiration and a friend to many in Kenya and Belgium

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The restoration and rehabilitation of damaged or degraded mangrove ecosystems in Kenya

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Towards the end of the twentieth century, scientific concern began to arise about the unprecedented loss of naturally occurring mangroves ecosystems around the world. The causes of this mangrove degradation range from urban development, agriculture, commercial or artisanal extraction of wood to shrimp farming. This destruction has led to reduced mangrove dependent fisheries, shortage of wood, coastal erosion and loss of human lives due to storm surges, as well as other consequences. This widespread degradation and increased awareness of the importance of mangrove forests, led to an upsurge in attempts to restore mangroves in various parts of the world. Many of the initial restoration projects were aimed at silviculture for wood production without assessment of recovery (or otherwise) of other mangrove goods and services. However, in recent times, the rationales of mangrove restoration have evolved and include coastal stabilization, fisheries productivity, biodiversity conservation, pollution mitigation and even public awareness. This paper presents a review of the functionality of restored mangrove ecosystems using functional indicators ranging from vegetation structure, natural regeneration, productivity, nutrient recycling to conservation of inherent biodiversity and socio-economic valuation. Finally, it looks at the constraints and opportunities for successful mangrove restoration.

Keywords:

Mangrove restoration, functionality, vegetation structure, biodiversity, socio-economics, opportunities and constraints.

Approach of Stellenbosch University in promoting aquaculture education in Africa

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The Faculty of AgriSciences at Stellenbosch University is one of the first dedicated agriculture training institutions in the region, founded in 1916. The Faculty currently hosts a total of 1800 undergraduate and 450 postgraduate students, over nine dedicated programs, including that of Animal Production. Aquaculture is a relatively new sector within animal production in South and Southern Africa.

The first formal training program in Aquaculture was introduced in 1990, as a minor subject within the four year BSc Agric degree in Animal Science. It was expanded onto a major level in 1994. This provided a basis for the subsequent introduction of post graduate courses, including MPhil, MSc and PhD in Aquaculture as from 1996. The lack of training opportunities on subsidiary levels has led to the introduction of a Certificate Program in 1997 as well as regular short courses in order to develop required capacities. The certificate program expanded onto a distance learning platform in 1998 in an effort to improve accessibility throughout the region. The latest addition was a Post Graduate Diploma in Aquaculture Production and Management introduced in 2012 to further enhance accessibility through acknowledgement of prior learning at other institutions.

International networks have subsequently been established with student exchange between Stellenbosch and European universities, including Gent and Leuven (Belgium), Wageningen (Netherlands), Stirling (Scotland) and Auburn (USA). Participation from African countries has grown steadily to approximately 10–12 participants in the certificate program, 2–4 in the undergraduate, 6–8 on the masters and 2–4 on the PhD level. An objective of Stellenbosch University (SU 2013) is to enhance its role and relevance in relation to teaching and learning and capacity building on the African continent (see also African Doctoral Academy).

The curriculum has subsequently developed to incorporate the main components along the value chain, including water ecology, breeding, nutrition, husbandry, health management and post-harvest technology. Production and financial management, together with marketing are incorporated in subsequent modules. A wide range of both freshwater (e.g. trout, tilapia, catfish) and marine species (sea weed, shellfish, molluscs, finfish) are reflected.

The key challenges with regard to aquaculture education and training remains that of accessibility, affordability and student compatibility as well as continental career opportunities for post graduate students in particular. Stellenbosch University is currently embarking on an information communication technology strategy (SU 2014) to enhance future teaching and learning opportunities that could address some of these challenges. Complementary teaching and learning networks throughout Africa and beyond, will also play a key role in meeting the training needs of the continent in relation to aquaculture development.

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The status and outlook of marine aquaculture development in South Africa

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Marine aquaculture was initiated in the 1990s with the onset of oyster (Pacific Oyster, *Crassostrea gigas*), mussel (European mussels, *Mytilus edulis*) and abalone farming (*Haliotis midae*), followed by the introduction of finfish culture (Dusky kob, *Argyrosomus japonicus*; Yellow Tail, *Seriola lalandi*) since 2010 (SA 2007; SA 2012). The industry was pioneered by the private sector therefore the focus on high value species. Marine aquaculture development in South Africa is facing particular challenges in terms of:

- a high energy coastline with limited sheltered bays to accommodate offshore aquaculture;
- long distances from world markets, increased cost of logistics;
- escalating cost of energy and labour;
- the cost of capital and high internal rate of inflation (>6 percent per annum).

The negative impact of the decline in fisheries resources on socio economic conditions of coastal communities has led to government initiatives to stimulate aquaculture development in order to provide for alternative livelihoods. These initiatives are directed mainly as large commercial development through capital investment and export market incentives, in an effort to stimulate economic growth and job creation (DTI 2012).

Abalone farming has become the most important sector on the back of successful export markets, contributing over 90 percent of income (USD 1,000 million) derived from the mariculture sector. Subsequent to the collapse of the wild abalone fisheries due to overfishing and illegal harvest, farmed production has increased from 20 tonnes in 1998 to over 2,400 tonnes in 2013, elevating South Africa to become the largest producer outside of China. The industry is well supported by advanced production technology (husbandry, nutrition, genetics, breeding, biosecurity, processing and marketing) which ensure global competitiveness. Production is predominantly based on pump ashore land based systems, with the first generation of ranching projects being introduced in 2013. Growth and marketing prospects are positive, with rapid expansion within the industry, mainly through increased production from existing operators.

Mussel production, as a lower value high volume product, is directed at the local market and has registered continuous growth over the last two decades to current levels of 22,000 tonnes. The sector is experiencing competition from imports, mainly from New Zealand and Chile. Production systems are conventional in nature and significant emphasis is placed on value addition through processing and product development. The oyster sector, also directed at the local market, seems to have reached market capacity at production levels around 4,800 tonnes per annum, with limited outlook for future growth.

Finfish production, in particular that of indigenous species, is currently attracting particular interest from both the market as well as investors. The first pioneering projects are currently established based on both offshore cage culture as well as land based recirculation systems. The outlook in terms of financial viability is still inconclusive, particularly in view of high capital cost and volatile market conditions.

The marine aquaculture sector in South Africa has made good progress over the past decade and is well positioned for future growth, supported competitive technologies and market demand.

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Research vessels as an essential tool for ocean exploration and data acquisition

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Emerging and innovative technologies deliver important oceanographic data on a global scale but ships remain the only means to provide direct access to the marine atmosphere, the ocean surface, water column and sea floor. Research ships and the associated equipment are crucial to gather the data and knowledge needed to manage and to secure marine resources for future generations.

Based on current and future science needs this presentation will describe what defines a research vessel and it will focus on the operational and technological implications of running science at sea. Besides the vessel, the marine science community needs a national equipment pool and facility services to manage and maintain both the vessel and its sampling tools and instruments. The international and interdisciplinary character of ocean science demands a careful cruise preparation and collaboration across borders. Dedicated shore and on-board staff are indispensable to accomplish this.

The value of the RV Mtafiti as a research platform for the Kenyan inshore and offshore waters will be outlined against the societal and scientific needs and the technological capabilities.

Government intervention in aquaculture development in Kenya

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Although aquaculture has been practiced for many decades in Kenya, fish farming has only recently become a serious alternative to capture fisheries. Before government intervention, aquaculture was mainly small scale. Since no structures for commercial aquaculture production were put in place, aquaculture was targeted at the poorest segment of rural farmers and was mainly at subsistence levels. Recently, the Government of Kenya initiated programs for revamping aquaculture development including changes in policy formulation, and increased research focus as well as direct investment. Through the Economic Stimulus Program funded Fish Farming Enterprise Productivity Program (ESP-FFEPP), Kenya encouraged the growth of the sector by helping communities construct, stock and feed approximately 50,000 fishponds across the country. Extension services were revamped through provision of motorcycles and training to fisheries staff, farmers and hatchery managers. Research was carried to produce fast growing seed and the capacity of broodstock in the country increased to over 200,000 brooders. The multiplier effect led to over 100,000 fishponds in about two thirds of the country, the number of functional hatcheries rising from 21 in 2009 to over 150 in 2014. Similarly, the commercial feed manufactures producing extruded floating fish feeds rose from 1 to 8 and 6 cottage feed producers in 2014. This has resulted in increase of aquaculture fish production from 4,000 metric tonnes (in 2009) to 48,000MT per annum currently. The government also spearheaded efforts to popularize fish farming through awareness campaigns and product value addition and diversification. Similarly, the government has now embarked on fish quality assurance efforts and standards setting for inputs and production processes to ensure aquaculture fish and fish products continue to access traditional and emerging markets.

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How to convey a complex message to a wide audience: avoiding the ocean divide between science and public understanding?

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Complexity of coastal conservation, communication for commitment to and co-management of our 'commons': how to convey such conundrums?

Scientists are known to be weak at communicating their findings beyond their peers. The causes are multiple: communication to a wide audience is not felt as a primary assignment (and rarely appreciated in academia), the messages are increasingly complex and cannot be reduced easily to simple statements, and scientists avoid absolute answers to pressing questions from society when they are not entirely confident that such answers are correct. Yet, society has a right to call upon scientists. The scientific process is borne mostly by public funding and society, the latter of which so righteously expect justification and feedback on the utilisation and output of funds. Inversely, scientists, whether covering fundamental or applied fields, cannot shy away from communicating their findings to the public, for instance on environmental challenges to name but one. Coastal conservation is complex, because it combines ecological borderlines and transition zones, with local and global processes (through ocean connectivity and the spatial scale of coastal problems) and intense human pressure. Coastal systems further confront private interests and 'commons', as the property and interests of all, and hence also the responsibility of all. Often pressure and conflicts are strongest towards the narrow coastal fringe.

In the framework of the VLIR–UOS funded project 'Green Dyke' in Sri Lanka (2008–2014), we developed a Coastal Resources Awareness Centre, which essentially is a fixed and a mobile version of a targeted exhibition and associated communication activities to a wide and complex audience. Drawing on this experience the authors present their approach in Sri Lanka, which can serve as a source of inspiration elsewhere, also in Kenya. Indeed, such communication will be targeting more than one audience, *e.g.* school children in organised visits (not coming 'voluntarily'), adults with limited education, adults with somewhat deeper interest, occasional visitors, specific target adult groups (coastal managers, nature conservationists,...). This defines (i) media used, (ii) language used, (iii) level used, however all in one 'physical' or virtual item (exhibition, website,...). The geographic and cultural context will put additional demands on each of these as well as on the recognisability of the message and examples used.

