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किसानों का हमसफर
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Vision 2050

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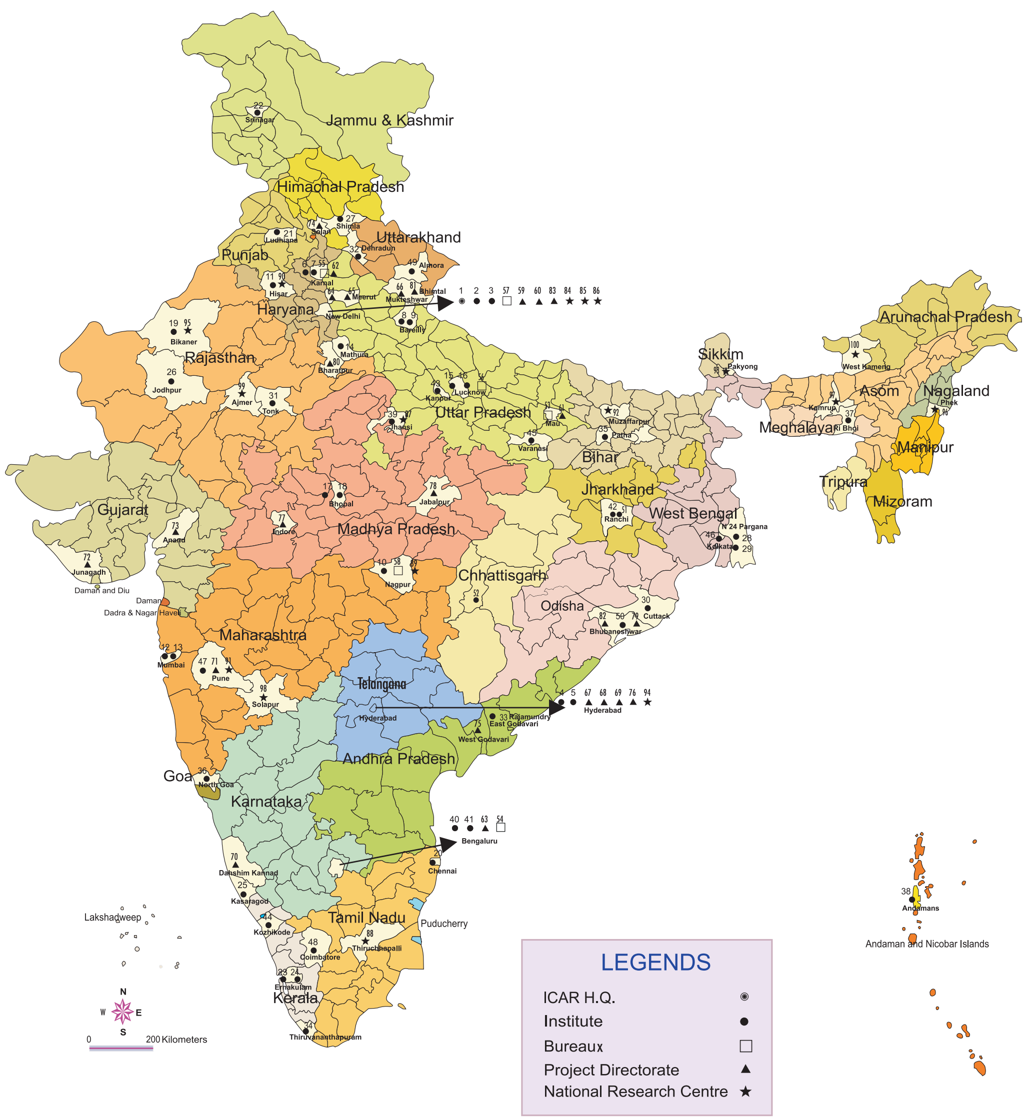

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- State Agricultural Universities ○
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Vision
2050

CIBA

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संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national program on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-Central Institute of Brackishwater Aquaculture (CIBA), Chennai has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
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Preface

Aquaculture is increasingly recognized as the best option to meet the growing demand for food. This sector has the resources to contribute significantly to the food and nutritional security, livelihood and employment and overall economic growth. Out of the ~9.50 million tonnes of fish produced in India during 2012-13, aquaculture contributed about half of it with ~5 million tonnes. Aquaculture has grown three times faster than agriculture has, at an amazing rate of 8.3% per year since 1970, and provided for 48% of the world's seafood consumption in 2009 (FAO 2009, Diana 2009). Although aquaculture has been traditionally practiced in many Asian countries, modern aquaculture is a relatively recent enterprise in most of the region where it is currently being practiced. Since 1980s, in many tropical developing countries including India, there was a drive towards non-traditional high valued export oriented aquaculture. Modern brackishwater aquaculture in India, more specifically shrimp aquaculture, is the paradigmatic example for such crops. The pace of development of shrimp farming from a tidal entrapment level to a large, multidisciplinary and sophisticated enterprise has been remarkable. Owing to the high export market demand, penaeid shrimp has become the focus of brackishwater aquaculture and is almost synonymous to the Indian coastal aquaculture scene.

With considerable resources of brackishwater resources along coastal states and inland saline areas, the scope and expansion of brackishwater aquaculture in India is highly promising in terms of economic, nutritional and social benefit. In the last few decades the growth of brackishwater shrimp aquaculture in India has been significant, and production of farmed shrimp in India has risen from about 20 mt in 1970 to 2,69,500 mt in 2012, contributing to the major share of the ₹ 30,000 crores of fisheries export earnings. While acknowledging the economic gains and employment opportunities provided by the brackishwater aquaculture sector, it is essential to recognize the skewed growth of brackishwater aquaculture towards monoculture of shrimp. Diversification of brackishwater aquaculture with different candidate species of shellfish and finfish to utilise the different trophic levels of farming system with broad stakeholder participation is to be realised. As aquaculture grows, it is inevitable to face confronting challenges (*viz.*

environmental consequences, issues of diseases, wild fish meal utilization in formulated feeds and changing market dynamics etc), which are too complex to resolve even at country level, leave it alone at individual business level.

Undoubtedly, brackishwater aquaculture must grow dramatically to meet the dietary protein requirement of exorbitantly growing population. However, modern aquaculture is profit driven and governed by free market principles, making the system compelled to address each stages and components of value chain, starting from ecosystem to the consumer, adhering to set standards in food safety and traceability. To ensure social acceptance and long term sustainability, aquaculture needs family and community roots, and aquaculture must be planned as a part of broader ecosystem perspective. Aquaculture expansion needs to be promoted on a environmentally-integrated mode, to ensure its own sustainability. This form of aquaculture would eventually lead into a "blue revolution". This blue revolution is not a modern clone of green revolution that require high inputs of fossil-fuel inputs to sustain high production levels, but an evolution incorporating the knowledge process of 21st century, that ensure the social equity and inclusiveness, financial gains, human wellbeing and environmental welfare. In other words this would be the ecosystem approach to brackishwater aquaculture (EABA).

Central Institute of Brackishwater Aquaculture was established in Chennai in 1987, and over the last 25 years the Institute has been playing a pivotal role in research and development in brackishwater aquaculture. Commendable progress has been made in the multidisciplinary areas of shellfish and finfish rearing (hatchery and farming) systems *viz*., broodstock development, induced maturation and spawning, larval rearing and seed production, live and formulated feed development, farming system technologies, disease diagnostics and health management, genetics and stock studies, climate smart aquaculture, community engagements using social science tools, policy interventions through state and other Govt. agencies. Cumulatively, these R&D interventions from CIBA have opened up new brackishwater farming initiatives, which benefits are passed on to farmers (small, large and industry scale) and other stakeholders. Some of the land mark achievements of CIBA such as development and transfer of hatchery and farming technology of sea bass, banana and kuruma shrimp, mud crab, development and popularization of formulated extruded feeds for shrimps and finfishes, DNA based molecular diagnostics, application of GIS mapping to demonstrate the environmental friendly climate resilient brackishwater farming systems and policy leadership enabling the successful introduction of SPF *Penaeus vannamei*, are the testimony of technology backstopping role of CIBA to the Indian brackishwater aquaculture sector.

We have a holistic look at the vision 2050 of this dynamic sector that harmonizes multidisciplinary team and problems solving approaches. We have undertaken meaningful exercise to develop this document, through critical appraisal of emerging scenario, stakeholder's consultations and in-house discussions. The present document, envisages the strategies to tap opportunities in the brackishwater aquaculture, and further, addresses the challenges identified. It is based on the guiding principle of sustainability, environmental integrity, economic benefits and social cause. We intended to offer a platform where science and technology meet together, that ultimately leads to right actions, acceptable to civil society, Union and State Government organizations. This vision document lays out challenges, pathways and options for both public and private sector that catalyse the collaborations and inspire the beginning of a shared journey.