Mangroves facing climate change: landward migration potential in response to projected scenarios of sea level rise

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Adaptation of species and populations to environmental change on a shorter than evolutionary time scales can be viewed as a balance between range shifts and biological exploitation of a species' or an individual's flexibility. In this contribution we present two specific research programmes of our team which deal with both separately. Regarding range shifts the most immediate impact is local appearance and disappearance of potential or actual habitat because of sea level rise. Mangrove forests prominently occupy an intertidal boundary position where the effects of sea level rise will be fast and well visible. This study in East Africa (Gazi Bay, Kenya) addresses the question whether or not mangroves can be resilient to a rise in sea level by focusing on their potential to migrate towards landward areas. The combinatory analysis between remote sensing, DGPS-based ground truth and digital terrain models (DTM) unveils how real vegetation assemblages can shift under different projected (minimum (+9cm), relative (+20cm), average (+48cm) and maximum (+88cm)) scenarios of sea level rise (SLR). Under SLR scenarios up to 48cm by the year 2100, the landward extension remarkably implies an area increase for each of the dominant mangrove assemblages except for *Avicennia marina* and *Ceriops tagal*, both on the landward side. On the one hand, the increase in most species in the first three scenarios, including the socio-economically most important species in this area, *Rhizophora mucronata* and *C. tagal* on the seaward side, strongly depends on the colonisation rate of these species. On the other hand, a SLR scenario of +88cm by the year 2100 indicates that the area flooded only by equinoctial tides strongly decreases due to the topographical settings at the edge of the inhabited area. Consequently, the landward *Avicennia*-dominated assemblages will further decrease as a formation if they fail to adapt to a more frequent inundation. Whether species will dynamically adapt to local climatic and environmental conditions we investigated the behaviour of their water transport tissues (as key to their ecological success) upon such changes both in their natural environment and experimentally. Vascular traits, shrinkage and swelling patterns (because of water status) through automatic point dendrometers on the trunks of adult *Avicennia marina* trees *in situ* and on seedling leaves and stems of *Bruguiera gymnorhiza* and *Rhizophora mucronata ex situ* are used to understand a tree's behaviour. Our findings suggest that freshwater availability (rather than tidal inundation) affected radial increment, either in a concentric or patchy pattern in *Avicennia*, and that shrinking and swelling followed but shortly after the onset of changes in salinity in the other two species. Such findings are indicative of rapid changes in mangrove individuals in the highly dynamic environment that mangrove forests are, but demand integration in order to understand eventual success or failure to survive.

The potential of integrating marine biotechnology with aquaculture for human health in Kenya

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In Kenya, fish-demand exceeds supply due to declining natural fish stocks. To offset the imbalance, aquaculture has gained popularity. Owing to the perceived potential of aquaculture in stimulating economic growth by creating business opportunities, employment and providing food security, Kenyan government supported aquaculture development by introducing an economic stimulus program (ESP) in 2009/2010 financial year. Through ESP, 48,000 fish culture ponds were introduced in 160 political constituencies at a total cost of about USD 15 million. The ESP program concentrated on promoting the culture of Tilapia (*Oreochromis niloticus*) and catfish fish (*Clarius gariepinus*) species because of their popularity as local food and quick production. The culture of marine fish species was not included in the program despite the potential present at the Kenyan coast.

The following challenges have been identified as preventing full development of aquaculture in Kenya: 1) inadequate extension services, 2) lack of quality fingerlings and feed, 3) lack of knowledge and skill in aquaculture technology and management, 4) inadequate aquaculture policy. Various aquaculture forums have identified collaborative research and development program as an effective approach in addressing these issues. These forums have identified three major researchable areas for achieving rapid results: 1) improved fish breeds, 2) affordable and ecologically clean quality fish food, 3) efficient fish production systems. These rapid result strategies can be achieved through institutional collaboration in: 1) capacity building, 2) access to capital, 3) value addition and 4) marketing. The application of biotechnology has been emphasized as a thematic area in: 1) improving fish breeds through selective breeding, fish strain comparison, identification and introduction of candidate local fish species, 2) identification and introduction of highly nutritious natural, live and formulated fish food with minimal residue, 3) introduction of fish production systems with potential to conserve water, stabilize favourable water quality, integrate with other agriculture systems and bio-accumulate macro- and micro-nutrients in fish tissue for improved human health and nutrition.

Sustainable use of coastal and marine resources in Kenya can greatly be enhanced by utilizing its biotechnology opportunities to develop aquaculture. For instance: 1) culturing, bio-accumulating and bio-encapsulating macronutrients in marine live feeds such as *Artemia*, fresh and brackish water *Caridina*, zooplankton, micro-algae, biofilms and bioflocs and, 2) extracting and incorporating gelatine and agar, from marine fish and sea weed, in formulating fish food can promote introduction of fish food which is ecologically clean, water stable and has potential to upgrade the nutritive value of fish tissue for improved human health and nutrition. In the light of the above observations, Karatina University has introduced an academic and research programme for Aquaculture and Fisheries Technology to build capacity and undertake innovative research to continuously improve aquaculture development in Kenya.

Blue carbon in the Western Indian Ocean

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'Blue carbon' is defined as the carbon that is captured and stored by the world's oceans and coastal ecosystems. Carbon is captured by living organisms in the oceans and stored in the form of biomass and sediments. Of particular interest for sustainable coastal management is the carbon stored in mangrove, saltmarsh and seagrass ecosystems. Carbon concentrations in these coastal ecosystems have been found to be much higher per unit area than terrestrial carbon-rich ecosystems such as rainforests; raising the importance of managing coastal ecosystems in the context of climate change mitigation. As scientists discover more about the carbon being sequestered in coastal ecosystems, so policy-makers explore more options for leveraging climate change financing for sustainable coastal ecosystem management. In addition, sustainable management of coastal ecosystems can also maintain and enhance valuable ecosystem services that are the lifeline of many coastal communities in the Western Indian Ocean. As well as carbon sequestration and climate change mitigation, coastal ecosystems can also provide critical goods and services such as shoreline protection, food production from fisheries, nutrient cycling, water quality maintenance, revenue from tourism, among others.

This presentation will provide a global overview of the current state of blue carbon and coastal ecosystem services scientific knowledge. It will then focus on studies and case studies relevant to the Western Indian Ocean. It will go on to explore the various policy and financing mechanisms that are being developed for blue carbon communities around the world. Finally it will present the largest comprehensive blue carbon project in the Western Indian Ocean; the GEF/UNEP/GRID-Arendal Blue Forests project which involves a large network of partnerships in the region.

Legacy and lessons from SWIOFP – 2 years on

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The South West Indian Ocean Fisheries Project (SWIOFP) formed part of the Global Environment Facility (GEF) Large Marine Ecosystems Programme in the Western Indian Ocean between 2008 and 2013. The project area comprised the Exclusive Economic Zones of 8 countries (Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania) and French islands of Reunion and Mayotte. SWIOFP aimed to: assess existing and potential offshore fisheries; provide scientific information for developing fisheries management plans; strengthen institutional capacity; and foster collaborative networks across the region. To achieve these objectives, SWIOFP was structured into 6 components: data and information management; crustacean, demersal and pelagic fish resources; biodiversity impacts of fisheries; and strengthening of regional fisheries management structures. Kenya hosted the SWIOFP regional management unit and secretariat at KMFRI, and also led the data component. The Implementation Completion Report, prepared by all participant countries in 2012/13, rated the performance of SWIOFP as 'satisfactory' for implementation, and 'moderately satisfactory' for outcomes. Many important lessons were learnt. On the up side was the truly participatory process in project design and implementation, which ensured stakeholder buy-in and relevance of project objectives. Hence, a strong regional collaborative network developed, and challenges could be addressed by pooling of scarce resources. An extensive Master's degree programme proved efficient in achieving 2 objectives simultaneously, at relatively low cost: contributing to SWIOFP scientific outputs through analysis of survey data; and capacity development to an MSc level. Linking fisheries research projects with RFMO's (such as the SWIO Fisheries Commission) provided significant benefits, and enhanced post-SWIOFP continuity. On the down side, project design was over-optimistic, given existing infrastructure limitations. Parts of SWIOFP (i.e. integrated region-wide fisheries observer programme; 40 surveys at sea using research and fishing vessels) could therefore not be implemented satisfactorily, and placed a heavy burden on project resources. SWIOFP relied on existing government employees and structures for its implementation, thus increasing their workload, but without financial incentives. Project implementation was therefore slower, compared to simply employing consultants, but it enhanced skills and networking within government agencies. The complexity of SWIOFP (multiple countries, languages, needs) required a long run-up time to render project management structures efficient, and real momentum was only achieved in the last 2 years, when project implementation was rated 'highly satisfactory'. Therefore SWIOFP would have benefitted from more time. Science (conceptualization, data collection, analysis, reporting, write-up) is a multi-year process, so that many SWIOFP outputs have only been achieved after project conclusion. This legacy needs to be incorporated into regional management strategies, with assistance of the SWIO Fisheries Commission.

Environmental safeguards in Kenya – oceanographic and coastal perspectives

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This paper addresses the historical evolution and improvements in the environmental management tools that Kenya uses in environmental governance to ensure environmental planning and sustainable resource use are planned for, developed, controlled and monitored to improve the economic, political, and social well-being of its people. A comparison of the global perspective is made with the national strategy. The potential of twining the availability of RV Mtafiti to the need to develop new national and regional monitoring or observer stations to inform the development or improvements of existing environmental management tools are explored within the national ocean policy and strategy, including new opportunities to exploit the resources of the EEZ. Examples of existing interventions in improving coastal livelihoods are discussed for a number of aquaculture interventions and for few natural resource management initiatives within the Kenyan coast and near-shore marine environments. Challenges in environmental management and governance are highlighted within the oceanographic and coastal perspectives in terms of environmental, social and economic interactions (governance, pressures from coastal zone overpopulation, environmental quality, sustaining critical coastal ecosystems and biodiversity) based on experiences from aquaculture interventions.

Linking science and community development: the community driven development approach

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The Kenya coastal region is rich with natural and cultural resources that underpin the livelihood of the majority of its inhabitants. Availability of knowledge, skills and institutions for sustainable utilisation of these resources is therefore critical for the livelihood of the coastal communities. Various Government agencies within the region have mandates to conduct research and transfer knowledge and skills to the coastal communities for improved management of these resources. While a lot of work has been done in this undertaking, gaps still exist between research findings and their ultimate adoption for improved management of natural resources and community development.

The Kenya Coastal Development Project (KCDP) has embraced the Community Driven Development (CDD) model in trying to effectively link science to community development. Through this method, a comprehensive approach to building capacity of the coastal communities in management of natural resources and community development is adopted. The approach comprises building the capacity of Community Based Organisations through training, technical backstopping and provision of small grants for implementation of priority projects within their locality. KCDP has developed a CDD programme – *Hazina Ya Maendeleo Ya Pwani (HMP)* which has been implemented within the coastal region of Kenya since 2013.

Lessons learned so far are that, the CDD approach has stimulated the interest of coastal communities in participating in the HMP programme. The community trainings, technical backstopping and small grants provided to communities has given them the confidence of wanting to be part of stakeholders that are critical in the management of natural resources and community development.

The paper provides the conceptual framework of HMP in the context of the Kenyan coast and highlights progress achieved to date. A description of some of the experiences gathered, challenges and difficulties encountered so far, is also provided.

Marine pollution along the East African coast: problems and challenges

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The Kenya coastal and marine environment possesses a variety of natural resources that support livelihoods of a rapidly growing population currently estimated at 3,3 million. These resources are, however, threatened by pollution, physical alteration and destruction of habitats, over-exploitation of resources, uncontrolled development, coastal erosion and climate change (ICZM Action plan 2011–2015). A brief, incomplete review of available (open) literature on pollution and ecotoxicological studies in marine ecosystems along the East African coast demonstrates that there is a general scarcity of information on the type and distribution of contaminants (exposure), their effects and their potential risks to man and the environment. In their review on marine pollution research performed in South Africa (including East African coastlines) during the period 1960 to now, Wegener and Degger (2012) concluded that (1) in general, relatively few papers are available on this issue, and (2) there has been a dramatic decrease in this number (to less than 50 papers per decade) since the 1980s. They also state that this observation can be linked to the lack of a marine pollution monitoring program in South Africa. Our review shows that these conclusions also hold for Kenya; indeed only a very limited number of papers on coastal water pollution are currently available in open literature. To better understand and manage the marine resources in the context of an integrated management of coastal and marine (offshore) resources there is a clear need to develop and implement research and sustained monitoring capacity of marine pollution and other environmental stressors (e.g. toxic algal blooms) in Kenyan waters. This paper is aimed at initiating discussions on a way forward to develop a tiered research and implementation approach.

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Blue carbon storage and climate change mitigations

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Coastal wetlands – mangroves, salt marshes and seagrasses – are some of the most threatened ecosystems on Earth. They are being degraded or destroyed at four times the rate of tropical forests and climate change threatens to accelerate these losses. The global CO₂ emissions from the degradation and destruction of these ‘blue carbon’ ecosystems is estimated at 45 billion metric tons annually, with an associated economic cost approaching USD 20 billion each year. Globally, coastal wetlands are some of the most valuable natural resources, providing essential ecosystem services such as protection from storms and sea level rise, erosion control, maintaining coastal water quality, carbon sequestration and storage, and food security. They are vital to human well-being along the coasts of all continents and particularly for some of the world's most vulnerable people.

Blue carbon is defined as the carbon stored, sequestered or released from coastal ecosystems of tidal marshes, mangroves and seagrass meadows. These ecosystems sequester and store large quantities of blue carbon in both the plants above ground and in the sediment below. For example, over 95% of the carbon in seagrass meadows is stored in the soils. Likewise, mangroves capture and store up to 5 times more carbon than any productive terrestrial forest. Due to the carbon sequestered and stored in these systems, when they are degraded or destroyed all that carbon is released back into the atmosphere as CO₂ emissions. The emissions released through ecosystem conversion are now being recognized by the IPCC and UNFCCC as significant sources of GHGs. Thus, effective management and conservation of coastal wetlands is now a critical priority, especially in regions where people are highly dependent on these ecosystems for critical services.

The Blue Carbon Initiative is an integrated program focused on mitigating climate change by conserving and restoring coastal marine ecosystems globally. The Working Group consists of experts in coastal carbon science, carbon assessment, remote sensing and international climate change policy. The group has identified sub-Saharan Africa as a critical priority for:

- Assessment of coastal wetlands for carbon storage and other ecosystem services, including field surveys, mapping, threat analysis
- Support for building capacity on science, conservation and management of coastal wetlands
- Building awareness of the importance of coastal wetlands
- Inclusion in global analyses

The current presentation will explore the status of blue carbon research in Kenya and the opportunities therein.

Keywords:

Blue carbon, NAMA's, Climate change mitigation & adaptations.

Fish stock assessment in the Kenyan EEZ: current status

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Kenya's marine fisheries resources support livelihoods and economic activities of more than 8,000 fishers. However, the fishery is mostly artisanal reef-based and recent indications are that the resource is overfished with declines of species abundance ranging from 50–80% over the last decades. Alternative sources of livelihoods are necessary to release pressure on the nearshore fisheries resources. The deep slope fisheries resources in the EEZ of Kenya and coastal Eastern Africa remain largely unassessed since the expeditions of the *Dr Fridtjof Nansen* of the early 1980s. The species distribution, diversity, biomasses and economic viability are largely unknown but can form alternative source of livelihoods and economic income to the artisanal fishers. The South West Indian Ocean Fisheries Project (SWIOFP) that concluded in 2013 surveyed the demersal fisheries resources on the Kenyan coast over a bathymetric scale that ranged from shallow (10–50m) to deep slopes (> 100km) on the continental shelf during the NEM season of 2012. Fish species biomasses were estimated along the coast using a bottom trawler over a 2-weeks period. Additional deep slope species biomasses were estimated using a dropline survey albeit over a shorter experimental period. We evaluate these datasets and discuss the potential of an offshore demersal fishery in coastal Kenya.

Marine fisheries research in Kenya

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Kenya has approximately 600km of coastline, an area of 142,000km² within the 200nm EEZ, and 103,000km² within the 150nm extension of continental shelf. The current National Economic Development Plan for Kenya (Vision 2030) identifies the contribution of marine fisheries to food security and economy development. Broadly, the Kenya marine fisheries may be divided into small scale fisheries, semi-industrial prawn fisheries, industrial tuna fishery, and recreational and ornamental fisheries. The small scale fishery supports the largest number of livelihoods and contributes most to the food security. Recent research has generally concentrated on the small scale inshore fisheries, semi-industrial prawn fishery while considerable data and information exist on recreational and ornamental fisheries. Research and assessments on small scale fisheries has a long history with results on the stock status ranging from over-exploited, optimally exploited to under-exploited, depending on the species as well as the exploited stock. The semi-industrial prawn fishery is one of the most studied, resulting in the first fisheries management plan in Kenya. The offshore industrial tuna fishery is part of the Indian Ocean tuna fishery, exploited by Distant Fishing Nations purse seine and long line vessels from Europe and the Far East. Catch statistics from the fishery indicate tuna stocks in the region to be an optimal exploitation for most species, while a few key species have shown indications of decline during the last few years. Opportunities to achieve the goals set for the sector towards economic development exist in the exploration of new stocks including deep water and continental slope demersal stocks and crustaceans to increase catches as well as benefits from the territorial waters. Research on the migration patterns of medium and small pelagic species as well as the by-catch associated with the industrial tuna fishery are the priorities for tuna and key pelagic stocks within territorial waters and the Exclusive Economic Zone. The direct benefits to the local economy may be increased and the sustainability of the marine ecosystem ensured through value addition of the fisheries products, the improvement of local fishing fleet, land based infrastructure for storage as well as fisheries processing capacity. A regional approach to the management of trans-boundary stocks will ensure their sustainability and continued benefits to the West Indian Ocean states.

Key words:

Marine fisheries, small scale fishery, semi-industrial prawn fishery, tuna fishery, research priorities, Kenya

Integrated coastal zone planning and implementation

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Integrated coastal zonal planning and implementation are issues of policy and governance, so what is the role of science? This contribution stems from the team's original interest in contributing to a better and sustainable coastal management. Since this original idea, Kenya has evidently not waited. Based on its considerable domestic expertise and in view of environmental and economic challenges for the country much has been done to elaborate an integrated coastal zone planning. This resets and should redefine the role of science in the complexity of global and local stakeholders' interests in the coastal zone. Often, data gaps, lack of baselines, lack of integrative insights weaken the effectiveness of such planning. Also, the valuation discourse appears to direct disproportionately conservation and management priorities and must be assessed critically by science. Scientists are keen not only to deliver commissioned and/or applied policy-support research but also to generate an 'overhead' of fundamental understanding, thus looking ahead to future questions and allowing for the transfer of insights to other locations. Indeed lessons learnt elsewhere must accelerate progress in a science-based conservation and management, moving beyond mere empiricism or trial and error. We will present our view on how to insert our scientific work into a general strategy of effective coastal zone planning.

Surveys with the RV Dr Fridtjof Nansen: experiences from the Western Indian Ocean Region

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The UN–flagged Norwegian research vessel Dr Fridtjof Nansen has been carrying out surveys in tropical and sub–tropical regions for the past forty years. In the period between 1977 and 1990 sixteen surveys were carried out off Kenya, Madagascar, Mozambique, Seychelles and Tanzania in the South West Indian Ocean region. The surveys were on pelagic and demersal resources and covered all trawlable parts of the continental shelf and slope outside the inshore reef zone from depth of about 10 to 500m. Large pelagic fish in offshore waters were not covered in the surveys which also looked at the hydrography of the area. Results of the surveys carried out in Kenyan waters were presented at the 'Norad–Kenya seminar on marine fish stocks and fisheries in Kenya' which was held in Mombasa in 1984. On the basis of the estimates from the survey, participants at the seminar concluded that the resources that had been identified and assessed did not warrant the development of an industrial fishery in Kenya.

Under the auspices of the EAF–Nansen project, the RV Dr Fridtjof Nansen returned to the SWIO region in 2007 and carried out surveys in collaboration with the Agulhas and Somali Currents Large Marine Ecosystems (ASCLME) Project, and the South West Indian Ocean Fisheries Project (SWIOFP). Areas surveyed included the EEZs of Comoros, Mauritius, Madagascar, Mozambique, and Seychelles as well as the Mascarene plateau and the Southern Indian Ocean seamounts. Unfortunately, due to the incidence of piracy in the northern part of the region, no surveys were carried out in the waters of Kenya and Tanzania. The results of these surveys have been reported and extensively discussed through the two projects. According to the EAF–Nansen project Data Policy, the data from all the RV Dr Fridtjof Nansen surveys may be obtained from the countries in whose waters the surveys were carried out.

Microbial biodiversity in Bohai Bay saltworks and their biotechnological utilization

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Both in the field of aquaculture and of salt production, China is among the top producers at world level, with an annual aquaculture production of 53 million tons (data of 2010) and 100 million tons of salt production (data of 2012).

The multi-pond solar saltworks inhabit diverse microbial groups. Along the salinity gradient, the majority of microbial community changes from moderately halophilic bacteria to extremely halophilic archaea, and the biodiversity decreases as the environment becomes more hypersaline. In the crystallizer pond, the blooms of carotenoid-riched *Dunaliella* cells, halobacteria and archaea ensure the increased heat absorption as well as the reduction of the dissolved organics, eventually resulting in the enhanced evaporation and improved salt crystallization.

Apart from the ecological importance, the use of halophiles in biotechnology has been recently paid special attention. High salinity and long-term selection pressure have resulted in the unique cell structure, physiological functions and metabolic mechanism of the halophiles. Halophilic bacteria and archaea are a useful biological source to produce polyalkanoate, carotenoid pigments, etc. Moreover the easy lysis of the cells in the absence of salt and little danger of the contamination in high salt concentration of the culture medium facilitate the industrial application of the halophilic microorganisms.

We studied the microbial biodiversity of brine water with different salinities and seasons in Bohai Bay saltworks, the main salt production site in China. A number of culturable bacterial and archaeal strains were isolated and identified, and the culture conditions of the biotechnological compounds such as poly- β -hydroxybutyrate and bacterioruberin were studied with specific strains. This is expected to provide useful information on the potential utilization of microbial resources in saltern ponds.

The importance of oceanography and hydrography in Kenya

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Kenya is one of the countries participating in the Global Sea Level Observing System (GLOSS), a programme developed by IOC of UNESCO to address the growing concern about the rise in mean sea level around the globe. There are two GLOSS tide gauges managed by KMFRI located at Mombasa and Lamu along the Kenyan coastline. Both stations are recording and transmitting hourly sea level data in real time to international sea level data centres. The two stations are also dedicated components of the Indian Ocean Tsunami Warning System (IOTWS). Data from the two stations (and others like them in the region) can be used to either confirm or cancel a tsunami warning throughout the region.

Kenya is actively participating in a regional initiative for the Western Indian Ocean aimed at enhancing regional collaboration between the ocean and climate experts in order to prepare seasonal ocean state forecasts to assist in improving regional climate forecasts.