I would like to record my grateful appreciations to all my colleagues presently working and those who have retired from this institute after rendering meritorious services, who contributed in the preparation of the vision document. I express my deep gratitude to Dr S. Ayyappan, Secretary, Department of Agriculture and Education (DARE), and Director General of Indian Council of Agricultural Research for his invaluable guidance in the preparation of this document. I thank Dr. B. Meenakumari, Deputy Director General (Fisheries), ICAR, New Delhi for the critical inputs.

K.K. Vijayan
Director
Central Institute of Brackishwater Aquaculture

Contents

Context

The fisheries sector has been conventionally playing a pivotal role in addressing the key global challenges of food and nutritional insecurity, poverty alleviation, sustaining economic development, providing livelihood and employment opportunities as well as fostering human well-being. With the projected 9.7 billion humans inhabiting Earth and India becoming home to 1.6 billion human populations by 2050, the fisheries and aquaculture sector will be expected to shoulder challenges primarily that of food and nutritional security, in the emerging scenario of climate changes.

The fisheries and aquaculture sector today touches the lives of about 10-12% of human population by being the harbinger of direct and indirect employment and livelihood opportunities. Fish and fish products are internationally the most extensively traded commodities, and the international trade in fish products is greater than the individual gross domestic product of 70% of world nations. In India, fish plays its pivotal role as the principal item of export, contributing 5007.7 million USD of prized foreign exchange.

> Fish and fish products are internationally the most extensively traded commodities, and the international trade in fish products is greater than the individual gross domestic product of 70% of world nations. In India, fish plays its pivotal role as the principal item of export, contributing 5007.7 million USD of prized foreign exchange.

Fish caters to 6.5% of the total protein consumed in the world and our global and national apparent per capita fish consumption is currently estimated at 19.2 kg and 6 kg respectively. The increasing recognition of unique nutritional and health benefits of fish consolidates its position as an affordable health food capable of meeting the requirements of a diverse spectrum of consumers and also holds the potential to seal food and nutritional security especially of the vulnerable populations even when consumed in small portions. Fish is universally accepted as an important source of good quality protein, long-chain-polyunsaturated fatty acids, a major source of iodine, having positive health benefits with respect to cardiac health and cognitive abilities. Fish, among the diverse forms of animal meat, is also the most efficient source of protein and one having low climate change impact. We are evolving towards an increasingly urbanized world of richer people with higher disposable incomes who can afford healthy food such as fish and fishery products. This creates a scenario of expanding domestic demand for fish, which is reflected in Indians and south-east Asians who consume the second highest quantity of fish and fish products.

Despite increased fish productions globally, the Food and Agriculture Organization (FAO), International Food Policy Research Institute (IFPRI) and the World Fish Centre (WFC) have predicted severe short supply of fish due to ever increasing domestic and international demand. We also witness surge in the international demand for fish certified as 'sustainably farmed' and a visibly increased demand for organic fish products even among the middle class of the developing nations, including India, requiring increased production of food through aquaculture. According to the FAO, currently 57.8% of the global food fish supply comes from capture fisheries and aquaculture contributes to 42.2% of the total fish production of 158.0 million tons (FAO, 2014). It is acknowledged that our global fishery is currently an under-performing asset and in need of recovery due to concerns related to over-exploitation. Hence with the stabilizing production trends witnessed in capture fisheries and in the context of our increasing obligations to biodiversity and ecosystem conservation, aquaculture sector is poised to increasingly shoulder the challenges of increased fish production.

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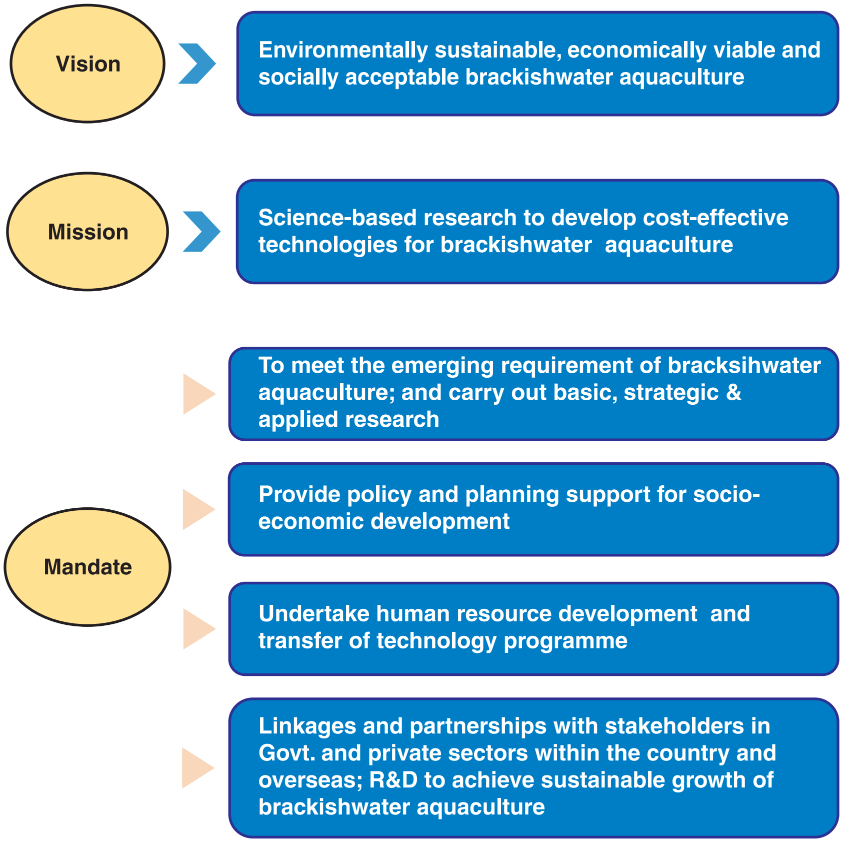
Globally, aquaculture is the fastest growing food producing sector with an annual growth rate of 6.5%. Indian aquaculture sector too by having demonstrated a 6.5 fold increase in the past two decades, and contributing 4.43 million tonnes to the total fish production of 9.06 million tonnes, upholds our pledge towards increasing fish supply and ensuring food security. Considering the vast brackishwater resources available in India to the extent of 1.2 million hectares and the sector currently utilizes only 14%, and therefore, huge opportunities exist here to reduce the pressure on wild stocks. The sector can emerge as the major contributor to the highest geographical aquaculture expansion in the immediate decades, to 2050. Brackishwater sector in India stands on the pillar of shrimp farming, with a small group of industrial mode of farming, where the farming area is more than 5 ha, and supported by large number of small stakeholder owning farms lesser than 2 ha who comprise around 90% of brackishwater farming community. Brackishwater aquaculture sector in India is one of the most vibrant food producing sectors in India that contributes 1.6% of total export earnings with about 300,000 employees. Brackishwater aquaculture sector is also built on the foundations of farm holdings still following the traditional systems of shrimp farming. Global policy makers agree that when compared to other sectors, growth originating in food producing sectors, particularly with respect to small stakeholders, provides two-fold higher benefits to the livelihood of the rural poor. In this way Indian brackishwater aquaculture sector has tremendous potential, and prominent role to play with 857 million rural populations with access to brackishwater resource. Engaging them for the transition towards a blue socio-economic growth, commonly called as 'Blue Growth', is envisaged for 2050.

CIBA focuses on the capacity of Indian brackishwater aquaculture sector through a schematic approach of planned geographic expansion, species diversification and sustainable intensification supported by adequate technological backstopping. Our shrimp farming sector emerged from the cradles of traditional farming systems of Kerala and West Bengal into a commercial export oriented sector in the 1990's dominated by the Giant tiger shrimp *Penaeus monodon*. The brackishwater aquaculture in India got its fillip with the demonstration by the DBT sponsored project on semi-intensive shrimp farming at Nellore, Andhra Pradesh, by TASPARC, during 1989-1993. The phenomenal rise of the shrimp industry was hard hit by the emergence of white-spot disease (WSD) in 1994. CIBA has played a key role in developing diagnostic kits for white-spot syndrome virus (WSSV), the first of its kind in India, and supported the formulation of best management practices (BMP's) for Indian shrimp culture. The institute also developed, commercialised and popularised the first indigenous formulated feed for farmed shrimp. This indigenous feed now has a prominent presence in the market and is able to compete with imported shrimp feeds. Today in a matter of two decades we witness a changed scenario of the shrimp farming sector being dominated by white legged shrimp *Penaeus vannamei*. The major species shift took place after a cautious risk analysis undertaken by the government with CIBA. The Institute played a key role in formulation of policy frame work for the introduction of this fast growing species with high export potential. With the hard lessons from the 1990's of the near collapse of the shrimp farming sector due to the emergence of WSSV, the Institute has thoughtfully adopted proactive interventions to manage and mitigate the incidence of unforeseen diseases in aquaculture sector.