Kenya has recently acquired an oceanographic Research Vessel RV Mtafiti. KMFRI is now in the process of putting in place a comprehensive programme to operationalize RV Mtafiti in Kenya's EEZ to conduct oceanographic and hydrographic surveys. In doing so, we are also reaching out to and engaging potential users and partners (at national, regional and international levels).

The National Disaster Operation Centre (NDOC), in collaboration with the Kenya Meteorological Services (KMS), KMFRI and other state agencies have developed Standard Operating Procedures (SOP) for Tsunami Warning and Emergency Response in Kenya. It aims to assist vulnerable coastal communities in Kenya to be prepared to respond appropriately and in a timely manner upon recognizing that a potential destructive tsunami may be approaching.

Kenya is hosting the Kenya National Oceanographic Data Centre (KeNODC) at KMFRI in Mombasa. This programme is part of the International Oceanographic Data and Information Exchange (IODE) supported by IOC of UNESCO. It includes on-line journals, information portals, and bibliographic database. Kenya submitted a bid to IOC-UNESCO to be considered as a Regional Training Centre (RTC) for the Ocean Teacher Global Academy (OTGA) at KMFRI, Mombasa and won. Kenya has also submitted another request to be considered as a Regional OBIS Node (RON).

Kenya is actively participating in Capacity Building programmes for the Data Buoy Cooperation Panel (DBCP) in the Western Indian Ocean (WIO) region. Kenya also hosted the 3rd DBCP workshop in Mombasa.

Kenya is actively participating in the UN Regular Process that aims to assess both the state of the environment and the impacts of key human interactions with ocean ecosystem including socio-economics. KMFRI has spearheaded the preparation of the State of Marine Environment (SME) Report for Kenya. KMFRI is also involved in the preparation of the State of the Coast Report for the Western Indian Ocean (WIO) region.

Aquaculture development in Tanzania: status, trends and perspectives

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The development of aquaculture in Tanzania has taken two major phases. The pre-independence phase, beginning from 1949 to 1961, in which the colonial government stocked rivers with trout in the Northern and Southern highlands to promote sport fishery for recreation. On the other hand, Tanganyika natives continued with *acadja* types of extensive fish farming in rivers and minor lakes and reservoirs for food security and prestige. In the mid-1950s, declining stocks of the native tilapias in Lake Victoria; *Oreochromis esculentus* (L.) and *O. variabilis* (L.), prompted massive stocking of the two species in fish ponds and impoundments as a measure for enhancing live gene conservation and food security. The second phase takes account of all post-independence endeavors in aquaculture development.

This paper is an attempt to briefly delve into the past to set the stage for our understanding of the stanza-based aquaculture development in Tanzania comprising spontaneous risings and fallings. We argue here that the current (1980s to date) rising is a private-sector led and deriving from a former private sector foundation that focuses on sustenance of profit margins among other benefits. In this light the paper takes stock of Tanzania's mariculture and freshwater aquaculture development in terms of their status, trends and perspectives. We give success stories and turn challenges into opportunities as we chart the way forward. We conclude that for aquaculture to be sustainable it must prove it is worthy as *a business*: economically viable, socially compatible, culturally acceptable and environmentally sound.

Short history of Kenya–Belgium collaborations and the marine science landscape in Belgium

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Belgium and Kenya have a long tradition of collaboration in marine sciences. This has to do with the 'Kenya–Belgium Project in Marine Sciences' or KBP. In the early eighties of the last century, realizing the importance of the world ocean, and the many services it provides to society, and recognizing that marine sciences are an essential enterprise in the development of a better world, the Belgian Government asked Professor Philip Polk to travel to Kenya and to investigate the possibilities of scientific collaboration. This mission resulted in the start of the 'Kenya–Belgium cooperation in Marine Sciences' in 1985. The KBP knew different successive phases that together ran continuously for more than 15 years, and it knew different simultaneous spin-off projects, with ramifications to many other European and East–African countries. The scientific output was significant. Many Kenyans were trained in Belgium, obtained MSc and PhD degrees, and many Belgian students and professors visited Kenya for collaborative research. This has resulted in a community of people who know, respect and trust each other, and who have sometimes established long lasting friendships. Many of the people that were active in KBP as young scientists now have important positions in KMFRI, in VLIZ, in the universities or in the Flemish and Kenyan ministries, even in international organizations like IOC. This is the strongest possible foundation to build upon. It's now up to this generation to transfer knowledge to a new generation of young Kenyans and Belgians, to create a new Kenya–Belgium marine science community.

This presentation will provide the short history of the collaborations between Kenya and Belgium but also give an overview of the current Belgian research groups conducting marine, coastal and/or estuarine research with an emphasis on those research groups that had, have or are interested in collaborations with Kenya.

A gap between small-scale community mariculture and mariculture as a business: can KCDP bridge the gap?

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Mariculture in Kenya is dependent on wild seed supply, is underdeveloped and can be traced back to the earlier 1980s. Community based small-scale mariculture was initiated about two decades ago along the coast of Kenya and organised community groups (OCGs) formed the entry point for the interventions. The OCGs were either formed by NGOs to specifically implement funded projects or were developed by communities out of influence from neighbour colleagues benefiting from group formation or just change of community merry go-round self-help groups. Most OCGs currently or previously involved in mariculture were originally conservation or environmental groups and only a few developed with core business being mariculture. The number of OCGs involved in small-scale mariculture increased by 360% between 2007 and 2013 while the area under pond culture increased by 404%, crab cages by 204%, while fish cages were also introduced during the same period. The period covered was before any major intervention by KCDP. The target species have been mainly milkfish, mullets, mud crab, prawns, seaweeds and *Artemia*, however, productions have inclined to mainly culture of milkfish, mud crab and prawns either under polyculture in ponds or monoculture in cages. Production capacity has varied between 0.06–0.2kg fish/m², 0.02–0.03kg prawn/m² and 5–20kg crab/month in 2007 and 0.08–0.44kg fish/m², 0.02–0.05kg prawns/m² and 15–40kg crab/month in 2013. Despite that, mariculture has been characterised with low and inconsistent annual production regimes that has been associated to a number of factors. However, through KCDP intervention over the last one and a half years, the fish culture and seaweed farming areas have doubled with more communities being introduced into mariculture. Therefore the issues of KCDP and income, production and sustainability will be discussed in this presentation.

An overview of the current status of Kenyan fish feed industry and feed management practices, challenges and opportunities

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The profitability of commercial fish farming operation is of paramount importance to all farmers. However, farmers must have access to well-balanced and cost effective feeds coupled with optimal on-farm feed management practices as a prerequisite to profitable production. This paper presents an audit of the current status of the Kenyan fish feed industry and on-farm feed management practices including opportunities and constraints from the fish farmer's perspective. The Kenyan fish feed industry has been boosted with the development of fish feed standards, which is expected to ensure quality fish feeds for all farmers. Much of the aquafeeds used in Kenya are either produced on-farm or by small-scale semi-commercial feed manufacturers, and improvements to the quality and preparation of these feeds are likely to bring about improved productivity and cost savings. Since feed management practices significantly impact the economic performance of production systems, adopting appropriate feed management strategies is instrumental to maximize returns. In a few instances, innovative farmers have reported developing their own feeding strategies such as spreading feeds at fixed points at the same time daily, bag and restrictive feeding techniques, break feeding schedules and promoting natural pond productivity. Provision of species-specific feeds addressing the nutritional requirements of the different life stages of fish is still an issue. Other challenges include inadequate access to finance, a lack of technical innovations, absence of feed formulation and processing knowledge and poor feed handling and storage techniques. The potential to develop public private partnerships with farmer groups to improve access to information should be considered. Programs that use the local media to provide farmers with extension messages must be encouraged. The government should frequently carry out spot checks on feeds supplied to Agrovets to ascertain its quality. Fish farmers should also be trained on feed formulation, transportation and storage to maintain a constant feed supply and save on costs.

Keywords:

Kenya, fish feeds, management, challenges, opportunities.

Benthic fauna from Kenyan marine sediments: a review

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Marine benthos are organisms found associated with marine sediments and vary in size from microscopic to sizes visible with the naked eye. In Kenya marine benthic studies have mainly focussed on soft sediment substrate in the mangrove forest floor. Gazi Bay has received the most attention with 80% of all benthic studies being carried out in the different mangrove species and very few in the adjacent seagrass. Another area that has received attention is Mida Creek where there are several studies looking at crabs and crabs behaviour. Other topics of interest identified in the Kenyan benthic studies were trophic interactions between endobenthos and epibenthos. Also studies relating to mangrove ecosystem recovery and function where benthic fauna were used as bio-indicators were common.

It is noted however, that there are few studies that relate to the impacts of human activity such as organic pollution, seed collection for mariculture, bait collection to benthic biodiversity and how these impacts are likely to affect the whole ecosystem. There is also paucity of information relating to status of other habitats such as seagrass beds, sandy beaches, mudflats, continental shelf and slope. With the development of gas and oil being so imminent, it is prudent to make inventories of benthic biodiversity both at the intertidal and deep sea areas that will serve as baseline for future monitoring work.

Community based aquaculture initiatives in coastal Kenya

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Mariculture presents an alternative supplement to the capture fisheries and can positively contribute towards food security, income generation and job creation. However, despite the huge mariculture potential in Kenya only a few community-based pilot projects and isolated trials for prawn, oyster, *Artemia*, mud crab, seaweed, and finfish culture have been done which have largely remained at experimental/demonstration stages. Despite this, a few initiatives in the culture of milkfish, prawns, crabs and seaweeds have started realizing some profits albeit at subsistence levels. This paper presents some of these initiatives and discusses the successes, challenges and constraints in community based aquaculture at the coast.

Keywords:

Community-based aquaculture, milkfish, prawns, crabs, challenges.

Biodiversity and health of marine and coastal ecosystems in Kenya

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Kenya's marine and coastal ecosystems, which include coral reefs, mangroves and seagrass beds, are threatened by a number of factors including unsustainable exploitation, poor coastal development and climate change. One of the most holistic approaches to protecting these ecosystems is ecosystem-based management approach, which recognizes the need to protect entire ecosystems instead of individual species. The KCDP programme is a GEF & World Bank funded project supporting partnerships of different stakeholders with a stake in marine ecosystems towards promoting an integrated management approach in order to maintain their functional and structural integrity of ecosystems, and to ensure economic and social benefits for local communities. The presentation will briefly provide an overview of issues impacting on biodiversity and health of marine ecosystems and gaps identified during KCDP interventions, with a view of providing a platform for future collaborative research work.

KCDP main objectives are to: 1. Contribute towards enhanced biodiversity conservation and sustainable use of marine biodiversity; 2) enhance marine biodiversity conservation through the strengthening of locally managed marine areas to meet their conservation and social-economic objectives and; 3) facilitate the transfer of best practices and the dissemination of relevant information on sustainable use of marine resources. The project has been under implementation since January 2011, designed to achieve the above-mentioned objectives, through developing and enhancing strategies and actions for marine ecosystems conservation and sustainable livelihoods in selected regions/areas. The following are some of the major achievements accomplished.

Strengthening of scientific base and development of management-oriented reports

Marine ecosystems (coral reefs, mangroves and seagrass beds) are the key ecosystems types associated with the main coastal fisheries in Kenya. They are of critical importance not only to most fisheries but also tourism which is another industry of major importance in Kenya. Dedicated scientific field studies have been undertaken on biodiversity and health status of coral reefs, mangroves and seagrass beds, in the south coast-Shimoni-Vanga, Kilifi-Malindi, and Lamu regions. An important major delivery under this component has been production of both scientific and technical reports highlighting on the current biodiversity and health status of marine ecosystems, major issues and recommended actions for their sustainable management and conservation. A second delivery is development of a database for monitoring, evaluation and reporting. The project has established an integrated information management system (IMS) to provide a central repository for data and information to guide in further research activities, conservation and management of marine resources.

The scientific biodiversity studies led to implementation of the following pilot projects in some areas:

- Pilot project 1.
Strengthening locally managed marine areas
Field trips on established CCAs have been made with aim of gathering data on their status and prospects towards improved marine biodiversity conservation and social-economic welfare of the local communities. A technical report entitled 'Community-managed areas (CMAs): needs assessment for a healthy coastal and marine environment and sustainable livelihoods' has been produced incorporating local community's views on interventions needed.
- Pilot project 2.
Restoration of deteriorated marine habitats, particularly near-shore reef systems
- Pilot project 3.
Strengthening of mangrove management and governance
- Pilot project 4.
Environmental and economic impact assessment of gated-basket trap

Improvement of the living standards of rural communities in Kenya through *Artemia* production in coastal saltworks

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Artemia (Crustacea), also known as brine shrimp, are typical inhabitants of extreme hypersaline environments and hence can be produced together with salt. Besides being the biggest salt producer in Eastern Africa, Kenya has not concentrated on the *Artemia* cum salt production. This is despite the fact that salt-*Artemia* integration helps improve salt quantity and quality while generating an additional source of income. About 30 years ago (1984 to 1986), KMFRI studied the potential of *Artemia* production in saltworks in Malindi, Kenya through the ABOS Project. The project proved that there is an untapped potential of producing *Artemia* locally. Kenya depends entirely on import of expensive *Artemia* cysts for shrimp and fish larviculture, from abroad. In 2010, a project aimed at assessing how to improve the living conditions of rural communities in the Kenyan coast by pond production of *Artemia* cysts and biomass in the locally available salt production systems commenced. The pilot site is located at Mnarani, an artisanal salt farm in Kadzuhoni village 20km North of Malindi town. The project targeted rural communities in coastal Kenya with the overall objective of building their capacity for *Artemia* production in existing salt production systems and application in local aquaculture initiatives to raise their socio-economic status by offering alternative livelihoods. It also helped to build capacity of local institutions to develop sustainable and environmentally sound models of *Artemia* pond production and application of locally produced *Artemia* in emerging aquaculture initiatives. Local community development centres, which have already developed very extensive aquaculture initiatives for the benefit of rural communities, were targeted for demonstration of project activities. Creating practical and theoretical expertise for the community and KMFRI through trainings has solved the lack of expertise problems. The communities within the salt belt have responded positively to the integrated *Artemia* production and several groups are already pursuing their own initiatives for *Artemia*/fish/salt production. It is expected that once the commercial salt farms take up the initiative of commercialising *Artemia* cysts and biomass as they do with salt then aquaculture development will be boosted and hence impacting more livelihoods positively. Several challenges that were encountered at the beginning of the project which include, eutrophication, predation and access to sea water have been addressed. However, land tenure and unstable weather conditions are still a challenge to beat.

Key words:

Brine shrimp, pond production, rural communities, aquaculture development.

Sustainable coastal and marine fisheries resources in Kenya: forging linkages between research and policy for societal benefits

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The coastal and marine resources in Kenya include the living and non-living resources such as coral reefs, seabed grasses, beaches and fish stocks and mangrove forest all providing useful services to Kenyans. Fisheries resources remain very important to the coastal communities in terms of livelihood, food and nutrition security. The demand for fish in the domestic and global market continues to increase as the population grows. The common vision of the agriculture sector in Kenya is 'a food and nutrition secure nation'. This calls for increased production and productivity. To ensure sustainable utilization of the fisheries and aquaculture resources in Kenya, the sector requires to invest in technology and innovations for societal benefits. For formulation of dynamic management decisions and policies, we need to get sound research findings to drive the sector. Development of the strategic priority actions to ensure food and nutrition security without jeopardizing the sustainability of the resources, will arise from uptake of these technologies. This paper looks at the status of coastal and marine fisheries and aquaculture resources in Kenya, the management and research responses. It further identifies the key research interventions that have been developed, the adoption and their impacts on management responses and societal benefits. It recommends further research needs to address the Country's development agenda and sustainability and suggests linkages that will increase information flow and synergies between research institutions and society.

Aquaculture research and development in Kenya: an overview

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Aquaculture is a key contributor to Kenya's fisheries sector. The fisheries sector on the other hand is recognized as having a pivotal role in both the economic and social pillars of Kenya's development. The aquaculture subsector as such plays a critical role in unlocking the potential for social and economic development of Kenya's people.

Despite being endowed with substantial water resources including inland lakes, rivers and a 640km coastline, Kenya's aquaculture potential has remained largely unexploited. A recent government intervention moved aquaculture production within the inland division from 4,000MT to 48,000MT representing a rise from 4% to 25% of fisheries production between the years 2009 and 2013. The marine sector with the 640km coastline and 200nm EEZ has not benefitted from any major intervention so far and the potential remains generally untapped.

The strategic research and development issues identified for Kenya to exploit her largely unutilized aquaculture potential include amongst others, inadequacy of production systems and species, insufficient quality inputs such as fish seed and feeds, capital and implements and weak provision of extension, advisory and outreach services. Kenya endeavours to pursue a science-based aquaculture development. Efforts in research are therefore demand driven, focused on addressing the needs of the farmers and the industry as well as gaps and weaknesses impeding production. The Kenya Marine and Fisheries Research Institute (KMFRI) and several universities have endeavoured to address some of the issues through its research efforts in genetic characterization and improvement of aquaculture species, formulation of inexpensive and quality feeds; live feed research; mariculture of seaweeds, mud-crab, oysters, finfish amongst other species and community based aquaculture project initiatives. KMFRI works closely with the State Department of Fisheries and other stakeholders in the effort to address the needs of the aquaculture fraternity.

Increased aquaculture production and productivity for sustainable food security, increased income and wealth creation will depend on a focused research support. Research strategic issues include diversification of aquaculture species base, improved culture systems, improvement of bio-security and fish disease surveillance as well as environmental research. These issues present opportunities for research collaboration, creation of synergies, avoidance of inefficiencies and duplication and sustainable growth of the sector.

Keywords:

Aquaculture research, development, strategic issues, collaboration, sustainable growth.

Kenya in the Western Indo-Pacific realm – its coral reefs in space and time

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The paleo-geology and paleo-oceanography of the WIO during the Cenozoic (67 mya to today) establish mechanistic explanations for extant patterns of reef coral diversity, that also extends to other species groups, including reef fish and stomatopods. These establish hypotheses claiming the northern Mozambique Channel is a centre of diversity for shallow marine species, with separation of a Red Sea/Gulfs province to the north, and Kenya falling in a transition zone between these two systems. On an ecological timescale the mesoscale current dynamics of the Mozambique channel may establish the northern part of the channel as a centre of biological dynamism, with high internal connectivity and energetics, and acting as both an accumulation centre for genetic material from the broader Indo-Pacific realm, and as a source for genetic material to locations to the north, west and south. For Kenya, this means that its marine systems lie downstream from this core region in the northern Mozambique Channel, but complicated by reversing currents on the Somali coast that carry species and ecological interactions from the Red Sea/Gulfs province to the north.

These patterns have implications not only for the evolutionary and systematic relationships among species, but also in the population and resource dynamics, and ecological recovery processes, of Kenya's marine systems. They cannot be managed in isolation from use and management systems to the north and south. Increased exploitation of marine resources, increasing coastal development, the likely expansion of economic activity driven by Kenya's emerging economy and the development of the LAPSETT corridor in the north, and climate change and ocean acidification impacts will place increasing pressures on Kenyan marine systems. Concurrently, changes in these same factors in other parts of the WIO will influence the fate of Kenya's marine resources, and in particular, massive development driven by fossil fuel extraction in the Mozambique Channel may be an important factor in the future wellbeing of Kenya's marine resources. An understanding of the regional dynamics and dependencies, and of the resilience and ability of local systems to sustain extraction and recover from disturbances will be critical to rational management of Kenya's EEZ and coastal resources and ecosystems.

Societal and economic benefits of research

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The coastal zone of Kenya is endowed with rich natural resources both in the ocean and on land. The ocean in particular has both fisheries and other resources that provide livelihoods and income to the coastal dwellers. There is however concern that the traditional exploitation of these resources has actually resulted in a 'natural resources trap' with poverty levels remaining extremely high among the local communities. In fact, the exploitation of some of the natural resources has been characterized by serious use conflicts. Some of the interventions that have been put in place by various stakeholders to address poverty have not yielded much because in many cases these interventions are not backed by sound scientific information. This paper therefore presents KMFRI's experience on how research information can positively result into societal and economic benefits particularly when the research information is effectively disseminated to communities and other stakeholders. It sheds light on the importance of understanding the socio-cultural and economic setting of the coast, the needs of the local communities, and applying scientific information to address these needs within the existing socio-cultural contexts.

Marine science in a global context and the Second International Indian Ocean Expedition

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IOC was created in 1960 as a body with functional autonomy within UNESCO to promote international cooperation and coordinate programmes in research, services and capacity building, in order to learn more about the nature and resources of the ocean and coastal areas; and to apply that knowledge for the improvement of management, sustainable development, the protection of the marine environment, and the decision-making processes of its Member States. This is important because there is a limit to what a group of enthusiastic well-meaning scientists can do internationally, without an intergovernmental organization to provide the operational, logistical and legal framework.

At around the same time that IOC was established, a major scientific expedition was taking place in the Indian Ocean. The 'International Indian Ocean Expedition', organized by the Scientific Committee on Oceanic Research (SCOR), involved more than forty (40) research vessels from 25 countries and generated a wealth of knowledge during its 6 years 1959 – 1965. The coordination of IIOE was handed over to IOC by SCOR at the end of 1962. The scientific information generated from the expedition has been published in 8 volumes of collected re-prints and at least 5 major atlases.

Next year 2015 marks the 50th Anniversary of the end of the IIOE. To mark this occasion, IOC and SCOR are planning the second International Indian Ocean Expedition.

The first expedition had a major impact on the development of marine sciences in the region, with a number of new institutions established, and existing ones strengthened. However the countries of Eastern Africa, some of which got their independence during this period, did not benefit as much from the training opportunities offered by the expedition, unlike their Asian counter-parts such as India and Pakistan, which were better prepared.

The second expedition comes at a time when major strides have been made in marine sciences, including emergence of new components of the ocean observing system such as remote sensing and Argo floats, as well as ocean modelling and forecasting. IIOE-2 provides an opportunity:

- (i) to enhance our understanding of the Indian Ocean and address knowledge gaps, especially in the Western Indian Ocean region;
- (ii) to address the issue of science to governance, knowledge transfer to government structure, and societal benefits of research results;
- (iii) for public awareness and public advocacy related to ocean issues;
- (iv) for capacity development at all levels.