Since its inception, CIBA has recognised the importance of species diversification and achieved the breakthrough in seabass breeding for the first time in the country. The Institute has also contributed significantly to the seed production and culture of mud crab, banana shrimp, kuruma shrimp, Indian white shrimp, cobia and pearl spot. However, breeding of mullet and milkfish are the immediate challenges in front of our scientists today. Significant breakthroughs have also been made in understanding the nutritional requirements for growth and maturation of brackishwater shellfish and finfish. CIBA also foresees the sustainability of the future aquaculture scenario being governed by farming of species of lower trophic levels. Adoption of a synergistic multi-trophic aquaculture approach will increase the thrust on sustainability and concerns on limited fish meal and fish oil availability, which are critical inputs in carnivorous fish feeds. Recognising the importance of using ingredients non-competitive to the human food chain and reducing input costs for aquaculture, the Institute has laid a major thrust in using non-conventional ingredients for reduction in fish meal usage up to 50% and developing competitive low-cost feed formulations for shrimp, crab and finfish species, which are playing a significant role in reducing overall production costs for farmers. However, we also realise that concerns regarding minimising the fish-in and fish-out (FIFO) ratios especially in the case of carnivorous fish which need to be balanced with maintaining the farmed fish product quality equally healthy at par with its wild counterparts.

Presently, freshwater aquaculture is the dominant face of aquaculture globally. There is a looming uncertainty on the future of freshwater resources for aquaculture use. CIBA is equipping for gradual transition of the aquaculture industry's primary reliance to brackishwater resources. The Institute envisages for systematic horizontal and vertical expansion of brackishwater aquaculture areas and optimising system productivity and using geographic information system (GIS), remote sensing (RS) and carrying capacity tools.

CIBA is working on innovative system-based approaches integrating latest technological interventions for intensive production systems using less water, energy and fewer hands. For this the Institute has adopted a proactive approach and initiated development of technologies such as re-circulating aquaculture systems (RAS) sensors and automated feed dispensers. With raising concerns about food safety and increasing consumer niche for organic products, CIBA is also developing culture



practices in line with the principles of organic farming. through effective usage of RS and GIS tools analysed and dismissed the perception of adverse impact of mangroves in India due to expansion of the aquaculture sector. The Institute is also working with the support of Network of Aquaculture Centres in Asia-Pacific (NACA) and National Initiative on Climate Resilient Agriculture (NICRA) to develop low-carbon climate smart technologies in the forthcoming era of climate change.

CIBA has focused on disseminating the research innovations to multi-level stakeholders through extensive culture demonstrations, use of information communication technologies (ICT's), mobile phones and training more than 20,000 stakeholders since its inception. Globally it is alleged that female farmers receive only 5% of all extension services, while CIBA has trained and enabled a significant percentage of women entrepreneurs, farmers and won accolades on account of its successful partnership with women tribal self-help-groups. However, livelihood and living standards of large sections of coastal populations needs to be enhanced though brackishwater aquaculture.

Brackishwater aquaculture can contribute effectively for the improved food security and rural empowerment, exploiting the vast stretches of brackishwater in the coastal areas and inland saline waters. Initial experiments conducted by CIBA to involve rural women in mud crab aquaculture and seabass nursery rearing indicate the potential of rural aquaculture. An alternative or complimentary to the self help group model is 'family farming', in line with the model proposed by FAO in the 'year of family farming 2014'. Family farming is a means of organizing aquaculture production which is managed and operated by a family and predominantly reliant on family labour, including both women's and men's. A successful model for family farming for aquaculture of *Etroplus suratenesis* in Kerala has been demonstrated by CIBA, and this model can further be refined by integrating other aquacultured species, considering the location-specific situations and resources.

This document, CIBA vision 2050, summarizes briefly the challenges, issues, opportunities and perspectives of brackishwater aquaculture for the next four decades. The document presents the central perspective, more precisely a number of conceivable alternatives for future. Therefore, it does not claim as a comprehensive scientific perspective or a definitive road map for the future, but intents to catalyze the collaboration among the stakeholders and inspired shared journey

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Challenges

Food and agricultural organization estimates that nearly 870 million people of 7.1 billion world population are suffering from severe malnutrition. Nearly half of the world-protein-energy-malnutrition problem is in the South Asia. The food consumption among Indians will increase from 2400 kcal (kilocalorie) per day to 3000 kcal per day by 2050. The share of calories derived from cereals is declining in India with the ever increasing living standards. The number of undernourished people in India is expected to be 70 million by 2050, and fish and fishery products are expected to play a crucial role in feeding the future generation and in the nutritional demography of India. The aquaculture is considered to be feasible to meet the future challenge of doubling the fish production within the next four decades. Owing to the shrinking freshwater resources in India, much of the aquaculture expansion is expected to occur in brackishwater sector. However, changing global economic scenario presents us many challenges in brackishwater aquaculture. The specific challenges of Indian brackishwater aquaculture sector are summarized in this section.

Resources and Environment

India has vast coastal line of 8129 km with estimated potential brackishwater area of 1.2 million ha, however, only 14% is currently under use. Further, the development pattern is not uniform although shrimp production is increasing with the introduction of exotic white leg shrimp *Penaeus vannamei* in the country since 2009. The real challenge will be to develop plans to strategically utilize the potential resources effectively. The country has vast areas of open brackishwater resources for cage and pen aqua farming and large inland saline water resources that are non-viable for agriculture but viable for aquaculture. As area under brackishwater aquaculture increases on an unregulated mode, its conflict with other

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users in the catchment area for space and other environmental services becomes ever greater because of the lack of understanding of the aquatic environment and the erratic use of resources. Resource inventory and assessment of water bodies for aquaculture is essential to minimise the conflicts between the users. Most of the issues affecting ecosystems have not been scientifically assessed to evaluate and quantify the causes for the degradation. Finding the inter relationships among the environmental factors of coastal water bodies with a joint effort by state and central government agencies are essential to address the measures to be taken for sustainable development of eco resources.

Climate Change

The impacts of climate change will not affect aquaculture in all the areas or indeed all aquaculture farmers, in the same way. More focused studies are required to understand consequences of the climate change on aquaculture along with possible strategies to counter them. Climate change is also expected to further aggravate the already reduced freshwater flow leading to high salinity regimes. The understanding on the water quality particularly, ionic composition and their ratios in different source waters *viz*., seawater, brackishwater, low-salinity water, freshwater and underground saline water, and the subsequent changes in the quality of these waters in ponds is important for correcting ionic imbalances. It is predicted that future sea level rise along the coast of Andhra Pradesh makes this area under very high risk. For example, an area of 565 km^2 would be inundated, if the sea level rises by 0.59 m, as predicted, and that would affect severely the livelihood of small scale aqua-farmers. The poorest producers with least resources of financial capital, social or institutional support are least able to adapt to climate change, and will likely be the most vulnerable and hence the challenge will be to focus on the technical, social and policy aspects of adaptation. Adaptive tools for the aquaculture sector need to be refined and implemented to guide decision making under uncertainty. Aquaculture needs to be adequately addressed in climate change policies

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and programs dealing with global commons, food security and trade like agriculture. Development of technologies which minimize the effect of weather related environmental changes will be in great demand to protect the losses due to untoward weather conditions.

Policy Frame Work

Aquaculture development is expected to continue facing environmental, economical, climatic and social challenges. The key to future of brackishwater aquaculture in India is the creation of technological and political system that provides a long-term sustainable system. Sustainable system will be achieved, if all the facets of brackishwater farming such as production and technological know-how, economics and marketing, business and administrative and legal frame works are dealt simultaneously. Institutional arrangements are needed to help the sector. Brackishwater aquaculture sector has often suffered by unclear or unprotected property rights, externalities, imperfect information, high transaction costs and other constraints. Although development of Indian brackishwater aquaculture is regulated by Coastal Aquaculture Authority (CAA), and funding supported from National Fisheries Development Board (NFDB), so far no critical evaluation have been conducted to assess the efficacy of the regulatory and developmental agencies, and to improve and refine the regulatory frame work in the light of latest scientific knowledge. Further, fisheries being a state subject coming under the preview of state government, proper co-ordination among all the governmental agencies, under state and central Govt. research/ fisheries education institutions and the stakeholders is paramount in taking the sector forward.