Structured approach should be developed to ensure optimal use of these opportunities.

Experts/institutions in the region need to be actively involved in the cruises and other observation systems implemented in the region, including contributing to their planning. This will ensure better use of the opportunities provided by the expedition.

Quality control and value addition sub-component in KCDP

Component 1: Fisheries

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The main objective of QC and value addition sub-component is to improve the socio-economic benefits from fisheries through development of enhanced value chains and reduced post-harvest losses. The specific objectives include:

- to contribute to food security through reduced post-harvest losses by proper fish handling;
- to enhance fish quality assurance, value addition and marketing for improved livelihood.

The areas of focus of the QC and Value addition sub-component are: fresh, dry, smoked, fried fish value chain and marketing.

Fresh fish cold chain: an improved fish banda with icemaker and cold room is being introduced in Shimoni to cater for Kibuyuni fish banda as well in the fresh fish cold chain. Other infrastructure includes introduction of insulated containers for artisanal fishermen to carry ice up-stream, insulated containers at the fish banda, a fishing boat and fish collection boat with insulated containers.

Dry fish chain: the Sardine fishery at the coast are commonly dried by broadcasting on sand leading to contamination by birds, sand particles and rodents. Lower quality fish is produced with a limited market circulation and low income to the fisher-folk. Thirteen improved fish drying racks measuring 20ft by 3ft with nylon mesh have been introduced in the pilot site of Jasini-Vanga to avoid contamination of fish by sand particles during drying. Seventeen more are to be introduced to include Jimbo area.

Smoked fish chain: most freshwater fish in the North coast including Tilapia, catfish and *Protopterus* and some marine catfish are processed using traditional methods of fish smoking. This is practiced in Mwa, and Mpeketoni areas of Lamu county. The traditional methods use high amounts of wood fuel (contributing to high carbon footprint), have low fish smoking capacity and produce poor quality fish. Eight double door improved fish smoking ovens have been introduced in Mpeketoni. They use 60% less wood fuel (lowering carbon footprint), smoke more fish per unit time because of trays pile up one on top of the other and produce better quality fish.

Fried fish chain: small scale deep frying method is being practiced by a large number of women (Mama 'Karangas') at the coast and accounts for 68% of value added fish products along the coast. The fish is sold from early evening to almost midnight every day in display box shelves. They use paraffin candle light 'Korobois' to illuminate the fish. These emit smoke contamination increasing the carbon footprint. Three prototype improved fish display shelves have been introduced on trial basis in Kilifi Central of Kilifi county with eco-friendly and chargeable lamps replacing the 'Korobois'. This ensures no contamination of fish and no smoke emission with concomitant reduction in carbon footprint. The response from the community is very positive and a roll-out on pilot basis is awaited.

Product development, packaging and marketing: the first strategy towards value added product development was capacity building of KMFRI scientists and technologists. This was done by both local and external training in the Philippines at the Institute of fish processing. Technology transfer of product development has started being implemented with local communities. Product packaging and marketing: this is being done together with local consultants.

KCDP fisheries research: progress update for the year 2013–2014

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Kenya's marine fishery resources contribute extensively to the livelihoods and economies of the coastal fisher communities. However, the need to enhance sustainable exploitation of the resources has been triggered by rising resource–use conflicts and stakeholder concerns over the overexploitation of key target fishery stocks. To realize these fishery management goals, understanding the status of exploited fish stocks, particularly those of high commercial value is critical. In addition, there is need to explore alternative strategies to relieve fishing pressure in inshore areas. Towards this, the KCDP research sub–component invests in research towards promoting sustainable exploitation of fisheries resources and achieving greater economic benefits to fisher–folk. The subcomponent activities are based on six specific objectives:

1. to assess the status of priority fisheries stocks and impacts of fishing on the stocks;
2. to develop management strategies based on stock assessments;
3. to build capacity for conducting fisheries stock assessment;
4. to develop fish aggregation devices (FADs) and assess their effect in enhancing artisanal pelagic fisheries production;
5. to develop alternative environment friendly fishing technologies;
6. to develop resource use maps of key fishing grounds.

This presentation provides a summary of the progress made and achievements made towards meeting these objectives.

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KMFRI has been assessed and qualified to host a Regional Training Centre (RTC) for the OceanTeacher Global Academy Project. The project is aiming to develop a global training centre network and utilize this network to increase national capacity in coastal and marine knowledge and management. It does so by promoting the establishment of Regional Training Centres (RTCs) as well as their close collaboration through advanced information technology. The project will also develop further the OceanTeacher Learning System. The OceanTeacher Global Academy (OTGA) Project is an extension of the achievements of the OceanTeacher Academy (OTA) project which, between 2009–2013, developed a Learning Management System and teaching programme that has successfully organized 42 courses on ocean data and information management, involving over 1800 participants, at the IOC Project Office for IODE in Oostende, Belgium. The Enhancements in this second phase include (i) OceanTeacher Global Classroom, which will involve the establishment, by Member States, of regional training centres (of Excellence) and their interconnection through advanced video conferencing services; and (ii) the development of a wide range of courses responding the needs in ocean science, ocean observation, tsunami warning and mitigation, integrated coastal area management, marine spatial planning, etc. Special attention will be given also to North–South as well as South–South interaction of students, as well as to gender balance in terms of students and resource persons (lecturers and teaching assistants). The project is in fulfilment of the IOC–UNESCO partnership with the Global Ocean Forum on a commitment at the Rio+20 conference on ‘Building Global Capacity for Marine Sciences, Observation and Transfer of Marine Technology’. As a result a needs assessment was conducted for capacity development in the field of marine scientific research and ocean observation especially in developing nations and Small Island Developing States (SIDS), leading to the formulation and implementation of a global strategy to implement these needs, through partnership with countries, donors, UN Agencies, global financial institutions and the private sector. The commitment is based on the proposal contained in the UN Blueprint Report on Ocean and Coastal Sustainability and will be implemented in close cooperation with Global Ocean Forum led Voluntary Commitment on building global capacity for integrated ocean governance. The Project will target the following trainees/groups: staff of marine research institutions and related facilities, staff of Government departments involved with marine science and services, marine related practitioners (Government and Private Sector), university students (marine science and related disciplines).

Recent advances in marine aquaculture research – implications for Kenya and the region

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For coastal communities in the western part of the Indian Ocean the dual impacts of overfishing and rising populations have generated an urgent need to find alternative sources of food and income to replace or supplement capture fisheries. Aquaculture is a logical alternative, and its growth needs to be supported and sustainable.

The challenge for Kenya, and other countries in the region, is to develop and gain the economic benefits from coastal aquaculture enterprises, whilst conserving the ecosystem health of adjacent environments. In this context, recent advances in environmental management, selective breeding and aquafeeds have dramatically increased the production efficiency and sustainability of Australian aquaculture enterprises. These achievements are proven solutions to the concerns about the negative impacts that aquaculture can have by: increasing nutrient loads in adjacent environments, harvesting wild seed-stock for aquaculture enterprises, and using wild harvest fisheries products in aquafeeds.

The environmental management of Australian aquaculture is very strictly regulated; this has stimulated significant advances in site selection and environmental management technology. The CSIRO has developed and applied Geographic Information System (GIS), and bio-economic modelling to enhance the optimisation of aquaculture planning. These systems have been applied to broad-scale site selection and site-specific analysis of aquaculture enterprises. The development of recirculation or partial recirculation systems, together with simple discharge water treatment technology have enabled Australian prawn farms to operate adjacent to the Great Barrier Reef for 25 years with no adverse environmental impacts. The site selection and environmental management systems are directly transferable to the Kenyan coast.

Domestication and selective breeding are the sustainable alternative to using wild seed stock and are critical to improving productivity. Successful domestication and selective breeding of Australian stocks of black tiger prawns *Penaeus monodon*, has provided farmers with independence from wild broodstock. More importantly, the use of domestication alone has increased average harvest yields of *P. monodon* farms in Australia by 40%. Selective breeding of the domesticated stocks has improved growth rates, feed conversion efficiency, greater tolerance to gill associated virus (GAV) and enhanced market quality. *Penaeus monodon* is native to the Kenyan coast and the knowledge and technology required for successful domestication, and selective breeding of this species are directly transferable.

Every year 20–30 million metric tons of fish, one third of the global fish catch, is used to produce fishmeal to feed to farmed fish and crustaceans. There is a critical need to develop cost-effective alternatives to wild-harvest fishmeal in aquafeeds. Over the past 10 years, the CSIRO research team has progressively developed a novel prawn feed additive (Novacq™) that meets this need. Feeds containing Novacq™ improve prawn growth rates by 20 to 30% without using any wild fisheries products, a world-first achievement in sustainability. The Novacq™ technology is scalable and transferable.

In summary, the transfer and application of recent advances in environmental management, selective breeding and aquafeeds from Australia could significantly enhance the viability of new aquaculture enterprises in the coastal areas of Kenya, and other countries in the region.

An overview of the institutions and education programs of higher learning in aquaculture development in Kenya

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The development of a sustainable aquaculture industry, like that of any other industry, is largely dependent on the principals of good management practices, themselves a culmination of purposeful training, both formal and informal. Education institutions and other training institutions thus have a crucial role in the development of a sustainable aquaculture industry in Kenya, since the 'production' of good managers is a result of the education programmes, particularly of the higher learning institutions, and modes of implementation. In the Kenyan context, aquaculture training can be said to be at its infancy, making it a high priority development target, on account of the just-emerging challenges brought about by the massive expansion of the aquaculture sector after the Economic Stimulus Project (ESP).

Aquaculture training in Kenya is offered at the informal level through on-farm attachment, whereby knowledge is gained through hands-on practice, and formally in training colleges and universities following particular programmes developed for that purpose. The KWS training college based in Naivasha has for a long time been the main source of manpower that oversees the field extension programmes for the aquaculture sector. Currently, several universities, notably Moi University, Nairobi University, and Maseno University have degree programmes in fisheries and aquaculture, with a few other universities running programmes on general aquatic sciences with some aquaculture inputs. However, these courses as currently structured do not meet the market requirements necessary for sustainable aquaculture development in Kenya. There is a need to initiate market-driven educational programmes that involve industry players which are the end users of the products of the institutions of higher learning. This paper reviews the current status of aquaculture training in Kenya and outlines possible ways to actualize the training of aquaculture practitioners and managers for sustainable aquaculture in Kenya.

Review of coastal aquaculture development in Mozambique

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Aquaculture in Mozambique is still embryonic with a total production reaching 603 t.y⁻¹ and providing more than 1000 jobs, growing mainly coastal species. The present review is highlighting the coastal aquaculture development in Mozambique of crustaceans, finfish, bivalves and seaweeds. The main crustacean species cultured were brackish water shrimp, farming *Penaeus monodon* and *Fenneropenaeus indicus* in earthen ponds and, it was booming and reached 1067 t.y⁻¹ in 2005 when the world production started outstripping demand and the world market dominated by larger producers, pushed the prices down and leading to reduced production in Mozambique. Furthermore, the outbreak of white spot syndrome virus (WSSV) killed the already weak shrimp culture industry. Other farmed coastal species like commercial cage fish farming of *Rachycentron canadum* and *Argyrosomus japonicus* lasted only 5 years due to unclear reasons although this had been having good results. Seaweed culture did not last for long in Nampula and Cabo Delgado coast due to marketing, cultural and perhaps other unknown reasons while bivalve culture did not go beyond the experimental phase. It can be concluded that the potential of coastal aquaculture in Mozambique has to date not been meaningfully exploited despite a favourable political environment for investment as well as climatic conditions and identified and preserved coastal areas.

Key words:

Shrimp culture, WSSV outbreak, cage farming, coastal aquaculture potential.

South African estuaries: natural and anthropogenic drivers of ecosystem state

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Estuaries are defined by Whitfield and Elliot (2011) as: 'a semi-enclosed coastal body of water which is connected to the sea either permanently or periodically, has a salinity that is different from that of the adjacent open ocean due to freshwater inputs, and includes a characteristic biota'. Ecosystem services derived from estuaries include introducing freshwater to the marine environment, a refugium and nursery for fish and invertebrates, carbon sequestration, flood regulation, storm protection, provision of safe bathing areas and the production of food, fuel and building resources. South Africa has approximately 300 functional estuaries classified into five types namely: permanently open, temporarily open closed, estuarine bays, estuarine lakes and river mouths. The main driver of ecosystem health is related to the quality and quantity of inputs from the riverine and marine environments into the estuarine body which influences the physical and chemical properties and in turn productivity in the water column and adjacent habitats. The mouth of an estuary links the marine environment to the estuary and allows for the movement of organic and inorganic components, this movement is important for both ecosystems. The National Biodiversity Assessment of 2011 identified freshwater flow reduction, habitat modification, fishing and pollution as major stressors and called for management interventions with regard to these. Mariculture and desalination are emerging pressures on estuarine biodiversity. The response of estuaries to these stressors is measured using the Estuarine Health Index which analyses the relationships between abiotic and biotic components. The health index has shown that, in South Africa, the large important estuaries were in a 'fair' to 'poor' condition. Estuarine specialists have developed and continually update an estuarine botanical database; the data has already been used in the management of estuaries in South Africa especially in National Biodiversity Assessment and estuary management plans. The National Estuary Biodiversity Plan (SANBI, Department of Environmental Affairs) has identified 133 priority estuaries to be assigned protection status in order to meet defined biodiversity targets. Although legislation is in place (National Water Act), effective estuary management must take place across different government departments which can represent a complex challenge. The Integrated Coastal Management Act strives to achieve this through cooperative governance and the development of estuary management plans which include all stakeholders. Estuaries provide a number of ecosystem services, the value of these are influenced by the factors mentioned above. Healthy estuaries are more likely to support habitats that may be more resilient to climate change. This presentation aims to summarise the role of natural and anthropogenic drivers on estuarine health and to evaluate the management tools in place in South Africa to protect the integrity of these important assets.

A comparative survey of mangrove dynamics in India, Sri Lanka, Malaysia and Kenya

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In terms of geographical distribution of the mangrove forests, the South and Southeast Asian countries are supporting not only an extensive cover (51,800km²), but also a rich species diversity (17–40) (UNEP, 2014). While Malaysia remains as the second largest mangrove nation (5,800km²) next to Indonesia (31,890km²), India occupied the fifth position (3,682km²) (Spaldings *et al.*, 2010). Though Sri Lanka is small by the country itself, the island-wide estuarine/lagoon areas are still supporting some luxuriant mangroves (89km² with 20 species) that claimed to be (almost) stable for the last 20–30 years (UNEP, 2014). On the other hand, the mangrove cover in Africa (32,428km² with 11–20 species) stands next to the Asian continent. The present paper compares the mangrove vegetation dynamics (together with local conservation/management practices) observed from Coringa wildlife Sanctuary in India (Satyanarayana *et al.*, 2009), Galle–Unawatuna area in Sri Lanka (Satyanarayana *et al.*, 2011a, 2013), Tumpat mangroves in Malaysia (Satyanarayana *et al.*, 2010, 2011b), and Gazi Bay in Kenya (Satyanarayana *et al.*, unpublished results). In the case of Coringa, the mangroves were comprised of 15 species. *Avicennia marina* was the most important species contributing 43% of the total basal area (mean density, 123 trees 0.1ha⁻¹) (max. height 12m), followed by *A. officinalis* (39%) (25 trees 0.1ha⁻¹) (11.3m) and *Excoecaria agallocha* (12%) (72 trees 0.1ha⁻¹) (7.1m). All other species in the vicinity represented only ≤6% of the total wood volume on the ground (6–52 trees 0.1ha⁻¹). The mangrove composition at Galle–Unawatuna is characterized by 10 species of which *Rhizophora apiculata* was abundant (42% contribution to total basal area) (186 trees 0.1ha⁻¹) (8.7m), while *E. agallocha* (22%) (73 trees 0.1ha⁻¹) (6.5m) and *Bruguiera gymnorhiza* (21%) (79 trees 0.1ha⁻¹) (6.8m) are next in the order. At Tumpat, though *Nypa fruticans* and *Sonneratia caseolaris* were widely distributed among the five dominant taxa, only *S. caseolaris* (46 trees 0.1ha⁻¹) (15m) and *A. alba* (67 trees 0.1ha⁻¹) (12m) are accountable for 95% of the total basal area. At Gazi Bay, the habitat recovery of the (*Ceriops tagal*) reforested mangrove sites was assessed in relation to the natural sites. In this context, a combination of results indicating site selection/location, tree growth/foilage, fauna and its competition, etc., were all found important. The distribution of mangroves at Coringa and Tumpat also revealed several species-level associations whereas species' turnover in relation to the physical infrastructure developments was witnessed from Galle–Unawatuna. Besides the traditional fishing in mangrove areas, the other manmade activities such as tree felling, timber collection, forest clearing for aquaculture and agriculture, etc., are strictly prohibited in both India and Sri Lanka. On the other hand, sustainable use of the forest resources has been a priority of the Malaysian mangrove managers. In this context, the silvicultural management based on 30-year rotation and its regular exploitation for commercial (pole/charcoal) as well as non-commercial (food/shelter) purposes is benefiting several local people and their livelihoods (Quispe Zuniga, 2014). Viewing the importance of mangroves to local communities, its sustainable utilization patterns should be legitimated rather than imposing a complete ban. The local people given with appropriate share of revenue and responsibilities would be able to protect the mangrove ecosystems better than any law and order alone which can be also evidenced practically in Malaysia.

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Marine sciences in the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project

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The UNDP GEF Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project has been concerned with the improved transboundary, ecosystem based management of coastal and marine regions in nine countries of the Western Indian Ocean (WIO), including Kenya.

The project ran from 2008 to 2014, beginning with a baseline national and regional ecosystem assessment, a rigorous causal chain analysis, and culminated in the development of a regional Strategic Action Programme.

The Somali Current LME extends from north to south from the horn of Africa to the Comoros Islands and the northern tip of Madagascar. The Agulhas Current LME includes the Agulhas Current, which flows southwards along the east coast of South Africa, as well as its sources in the Mozambique Channel and its retroflexion south of Madagascar. As a result of studies undertaken through and alongside the ASCLME Project, it is now also scientifically probable that there is a third LME involved in this complex region. Before dividing in the vicinity of northern Madagascar, the South Equatorial current first reaches the Mascarene Plateau where a unique ecosystem has developed. This dynamic system of ocean currents and upwelling cells is responsible for regulating vital climate and influence weather patterns, sea temperatures, water chemistry, productivity, biodiversity and fisheries.

The LMEs are notably threatened by habitat modification, overexploitation of marine resources, pollution, and extreme events. Due to the interdependencies between the causes and effects of these threats, an integrated ecosystem-based management approach is needed to effectively mitigate them. A phased multi-project, multi-agency approach was planned that progressively strengthens management capacities at the regional scale to address transboundary environmental concerns within the LMEs, builds political will for threat abatement, and leverages finances, proportionate to management needs. The ASCLME project set out to gather new and important information about ocean currents and how they interact with and influence the climate, biodiversity and economies of the western Indian Ocean region. In parallel, it sought to strengthen scientific and management expertise, with a view to introducing an ecosystem approach to managing the living marine resources of the western Indian Ocean region.

An overview will be given of the science undertaken during the course of the ASCLME project, with special reference to Kenya.

Eco-toxicology in coastal and marine systems

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Marine ecosystems face unprecedented threat of marine pollution and anthropogenic activities. Contamination of toxic pollutants is ubiquitous in coastal ecosystems worldwide. Pollutant influences have changed and will continue to change on time scales of decades and beyond. Environmental exposure of toxic pollutants in marine ecosystems is species-specific and determined by how the species is exposed to different environmental media and the geochemistry of individual pollutants within ecosystem compartments.

Antifouling chemicals, especially tributyltin (TBT) compound, is a possible most toxic chemical deliberately introduced in the marine ecosystems. TBT was mainly introduced in the aquatic environment as a key ingredient in antifouling paints. A prohibition of the use of organotin compounds as active ingredient in anti-fouling systems in ships by the IMO was effective by 2008 in most industrialized countries. Paint manufactures have developed new compounds known as booster biocides (such as diuron and Irgarol-1051) to replace the usage of TBT in antifouling paints. Numerous studies have reported the occurrence of antifouling compounds such as TBT, diuron and Irgarol 1051 in marine environments. To date, very little is known on the adverse effects of antifouling compounds in coral reefs ecosystems. While the levels reported in various regions have reached the threshold levels for survival of corals over a short term exposure, the consequences that might be caused by chronic exposure of the environmental relevance concentrations of these chemicals in coral reef ecosystems remains uncertain.

This presentation is mainly focused on levels, behaviour and effects of toxic chemicals such as TBT, diuron and Irgarol 1051 on coastal areas including coral reefs ecosystems. This paper provides a fingerprint of the effects and consequences of anthropogenic activities in coastal ecosystems and allied resources.

Keywords:

Coral reefs, carbon production, stress, antifouling compounds.

Fisheries governance in coastal and marine Kenya under the Kenya Coastal Development Project

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The Ministry of Fisheries Development Strategic Plan (2008–2012) outlines Kenya's development agenda as set out in the Kenya Vision 2030. The goals of the strategic plan are geared towards achieving an effective institutional, policy and legal framework; sustainable utilization of the natural fisheries resources, promotion of aquaculture development; promotion of fish safety and quality assurance, value addition and marketing; improvement of infrastructure, strengthening human resource capacity, conduct fisheries research and strengthen monitoring and patrol units along the coastal areas.

These goals, which are being implemented through the state department of fisheries (SDF) and Kenya Marine Fisheries Institute (KMFRI), are in tandem with the actualization of KCDP Project Development Objective (PDO), which is to promote an environmentally sustainable management of Kenya's coastal and marine resources by strengthening the capacity of existing relevant government agencies and enhance the capacity of rural micro, small and medium-sized enterprises in selected coastal communities.

The project endeavours to improve marine fisheries governance, through increased marine fisheries management capacity, by implementing a cost-effective monitoring, control and surveillance (MCS) for inshore and Exclusive Economic Zone (EEZ).

Law enforcement remains the main challenge in fisheries management; however periodic inshore patrols in collaboration with Beach Management Units (BMUs) and development of Management Plans for Priority Fisheries is a possible alternative.