Environmental Impact

Unplanned expansion and intensification of the culture systems would put pressure on the aquatic environments leading to the degradation of environment, with negative outcomes such as pollution, poor water quality and emergence of diseases. Sustainable aquaculture seeks to assure a continued supply of aquaculture products within the ecological, economic and social limits, to realize a sustainable production in the long term. The other major challenge that could be expected in the coming years for this sector is to ensure the unavoidable intensification to produce more from the unit area without adversely impacting the environment. In general, aquaculture practice can generate environmental impact as a function of: applied technique, size of production, capacity of the receiving environment and site location. These include impact of soil and water quality, benthic layer, farming inputs, genetic pool and impact of non native species. Development of suitable technologies for environmentally balanced aquaculture will be the key challenge. Mitigation of environmental pollution through novel approaches such as microbial and nanotechnologies, practicing holistic methods like multi-trophic and organic aquaculture would be of greater help to the industry.

Diseases

As in the case of other rearing systems such as agriculture and animal husbandry, disease is the most significant challenge in the growth of brackishwater aquaculture sector. It is almost certain that disease will continue to impact the brackishwater aquaculture sector. In 1994, Indian shrimp farming witnessed the first outbreak of white spot disease in India, and since then the growth and sustainability of shrimp aquaculture has been severely impacted, due to the crop losses. In the absence of any proven therapeutics and prophylactic measures worldwide against the viral pathogen, control of WSSV still remains to be a challenge. The emerging and devastating new shrimp diseases, such as early mortality syndrome or acute hepatopancreatic necrosis syndorme (AHPNS) reported in the neighboring countries, is again a great concern to Indian shrimp farming, as it is well acknowledged that shrimp diseases eventually spread across the world in a brief period of time. Use of newer technologies for improving diagnostics and developing therapeutics, strengthening the quarantine and surveillance, improving BMPs on biosecurity and adoption of new farming practices such as crop rotation with alternate species would address this challenge. Development of specific pathogen free (SPF)/specific pathogen tolerant (SPT) seed is one of the effective tools in controlling infectious diseases that has been devastating the brackishwater aquaculture. Although SPF seeds are available for *P. vannamei*, there is no similar program to develop such seeds for native species of shrimp, *Penaeus indicus*. These programs need extensive investment over a span of 10-15 years. RGCA with NFDB has initiated a SPF program for *P. monodon*, and CIBA needs to initiate selective breeding programs for SPF and stock improvement using native species, partnering with stake holders, both institutional and private.

Food Safety and Tractability

Food safety concerns, especially the antibiotics, are increasing and the list of compounds that countries are screening have increased and additives that were conventionally added to feeds like antioxidants are also coming under the scanner. With the increasing consumer awareness and more and more of aquaculture becomes feed-based, this challenge and the transformation of aquaculture to a feed-based industry has to be met with better traceability, use of probiotics and developing better feed additives. Antimicrobial resistance is a matter of great concern across all the aquaculture nations, and the antibiotic residue in exported fish/shrimp is attributed to unregulated use of antibiotics in aquaculture rearing systems. There is no approved system for licensing aquaculture medicines (drugs, chemicals & biologicals) and prescribing them for use in aquaculture. Extensive date on the amounts and antibiotics groups used in brackishwater aquaculture need to be generated in order assess their interaction and impact with regard to the host, environment and consumer. The industry needs to have preparedness to produce for consumers with increased awareness about food safety and traceability, and conditions attached to markets and prices.

Feed

Formulated feed is the integral and vital input of aquaculture industry. For many farmed species, growth, survival and production largely depend on the quality and quantity of dietary nutrient inputs. Since 1995, aquafeed production has grown globally at an average rate of about 10.7%/year. Feed constitutes the highest operating cost during the production, and its characteristics and management distinctly affect the product, water quality and effluent. Any fluctuation in the cost of feed ingredients will significantly impact the cost of feed and ultimately on the cost of aquatic animal production. The production of formulated feed increased from 7.7 million mt in 1995 to over 35 million mt in 2010, and it is expected to reach around 70 million mt in 2020. In the context of limited availability of fish meal and fish oil, replacement of these in commercial aquaculture feeds with plant source proteins and vegetable oils is another potential area for researchers. “Fish in fish out” (FIFO) ratio need to be established for each category of aquatic animal production to monitor the quantum of wild fish usage in aquaculture. When global marketing is increasingly competitive and profit margins are shrinking, developing technologies to improve the utilization of feed which in turn reduce the cost will play a key role.

Aquaculture systems, their feed requirement and management must be considered together, supported by better understanding of biological aspects of the candidate species. Further, research efforts need to be directed towards biological and production systems that affect feeding behaviour, digestive physiology, nutrient dynamics, natural pond productivity and even the nutrigenomics, to achieve maximum animal growth coupled with a cost-effective feed management.

Certification

As the consumer awareness is increasing, demand for quality certification of the products will be greater than ever before. As with other food sectors, primary production (farming) and the energy consumption associated with activities such as acquiring raw materials, mode of transport, refrigeration, packaging and distribution etc. in the aquaculture supply chain will contribute to the sector's carbon footprint. Carbon labeling places lays more emphasis on greenhouse gases emission and issuing guidance and standards. Organic certification schemes through carbon labeling data ensure that responsible producers are able to benefit directly from potential price premiums associated with adopting mitigation and adaptation through low-carbon products. However, such a strategy demands a standardized approach to auditing carbon budgets across the sector and between production types and individual farms for the entire life cycle of the product. Additionally, HACCP and traceability of the aquaculture products will be mandatory and implementing these standards throughout the production system will be of great challenge.

Small-Scale Aquaculture

In India, more than 90% of the farms have small holdings with less than 2 ha. Research organizations need to develop technologies which are flexible for downscaling and upscaling based on the necessity. Real challenge will be to develop suitable package of practices which include culture of different species of organisms which synergistically enhance the overall farm production. Increasing the farmer's income through reducing cost of inputs, collection and use of market intelligence, economizing use of inputs like fuel by use of alternate/renewable energy sources and reducing cost of feed are some of the major challenges.

Mechanization

Like agriculture, labor shortage has started plaguing aquaculture. Precision farming in aquaculture aims to optimize field-level requirement and management with regard to farming practices, input requirement, environmental protection, saving labour and energy to derive maximum outputs. In view of the limited use of mechanization in aquaculture, labour saving interventions that are being developed like feed dispensers and mechanization for harvesting would need to be further scaled up.

Challenges vis-a-vis CIBA

The foremost challenge for CIBA, as a nodal Research Institute for brackishwater aquaculture, is to undertake studies on most pressing problems of the sector. The second challenge is on technology development. The large-scale trials for verification of technology need to be linked with 'scientists- farmers' interface being promoted by ICAR and forging more linkages with farmers associations and corporate sector farming initiatives. The third aspect of successful transfer of technology and Intellectual Property Rights (IPR) protection should be taken care adequately by 'Agrinnovate' effort of Business Planning and Development (BPD) units and more intense efforts on ICT use.

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Operating Environment

Aquaculture has been evolved through a combination of human observations and serendipity. Brackishwater aquaculture in India has been transformed from a fishery-based aquaculture, trapping of fishes/crustaceans and holding them until fished and marketed. This traditional pond-based fishery system has been evolved into a full-fledged mature agriculture/aquaculture system in late 80s. Although extensive production system of shrimp started as early as 1960s, the industry only really began to intensify in the early 1990s, after the successful demonstration of commercial tiger shrimp hatchery in Andhra Pradesh, with the setting up of the first commercial tiger shrimp hatchery in India, with the help of foreign technological support. These successful initiatives triggered the establishment of commercial hatcheries and shrimp farms in private sector, marking the golden period of tiger shrimp farming in India, till late 1994, when the industry collapsed due to widespread outbreak of viral disease (WSSV) and related crop failures. However, this development has not happened in the already existing traditional shrimp farming regions: Kerala, West Bengal, Karnataka and Goa. Interestingly, the modern shrimp aquaculture development largely centred in the areas where shrimp aquaculture did not have any prior history such as Andhra Pradesh and Tamil Nadu, which could be attributed to the entrepreneurship of the Andhra Pradesh and Tamil Nadu farmers, supported also by seasonal and geographical advantage of this region.