Integrated water resource management and aquaculture for equitable and sustainable livelihoods in East-Africa

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Aquaculture is the fastest growing food-production industry. It all started in Asia, especially in China, but it was only in the last 3 to 4 decades that spectacular growth took place with a progressive increase in the contribution of aquaculture to global seafood needs from less than 10 percent in the 1970s to about 50 percent of what we consume now. This trend will continue as demands increase and fisheries stocks are exploited near or greater than maximum sustainable yields. Calculations based on present per capita consumption and estimated population size 10 years from now reveal that aquaculture will have to provide more than 25 percent more on an annual basis within the next decade. When considering the available global resources for food extraction or production, it is clear that land for crops and pasture will come under serious pressure. It should be clear that aquaculture is expected to expand very significantly. However, can this all be achieved following our current expertise and experience? Can it be accomplished without causing environmental risks or human health problems? The answer is yes but only when we adopt new approaches when addressing sustainability issues. In future aquaculture developments we must embrace ecological principles and reconsider the monoculture approaches that we have increasingly introduced with the modern forms of business aquaculture.

Marine sciences in the Western Indian Ocean region: the story of WIOMSA

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In 1993, when WIOMSA was established, the Western Indian Ocean (WIO) region was characterized by very few marine scientists, the majority of them being fisheries biologists; absence of research priority setting mechanisms at the regional level; poor dissemination and communication of research results to various stakeholders and interest groups; little exchange of information and research collaboration amongst scientists in the WIO; links to priority management issues were sporadic; and absence of a research grants programme that responds to priority needs of the region.

Two decades later, significant progress has been made, with the most notable one being the transformation of WIOMSA from a professional network with few activities, to a regional center of excellence, and a major catalyst in coastal and marine sciences in the WIO region.

This presentation reviews the development of marine sciences in the WIO region over the two decades by analysing the challenges faced, including: non-alignment of the research goals and societal and policy-relevant needs; inadequate multidisciplinary research; few social scientists involved in coastal and marine research, and fewer institutions and individuals with the means to undertake the regional research. Mechanisms/processes used by WIOMSA and other regional organizations are described as well as lessons learnt highlighted. Some priorities for future actions aiming at sustaining the achievement made in marine sciences in the region are described.

The Kenya Coastal Development Project: matching science with development

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The Government of Kenya is implementing the Kenya Coastal Development Project (KCDP) with financing from the International Development Association (IDA) and the Global Environment Facility (GEF). The project provides support for interventions in fisheries, natural resource management, alternative livelihoods, capacity building and provision of small grants for community development. KCDP is implemented by 7 government agencies and oversight is provided by the Kenya Marine and Fisheries Research Institute (KMFRI). The project became effective in 2011. The presentation will highlight the achievements made in each of the core project areas and lessons learned in enhancing the linkage between science and development.

Sustainable *Artemia* pond production in coastal saltworks as a tool to solve aquaculture challenges

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Recently, successful aquaculture meant to complete the cycle from hatchery to nursery and grow-out phases. The big challenge for the first phase is live foods as they provide substantial nutrients, enzymes for most of early shrimp/fish larval stages (Bardach *et al.*, 1972; Goodwin, 1976; Kinne & Rosenthal, 1977). Nowadays, more than 80% of *Artemia* cysts have been used for marine shrimp hatcheries, but the main cyst source however comes from the wild (e.g. collected from salt lakes in USA, Russia, China) which are usually expensive and thus become bottle-necks to poor and developing countries. A successful story of *Artemia* farming in Vinh Chau (Vietnam) from introduction, adaptation of the original *Artemia* species (i.e. *Artemia franciscana* from solar saltworks in San Francisco, USA) to the new habitat (Vinh Chau), pond culture techniques and technology transfer to open out the possibility of fulfilling the need of *Artemia* cysts for local aquaculture development. In fact, the pond culture procedures of *Artemia* farming in solar saltworks in Vinh Chau through a so-called 'trial and error' to extensive - semi-intensive and intensive required a lot of efforts from indoor to outdoor application. As in the first phase, *Artemia* was stocked at a wider range of salinity (i.e. 60–150ppt) at appropriate evaporation ponds, low stocking density, direct feeding with manure or rice-bran lead the cyst production varied around 30–50kg wet weight/ha (in the period of 4 - 5 months in the dry season) (Vu Do Quynh, 1991; Brands, 1995; Nguyen Van Hoa *et al.*, 2007); later on, it was found that *Artemia* could invade to any area where salinity met in the range of 80–120ppt (optimal range) and the key success as the fertilizer pond (kitchen pond) which needs at least 20–25% of the total culture area. Besides, the amount of manures and fertilizer had been fine-tuned according to the N:P ratio and the optimum rate of N:P varied from 3:1 to 5:1 (Nguyen Thi Ngoc Anh, 2009). Such a system was assigned as semi-intensive which could produce up to 70–90kg wet weight/ha. Recently, an intensive system for *Artemia* farming in Vinh Chau is being considered as an improvement of semi-intensive with the control in stocking density, pond level, aeration, supplementary feeding next to the biofloc technology application. The latest has been convinced not only to enhance cyst production as a whole but also to protect environment as less manures and fertilizers have been provided into the system. Thanks to the progress on *Artemia* farming technology in Vinh Chau and nowadays per hectare of solar saltwork could produce as high as 150–200kg wet weight/ha throughout the dry season. As the main solar saltworks in the Mekong Delta (Vietnam), Vinh Chau and Bac Lieu now could produce up to 50 tons (wet weight) of *Artemia* cysts per year and to be worth about USD 2–3 million. The most important issue is to sustain the local development of aquaculture activities as the cysts produced could be used for production of 7 billion of shrimp post larvae (PL), approximately.

Artemia farming in Vinh Chau is now to be considered as a new approach to generate higher income for poor salt-farmers (i.e. salt-farmers could increase their profit 3–5 fold compared to traditional salt production). At the time being next to the cysts, *Artemia* biomass is now being used for nurseries directly or incorporated as pellets for the grow-out phase of a number of shrimp/fish species.

Keywords:

Artemia culture, solar saltworks, culture model, environment protection.

Building a regional training network of coastal, marine and continental water body scientists in the WIO region

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The South Initiative 'International intensive Southern training programme and network Development for marine and lacustrine scientists (InteGRADE)' is intending to (1) build a regional training network of coastal, marine and continental water body scientists in the Western Indian Ocean region (WIO) and to (2) organize a pilot event in the South on basis of the network initiating the establishment of an international intensive southern training programme (on research capacity, new scientific developments, governance and policy,...) within the disciplines of marine and continental water body research and management. The concept is to involve lecturers, academic scientists, managers, NGO collaborators and students at an international, intensive training programme in the South. There is an emphasis on valorizing alumnus involvement.

Problems in management of coastal and inland water resources and responses to global challenges are often related to the lack of transboundary approaches and flow of information through scientific networks. Flanders has built capacity in relevant fields, often created nuclei, yet regional and international South-South scientific networking remain an underutilised resource for valorization.

Through collaboration between the different stakeholders on themes such as climate change, water and coastal management, sustainability of utilization of marine resources by coastal communities, sustainable tourism including eco-tourism, coastal ecosystems in WIO, resources from freshwater and continental water bodies, with as a target and hub the Zanzibar archipelago, it is expected to provide a training with innovative approaches and tools in specific fields of marine and lacustrine science and management in a multiplication strategy (valorizing alumni / graduates and providing a training format to the network with a multi-disciplinary approach, which can be continued post project).

Challenges for aquaculture development in eastern Africa

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Aquaculture has enormously expanded over the past few decades worldwide with high diversification of culture systems, species, and degrees of intensification. Despite a number of remarkable developments in sub-Saharan Africa, overall its pace of aquaculture development has been slower than on other continents. Several African countries, including in East Africa, have important freshwater and marine resources, yet present aquaculture activities are often traditional, extensive, and operate below capacity. As main bottlenecks often the lack of appropriate 'seed' and 'feed' are mentioned; i.e. resp. the production of sufficient numbers of good quality fish/shellfish larvae for stocking, and the availability of affordable high quality feeds for grow-out. Various macro- and micro-economic, social and cultural factors can be held responsible for the present status of African aquaculture.

However, fast population growth and uncertain yields from traditional agriculture and terrestrial husbandry, aggravated by climatic changes, currently press governments to explore diversification of food resources. This growing public awareness is illustrated by the increasing number and the more coherent character of initiatives (deployed by policy makers, research entities and donor organizations) to give aquaculture production a more prominent position among other food producing sectors as one of the tools for community development within the framework of national poverty reduction plans.

RV Mtafiti scientific strategy for sustainable research in the Kenyan and WIO waters

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The RV Mtafiti, formerly RV Zeeleeuw from Belgium was widely used for oceanographic research surveys in the North Sea. Following renewal of the cooperation framework in marine science signed between the Flanders Marine Institute (VLIZ) for the Flemish Government and the Kenya Marine and Fisheries Research Institute (KMFRI) for Kenya Government on 19 October 2012, the two institutions embarked on activities agreed in the memorandum (MoU), among them, capacity building and benchmarking for research. Hence the offer to transfer RV Zeeleeuw to KMFRI was made towards fulfilling the need and wide gap that was seen to exist in Kenya. The vessel was therefore christened RV Mtafiti and prepared for relocation to Kenya.

In this paper, we present the strategy we have laid out for sustainable research on RV Mtafiti.

Coastal ecosystems, coastal forestry and fisheries

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Coastal ecosystems include estuaries, open ocean, coral reefs, mangroves, sea grass beds, lagoons and salt marshes. Due to their accessibility they are continually being exploited by humans for goods that they provide. They also provide important services such as habitat provision, shoreline stabilization, and water quality and are active carbon sinks. Increased human population has led to a rise in demand and utilizations of harvestable goods, leading to their degradation and in some cases species extinction. Coastal forests especially mangroves forests are globally on the decline due to overharvesting coupled to other causes such as pollution, pests and diseases among others. Coastal fisheries are on the decline due to overfishing, habitat degradation, pollution, mangrove forest degradation and fish species are continually being endangered. Climate change due to global warming is a threat to coastal ecosystems especially through sea level rise and increased sea temperatures. This calls for the need for sustainable management of coastal ecosystems for conservation, productivity and sustainable use. Various efforts have been directed towards conservation and sustainable use of coastal ecosystems. Concerted efforts have been directed towards reforestation of degraded mangrove forests and this has led to restoration of biodiversity in this ecosystem. Creation of marine protected areas has seen the protection of coral reefs, sea grass and mangrove ecosystems from continued human influence. However, methods and degree of protection varies across countries. Payment for ecosystem services and carbon markets programmes has encouraged the local communities to conserve coastal ecosystems as stakeholders. The recent Economic Stimulus Programme by the Kenyan Government has helped to reduce pressure on marine fisheries and reduce poverty levels among the coastal communities. Forestry programmes that encourage planting of other tree species have created alternative sources for wood and fuel thus reducing pressure on mangrove forests. Despite the efforts towards effective management and sustainable use of coastal ecosystems, human activities remain the enormous threat to coastal ecosystems on the global, regional and local scale. In Kenya development of a strategic management plan for coastal ecosystems in Kenya through the Kenya Coastal Development Programme will guide and oversee the effective and sustainable management of coastal ecosystems for sustainable utilization, productivity and conservation for future generations. This will reduce poverty, improve livelihoods and increase societal benefits from coastal ecosystems.