Brackishwater Resources

The brackishwater resources were delineated in late 1970s by conduct of micro survey. Indian coastal areas have nine states, two island territories with a coastline of 8118 km. It has 97 major estuaries with a total area of 3.9 million ha and backwaters of 3.5 million ha. The total mangrove area is 6740 km^2 and of these 57% of mangrove ecosystem are in the east coast and 23% are in the west coast, and 20% are in Andaman and Nicobar islands. Among the coastal brackishwater ecosystem, about 1.2 million ha has been identified as potentially suitable for brackishwater aquaculture whereas only 0.17 million ha (14.8%) were developed for shrimp or brackishwater aquaculture. West Bengal and Gujarat have the majority of the potential area for brackishwater aquaculture owing to the high tidal amplitude. Andhra Pradesh developed almost 57% of area available for shrimp culture whereas Maharashtra and Gujarat utilized only 1.2 to 0.6% of the available area. Due to vast changes that happened in the last four decades, the brackishwater resources need a reassessment throughout the country using Remote Sensing and Geographic Information System tools. This will enable the State government to frame suitable policies on the basis of master plan and release the coastal land being held by them to aquaculture, to both those small rural folks to have livelihood and to private sector to have an industrial path.

Brackishwater Aquaculture Area in India

State	Potential Brackishwater Area in ha (% of total area)	Area Developed (%)
West Bengal	4,05,000 (34.01)	50,405 (12.44)
Odisha	31,600 (2.65)	13,400 (2.65)
Andhra Pradesh	1,50,000 (12.60)	84,951 (56.63)
Tamil Nadu	56,000 (4.70)	6,104 (10.90)
Pondicherry	800 (0.07)	144 (16.00)
Kerala	65,000 (5.46)	14,875 (22.88)
Karnataka	8,000 (0.67)	1,945 (24.31)
Goa	18,500 (1.55)	340 (1.84)
Maharashtra	80,000 (6.72)	1,135 (1.42)
Gujarat	3,76,000 (31.57)	2,371 (0.63)
Total	11,90,900 (100)	175,670 (14.75)

Paradigm Shift in Species Farmed

Tiger shrimp *P. monodon* has been the mainstay of brackishwater aquaculture in India and other south east Asian countries. However, the aquaculture production of *P. monodon* has displayed a worrying downward trend in most of the countries including India during the early 2000. Much of decline in global production of *P. monodon* can be attributed to disease outbreaks. Further, other production-related problems such as slow growth syndrome impaired the industry seriously. This downward trend in the production is expected from an aquafarming system based on an undomesticated wild species. It is believed that the management strategies to keep up the production become insufficient, once it has reached the threshold limit.

A new blue print for shrimp farming industry is required to overcome the disease threat and resume the growth in production. This is largely based on the commercial-scale domestication of the species and development of specific-pathogen-free (SPF) shrimp stock with adoption of strict biosecurity protocols. Owing to the non-availability of SPF stock of native penaeids, non-native white legged shrimp, *P. vannamei* has been introduced in India during 2005-2009. In India, from 2010, a dramatic growth of farmed shrimp production due to the introduction of *P. vannamei* was recorded, with 90,000 MT in 2010 to 2,70,819 MT in 2013-14. Selectively bred superior aquaculture traits of *P. vannamei*, such as high survival rate, fast growth rate, tolerance to high stocking density, lower dietary requirements, more efficient utilization of plant protein in the formulated diet and stronger adaptability to low salinity, make this species the most preferred species for shrimp aquaculture. Also, the biological advantages such as column feeding habits and captive reproduction, contributed in the successful growth of *P. vannamei* farming.

Diversification of Farmed Species

It is well acknowledged that aquaculture industry can be ground breaking, if it is managed to commercialize a large number of new species. Many species of finfishes, crustaceans and molluscs are available and yet to be commercialized as aquaculture species. The finfishes such as Asian seabass (*Lates calcarifer*), grey mullets (*Mugil cephalus*), milkfish (*Chanos chanos*) and pearl spot (*Etroplus suratensis*) are important candidate species for brackishwater aquaculture. The production procedures for these species are under various stages of standardization and transfer of technology. Asian seabass is one of the most preferred species, and CIBA has successfully bred this species and hatchery production technology has been perfected, followed by farming. Nursery rearing technology for the production of fingerlings, and different production systems, in pond, cages etc. have been developed and demonstrated to farmers. Grey mullets (*Mugil cephalus*) and milk fish (*Chanos chanos*) form an important component in the traditional farming systems using wild seeds, and technology for polyculture has been demonstrated to small-scale farmers. However, closing the life cycle and development of hatchery technology, and formulated feeds etc. are imperative for the propagation of these brackishwater fishes. Also, farming of species with local preference such as *Etroplus* and *Hilsa* need to be promoted, by fine tuning the broodstock development, breeding, larval rearing and farming technologies. Mud crabs, species of *Scylla*, are one of the most sought-after sea food commodities in India. The technology for seed production, nursery rearing and grow out production have been standardized and are under various stages of technology transfer. What is required is the successful demonstration and popularisation of mud crab aquaculture to fit in different mode of sustainable brackishwater farming systems. Species such as *P. merguiensis*, *P. japonicus* and species of genus *Metapenaeus*, are valuable species for aquaculture in India. The hatchery production of these species are standardized and many experimental grow out culture trials have been conducted. These species have regional importance and have high market values, especially in the growing domestic markets. Strategies have to be developed for the popularization of these species. Farming of candidates oyster species such as *Crassostrea. madrasensis, C. cuculata*; mussels such as *Meritrix meritrix*; and sea weeds such as *Kappaphycus* sp, *Gracilaria* sp. is yet to be taken up.

Farmed Products Under WTO Regime

Awareness about fish as a health food is growing among the educated population. The domestic demand for fish is on the rise in terms of quantity and quality. The quality requirements of export markets have become more and more stringent in the last two decades. More liberal import and export policies are coming up allowing liberal import of inputs and outputs by the farmers. The World Trade Organization (WTO) regime, which treats fish as an industrially produced commodity, has made the shrimp production more competitive across the globe. Cost-effectiveness has become the mantra of the day in this global race. In sum, demand for fish and fishery commodities may change in quantum on positive side and Indian fish prices need to be kept competitive in comparison with international producers as per WTO norms.

Intellectual Property Rights and Regulations

New technologies that come with IPR protection may lead to more contract and corporate farming. The new IPR regime may lead to exclusive use of technology by farmers with resource endowments. In developed countries, aquaculture systems are well engineered and under the stringent federal regulations. The zonation of aquaculture production currently helps Thailand and Vietnam to control their production as per demand and keep up the price. Similar developments in India could lead to further marginalisation of small-scale farmers unless policy measures are put in place. To ensure participation of small scales-farmers, aquaculture development may need downscaled versions and tailor-made technologies for use by Self Help Groups and small and medium farmers with low resource endowments. More governmental support is required for these farms, with CIBA playing a facilitators role.

Linkages

Though large scale developmental efforts are beyond the capacity of CIBA, the Institute is poised to play a role in providing science supported policy advisory. In order to be more effective in this area and for fast phasing the technological incubation process, CIBA has to develop more working relationships with other leading aquaculture laboratories that may come up in coming decades under private Research and Development and existing and new units that may be created across the country from fisheries colleges, general universities, working under different wings of Ministries of Agriculture and Commerce.

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New Opportunities

India by virtue of 8118 km coastline is bestowed with large potential area of 1.2 million ha brackishwater, inland and coastal resources suitable for pond, cage and pen aqua farming, out of which only 12% is being developed at present. To face the stiff competition from other sectors, aquaculture needs a transformation from an energy consuming and non-environment friendly system to an energy-efficient and environment friendly system. Huge opportunity for expansion is available in the state of Odisha and West Bengal in the east coast and Gujarat, Maharashtra, Karnataka and Kerala in the west coast. In addition, the lands not suitable for agriculture out of 7 million ha inland saline areas in Punjab, Haryana and Rajasthan have the potential for brackishwater aquaculture. More inundated areas may also be available for culture in future due to sea level rise or tidal waves associated with extreme climatic events (for example: tsunami inundated areas in Andaman & Nicobar Islands).

Marketing

India has the opportunity to expand its culture area to increase its share in international market. Increasing the export share of shrimp will significantly improve the revenue generation from aquaculture trade. Changing consumer preference together with increasing income and purchasing power controls the demand and supply thus, regulating the growth of aquaculture sector. Opportunity will be to develop research and development programs according to changing population demographics. Over-dependence on international markets can lead to vulnerable economic trends in exporting countries. India is an emerging consumer market and, therefore, there is a great opportunity to develop programs to create awareness on utility of fish/shrimp as health food. Currently, USA, Europe and Japan are our main markets for shrimp, however, there is ample scope for developing domestic market. With the growing purchasing power of Indian middle class, it is possible to develop strong domestic market for brackishwater aquaculture products similar to terrestrial agricultural crops, milk and poultry products. Supply chain systems to collect farm produce and deliver to human consumption are in high demand. Development of domestic fish markets with these networks will be a great opportunity generating employment and business.

Diversification Aquaculture

Presently, only two species of shrimp and few species of finfishes are being cultivated in the country. Based on the preliminary studies, at least 10 species of shrimp, 8 species of finfish and 2 species of crab are found to have potential for commercial cultivation. There is a wide scope for diversification of species and to develop technologies for their economical culture. These potential species may be developed for monoculture or mixed cultures following the multilayer trophic ecosystem-based management practices. Enormous opportunity exists for the development of culture technologies suitable for different agro-climatic conditions of the country.

Breeding and Genetic Selection

Genetic improvements have made tremendous contributions to ensure the sustainable expansion of terrestrial agriculture and animal husbandry. Development of specific-pathogen-free founder stock is the prerequisite for any genetic improvement breeding program. Brackishwater aquaculture, with few exceptions, is based on the culture of unselected or semi-selected species. Further, role of SPF shrimp in management of disease has been well accepted worldwide. As presently only two species are being cultured, there is great opportunity for developing SPF broodstock and larval production systems for other potential species of brackishwater finfish and shellfishes. Recent developments in biotechnology and information technology have paved the way for deeper understanding of the molecular mechanisms involved in physiology, reproduction and diseases. Further, basic understanding in molecular mechanisms in physiology will help in technological interventions in reproductive biology and culture practices. Future opportunity will be to use these biotechnological tools in developing sensitive, easy and cost-effective techniques for designing effective breeding programs.

Ecosystem Management and Ecological Aquaculture

Maintaining the quality environment is very important as culture systems gets into intensification mode. Understanding of pond ecology & productivity, microbial dynamics and nutrient flow interaction helps in managing soil and water quality using safe, cost-effective methods like, probiotics, RAS, biofloc technologies that may be considered as great opportunity for increasing the production from unit area. Discharge water management in brackishwater aquaculture operations is always considered challenging from environmental sustainability point of view. Recent research has shown the effective utilization of shrimp pond discharge water for cultivation of halophytes which has a wider application in food and pharmaceutical industry. Among the vast marine resources, seaweeds are not utilized to its potential in brackishwater. These seaweeds can be grown as culture species, and also in discharge water treatment system as secondary aquaculture and have potential for developing wide range of pharma products for applications in human and animal medicine and agriculture. Similarly, aquaculture of bivalves integrating with shrimp and fish has great potential to maintain water quality at an optimum level, and further the produce has great potential in international market

Hazard Analysis and Critical Control Point (HACCP)

Quality consciousness in developing countries including India has prompted aquaculture systems to adopt HACCP concept at all levels of culture operations from broodstock rearing to human consumption. There is a great opportunity for developing policies and methodologies to meet the expectations of the society. Programs for traceability and monitoring farm inputs and culture practices need to be developed to produce and deliver quality food for human consumption.

Brackishwater Species for Hobbyist

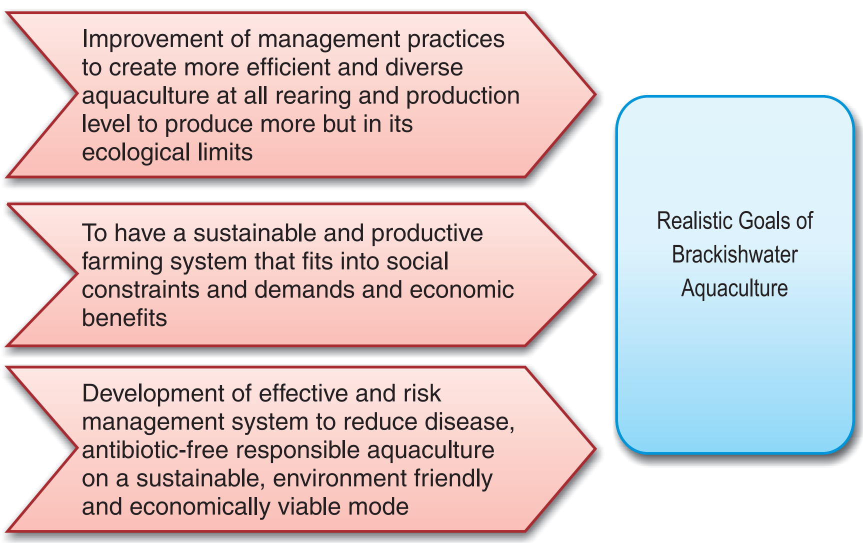
Over the years, aquatic animals are mainly exploited for food and little attention was given to other uses. There is a great potential for brackishwater/marine aquarium keeping, and ornamental industry has grown stronger and presently represents a multimillion dollar industry. Further, recent trends in sport fisheries have opened up new arena of aqua tourism. The existing natural extensive riverine and marine backwater systems in addition to the aquaculture systems can be utilised for development of sport fisheries. Indian species of aquatic animals having potential for this purpose may be selected and developed under specific programs.

Partnership and Linkage

Planning for expansion and diversification of species and culture systems need to be supported with appropriate amount of institutional support for research and development. There will be a great opportunity for research, academic, commercial and industrial organizations to contribute in terms of capital, technical knowhow and scientific knowledge. Programs with joint working groups will be able to develop newer technologies and help to achieve targeted productions. Several developed technologies addressing the needs of farming community need suitable scaling up before being put into practice. As research institutions lack such infrastructure facilities, there is an opportunity for partnership between scientists, farmers and the entrepreneurs such as public-public, public-private, public-civil society and NGOs/producer companies to develop the technologies. Working directly with 'farmers first' approach will help in 'technology development to adoption chain' and providing solutions to real field problems. Recent developments in information and communication technology (ICT) tools like M-extension (mobile-based extension), W-extension (web-based technology transfer) & Knowledge portals have the scope for transfer of newer technologies to effectively address the problems of farmers at a short period of time. ❑

Goals and Targets

Aquaculture has transcended many civilizations, although its evolution into the fastest growing food producing sector occurred only in the past few decades. The coming years will witness heightened expectations from the sector to play a larger role in fulfilling the food security of the growing populations. In an environment of multiple constraints, our commercial aquaculture sector will need to remodel itself to require lesser energy, water, land, manpower and nutrient inputs that inculcate higher operating standards and optimize overall fish production giving much deserved considerations to food safety and consumer preferences. Synergistically small aquaculture enterprises will need to be developed as effective tools for poverty alleviations, fighting nutritional insecurity and providing livelihood opportunities especially among the poor strata of rural populations through a process of economic intensification of the available system and technology downscaling for increased adoption.



CIBA's vision of increased brackishwater aquaculture production can be accomplished with well-planned and executable goals. These conceptualized goals will form the road-maps envisaged for aquaculture in 2050. Key factors of future aquaculture research will be basic and applied research activities on prioritized areas with adoption of new and emerging technologies. The research can focus mainly to achieve the following goals.

Mapping of the Potential Suitable Brackishwater Area

Exploration of new areas for aquaculture requires scientific mapping of the potential brackishwater areas available in the country. An interactive GIS-based remote sense mapping can identify potential sites in the country for aquaculture. Linking these reference maps to details of the geographical and physical features of the site with government legislations, carrying capacity estimation of the culture environments and water quality parameters can aid in better site-specific plans.

Diversification of Species by Introduction of New/Emerging Species

One of the primary objectives of the Institute is to augment aquaculture by exploring new/emerging species options, particularly high value species and species low in food web. Culturing species capable of utilizing the various niches in an environment with scientific based culture environment can augment production. CIBA should target to develop breeding and culture technologies for major candidate species in brackishwater. Strict policy regulations are to be enforced to eliminate the import risk factors associated with introduced species.

Development of SPF/SPR Stock of Indigenous Species

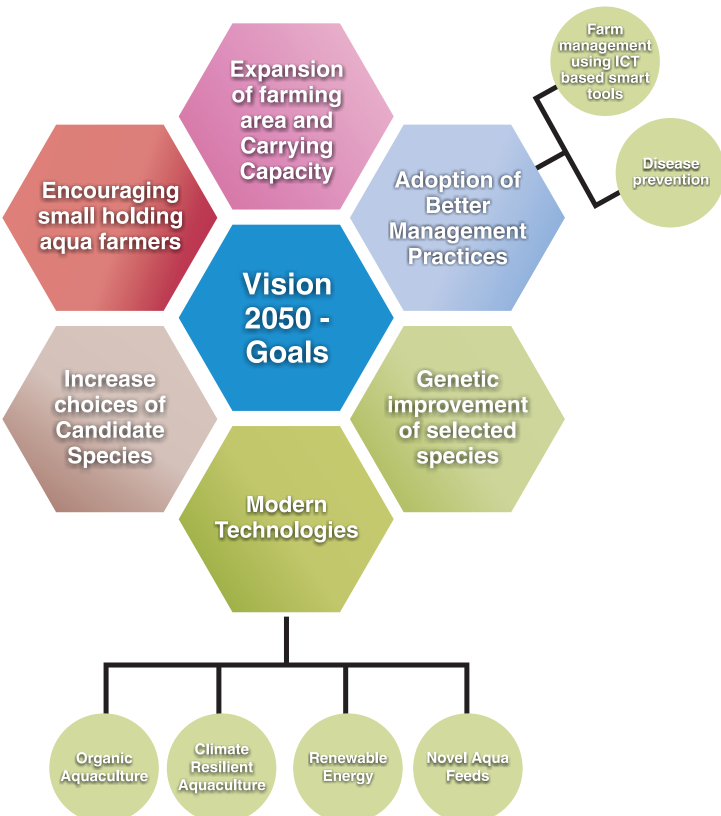
In addition, to the high value species introduced for aquaculture, development of indigenous species, especially those that occupy the lowest and middle tier in the food chain, has to be given equal priority for enhancement or restocking in natural environment. Efforts need to be made for genetic improvement, seed production and also commercialization of locally developed SPF and SPR stocks of indigenous penaeid shrimps species (*P. indicus, P. merguiensis, P. monodon*) which can be done in a public-private partnership (PPP) mode.

Biotechnological Approach to Prevent Disease

Attempts to minimize the outbreaks of disease, which negatively impact aquaculture productivity by adoption and stringent enforcement of Better Management Practices (BMPs) and aquaculture biosecurity measures are need of the hour to prevent entry and protection against exotic diseases. Use of novel biotechnological tools to design specific and sensitive tools for diagnostics, prophylactics and therapeutics for known and emerging diseases have to be developed.

Development of Novel Feed Technology

Feed, an integral part of aquaculture, accounting for about 50% of the operating cost. CIBA will continue its efforts to identify novel low-cost feed ingredients and development of nutritionally complete diets that support optimal performance and health of candidate species. Research should be carried out on alternate feed ingredients to fishmeal (microbial biomass such as fungal and micro algal biomass after biofuel extraction, bifloc biomass from aquaculture system), and judicious utilization of fishmeal rather than on complete replacement are to be evaluated.



Integration of Scientific Based Climate Resilient Technologies in Brackishwater Aquaculture

In addition to managing the traditional farming practices, CIBA should aim for the adoption of scientific based climate resilient technologies like polyculture, circular pond-based systems, race ways, near shore pens, floating cages, coastal long lines, re-circulating aquaculture system (RAS) etc in the culture sector. Customized Integrated Multi-trophic Aquaculture (IMTA) models also have to be popularized.

Utilization of ICT-Based Smart Tools for Farm Management

Development of ICT-based smart tools for farm management such as custom made sensors and integrated automated solutions for monitoring the water quality parameters (for example: pH, DO, salinity, ammonia etc) and control of pumps, valves, feeders, cameras, aerators are to be continued by CIBA which can improve the sector.

Organic Aquaculture

Organic aquaculture is a process of production of aquatic plants and animals with the use of only organic inputs in terms of seeds and supply of nutrients and management of disease following aquatic principles. Organic food has a separate niche market. Opportunities for organic aquaculture as economically viable form of management need to be explored.

Utilization of Non-conventional Renewable Energy

Energy crisis coupled with environmental degradation and impacts of global warming has created an urgent need for energy conservation efforts by utilization of non-conventional renewable energy in commercial aquaculture. India being in the humid tropics, efforts need to be oriented to harness the high levels of solar radiation as energy sources for aquaculture. In addition to being a cost effective technology, it can also reduce the carbon foot print. A proposal for a policy level decision to promote use of solar energy as a credential component of best aquaculture practices can be suggested by CIBA.

Enhancing the Skill Sets of Manpower Engaged in Brackishwater Aquaculture

CIBA should develop platform-based communication and information technology (ICT) for interaction with stakeholders in brackishwater aquaculture. This platform can act as an advisory system on farming systems, production, markets and export. Also to have extension system to organize dissemination seminars involving all levels of fisheries personnel and the private sector. CIBA can empower local small farm holders with adequate knowledge to ensure a healthier socio-economic status and prosperity by more women and family participation in aquaculture.

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Way Forward

"As aquaculture production expands, it is paramount that we avoid some of the mistakes made during the increased intensification of agriculture in the Green Revolution; understanding both environmental impacts and mitigation measures is important for designing responsible aquaculture production systems for tomorrow."….Diana et al. (2013)

Long-term sustainability of brackishwater aquaculture sector can be achieved with meticulous planning and effective management. We propose here a proactive approach to meet the herculean challenge of food supply demands of the projected 1.61 billion India's population by the year 2050, by way of contribution through increasing seafood production from brackishwater aquaculture sector, while ensuring ecological sustainability, coastal fisher societal development and meeting global trade regulations through public private partnership approach. The outlay by the Indian Government for fisheries research in total agricultural research has grown from 2% in the Fourth Five Year Plan (1969-74) to just about 4% in eleventh five year plan (2008-2012), which need to be substantially enhanced to achieve results. Technologies are the main drivers of growth. The over-riding consideration should be that the technology and investment target poor people for inclusive growth in providing benefits of aquaculture development. It is envisioned to increase brackishwater aquaculture production through increasing area under culture based on region-specific biotic carrying capacities; carrying out focused research on intensification and diversification of species using selectively bred high yielding disease tolerant/pathogen-free/resistant stock; increasing productivity through ecosystem-based aquaculture approach such as integrated multitrophic aquaculture (IMTA) and closed equilibrated biological aquatic system (CEBAS), harnessing innovative groundbreaking biotechnology tools while addressing environmental sustainability, and public health safety of seafood produce on "One

It is envisioned to increase brackishwater aquaculture production through increasing area under culture based on region specific biotic carrying capacities, carrying out focused research on intensification and diversification of species using selectively bred high yielding disease tolerant/pathogen free/ resistant stock.........

health" concept. International standards have to be followed to counter highly volatile and stringent, non-tariff barriers such as anti-dumping duty. The rapid rise in information and documentation requirements of safe handling, processing and traceability also have to be addressed. Government investment in coastal villages and towns in the form of infrastructure such as power and roads will have to be given thrust in order for these economies to grow and reduce unemployment and deprivation. Creation of a Coastal Communities Fund to help coastal towns and villages to provide training and employment opportunities for people. Globally, disruptive energy technologies such as unconventional oil and gas, solar technology, and both grid and off-grid and offshore renewable energy sources like wind, solar, and seaweed biofuels should be harnessed.

Utilization of Brackishwater Resources and Integrated Coastal Zone Management (ICZM)

Increasing aquaculture production could be substantially achieved if we could tap the available potential areas in an environmentally sustainable way. Reassessment of actually available resources requires to be examined on priority to plan and further develop aquaculture in utilising untapped inland saline and coastal brackishwater resources. An interactive GIS-based mapping linked to a database on details of the land geography, tidal pattern, soil and water quality characteristics would help in this endeavour to enable ecosystem approach to aquaculture (EAA). Such an expansion would be possible on a collaborative mode, led by CIBA partnering with State Governments, central laboratories such as ISRO and regulatory bodies such as Coastal Aquaculture Authority (CAA), aquaculture developmental authorities such as MPEDA-RGCA. Policy guidelines have to be developed for leasing of brackishwater bodies to increase the farming area. Revenue classifications of land and regulatory limitations for regularising new areas have to be reviewed. Integration of brackishwater aquaculture into integrated coastal zone management (ICZM) plans and remedial measures to revitalisation of abandoned brackishwater aquaculture farms due to disease-linked crop losses have to be addressed.

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Responsible Aquaculture Development

Although the central focus would be on brackishwater aquaculture development to increase production, earn foreign exchange, create employment and generate livelihood, the predominantly small-scale holding nature of aquaculturists and traditional nature of production are challenges to planners and managers. Effective regulation of aquaculture activity by these small holding farmers would hold key for the overall brackishwater aquaculture development. A paradigm shift from production-driven planning strategies towards more responsible aquaculture development with assured income would ensure sustainable production systems. Compliance with international agreements and national regulatory frameworks, trade and market forces, concerns of civil society, food safety issues and emerging issues such as climate change and emerging diseases. This would pave way in the effective use of various aquaculture planning and management tools (APMT). APMTs broadly include methods, guidelines and processes used for planning, development, management and decision-making such as tools for assessing risks in aquaculture (e.g. pathogen risk analysis, food safety risks, genetic and ecological risks); international trade (e.g. import risk analysis or IRA); impacts (e.g. environmental impact assessment or EIA); governance (e.g. codes of practice); management (e.g. better management practices or BMPs, good aquaculture practices or GAPs, certification); and socio-economic assessments. The aquaculture activity in the country should periodically evaluate the status of the use of APMTs, and this would help in revising planning and management for sustainability.

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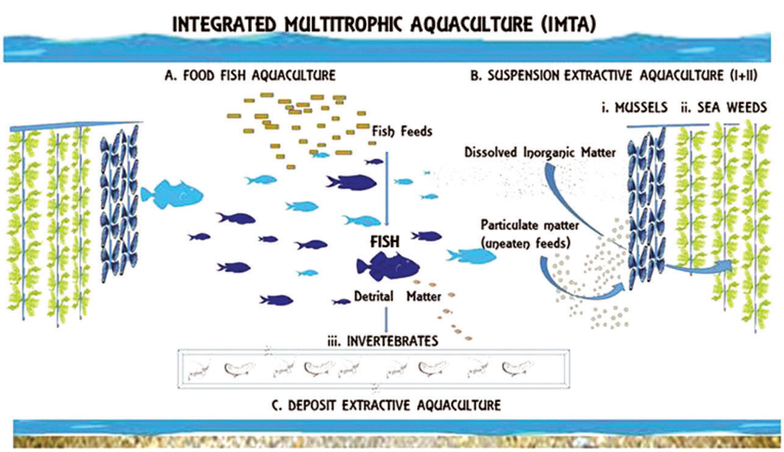
Ecosystem Approach in Brackishwater Aquaculture (EABA)

This is a strategy for the integration of the aquaculture activities within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems. Promoting EABA requires its inclusion in the aquaculture development policies. Implementing the EABA will also require strengthening institutions and associated management systems to facilitate integrated aquaculture development.

Both land-based and near-shore aquaculture systems which combine “fed aquaculture” species such as finfish, with “inorganic extractive aquaculture species" such as seaweeds and "organic extractive species" (or suspension/deposit-feeders) such as bivalves cultivated in proximity, collectively described as integrated multitrophic aquaculture (IMTA), is expected to increase significantly the sustainability of aquaculture. This type of biomitigative system optimise economic, societal and environmental benefits, including the recycling of waste from higher trophic-level species into production of lower trophic-level species of commercial value (Troell et al, 2009). Such new sustainable culture systems need to be initiated and would require enhanced capital and collaboration among research, state Government and seafood production promoting agencies.

The closed equilibrated biological aquatic system is an artificial aquatic ecosystem which consists of four subcomponents: an aquatic animal habitat, an aquatic plant bioreactor, ammonia oxidizing bacteria filter and a data acquisition/control unit. It is a precursor for different types of teleost fish and aquatic plant production sites (Bluem and Paris, 2002). Although this is primarily an experimental model in space for basic zoological, botanical and interdisciplinary research, it opens the theoretical possibility to adapt it for combined production of animal and plant biomass on ground or in space. Similar systems could be developed, which can efficiently provide disease-free aquaculture ecosystems, with a risk-free production on desired locations and enabling markets.

This kind of land-based, next-generation closed-loop recirculating aquaculture systems offer a unique combination of conservation goals, socioeconomic benefits, and potential for scalability. Such technology could lead the way toward a revolutionary transition of fish production



leading to the large-scale "domestication" of fish. Land-based recirculating systems recycle 97-99% of their water and create virtually no discharge (including nutrients, chemicals) to natural water bodies, either marine or freshwater. As a closed system allowing no contact with natural populations, coupled with strict protocols for disease detection, prevention and control, there is virtually no risk of introducing disease to the natural environment from closed-loop recirculating systems.

Species Diversification and Selective Breeding Programs

In order to sustain and improve aquaculture productions while devastating diseases such as white spot disease persist, there is an urgent need for India to invest in genetic improvement program to develop specific-pathogen-free (SPF), specific-pathogen-resistant (SPR) or specific pathogen tolerant (SPT) stocks of native candidate aquaculture species. With an average genetic gain in growth rate of 12.5% per generation, production can be dramatically increased if genetically improved animals are used. Selectively bred animals for faster growth have also been shown to have improved feed conversion and higher survival (Gjedrem et al, 2012). National brood bank facilities for high value finfishes such as seabass, cobia, milk fish, and mullets and broodstock multiplication centres for demand-driven cultivable shrimp species such as tiger shrimp and Indian white shrimp for consistent supply of high quality SPF/SPR/SPT brood stock would aid in the diversification of Indian brackishwater aquaculture, instead of relying entirely on exotics species. Currently, most of India's brackishwater aquaculture depends on only one imported species, and the native species have been relegated because of the international market pressure. Hence research on closing the life cycles of native candidate aquaculture species under captive conditions with required infrastructure in place hold the key. Additionally, to be successful in these programs, research on aquatic animal genomics and bioinformatics should be pursued vigorously to augment the breeding programs. CIBA can take lead in such programs while the funding and infrastructure could come through public-private partnership.

The key approach on the way forward to realize the vision 2050 would he building strategic partnerships and alliances with public and private institutions within India and abroad. Recently, CIBA signed an MOU with a private entrepreneur for developing breeding technology for milkfish, which was unrealized thus far due to limited hatchery facilities available with the Institute. Similar collaborations would be encouraged for development of breeding/farming technologies for climate/zone specific native fin fishes and shellfishes.

Commercial exploitations of other ornamental shrimps and crabs (*Stenorhynchus seticornis*), the yellow line arrow crab, and family of Lysmata, Saron (eg. marble shrimp) and Thor, (*Hymenocera picta*) could be explored. Additionally, a number of short-term research on various applied aspects such as intensification of nursery rearing and raceway technologies with biofloc and biofilm technology have to be standardized. Microbial dynamics need to be understood in detail in order to track pathogens, maintain biosecurity and optimum environmental quality using NGS and metagenomics tools. Indigenous specialised live feed-based products of copepods, cladocerans, brine shrimps such as packaged starter cultures, concentrated dried or freeze-dried products, frozen cubes etc., micro algal biomass, biofloc biomass from aquaculture system, finisher diets or technologies which help to enhance the value of the produce with nutritionally rich substances such as poly-unsaturated fatty acids (PUFA), are researchable issues with direct application in the aquafarming. In regions wherever possibilities exist, traditional farming systems should be encouraged to transform into organic farming to further the cause of sustainable brackishwater aquaculture.

Surveillance Programme on Disease Monitorig and Reporting

As the disease management is a difficult proposition in aquaculture, the best option available is to have two prone approach for prevention and protection against the existing and emerging pathogens. Better management practices (BMPs) and regulatory framework in the movement of aquatic animals across the farming areas in par with international standards are required. Timely response and targeted actions are important in the assessment of threat and follow up contingency plans. A good surveillance program, using novel diagnostics in place can identify the pathogen and prevent the emergence and spread of the diseases. 'National Surveillance Program for Aquatic Animal Disease' initiated through a network of fisheries research institutions active in aquatic animal health research with NBFGR and NFDB is a way forward in the aquaculture disease monitoring in India.

Designer Seafood Using Tissue Engineering/Stem Cells

> *"We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium". Winston Churchill, Fifty Years Hence, The Strand Magazine (December 1931).*

This adage, almost a century back indicates that the possibility of growing meat on an industrial-scale has been imagined long ago. *In vitro* meat, also called cultured meat, or test-tube meat, is an animal-flesh product that has never been part of a living animal. *In vitro* cultivation of stem cells from animals has been possible since the 1990s, including the production of small quantities of tissue which could, in principle be cooked and eaten. *In vitro* muscle protein production system (MPPS) for the fabrication of surrogate muscle protein constructs as food products was produced using adult dorsal abdominal skeletal muscle mass of gold fish for the space travelers in 2002 (Benjaminson, et al 2002). NASA has produced *in vitro* meat from turkey cells. The first *in vitro* beef burger, created by a Dutch team, was eaten at a demonstration in London in August 2013. This has shown the way to an innovative, viable means for the production of healthy, nutritious food to alleviate food supply and safety problems in both the public and private sectors worldwide. Such innovative R & D needs to be adopted to enhance seafood production that has defined qualities of taste, texture, flavor etc., in a system independent of ecosystem without any issue of environmental degradation and pollution.

New Science to Grow Healthy Fish

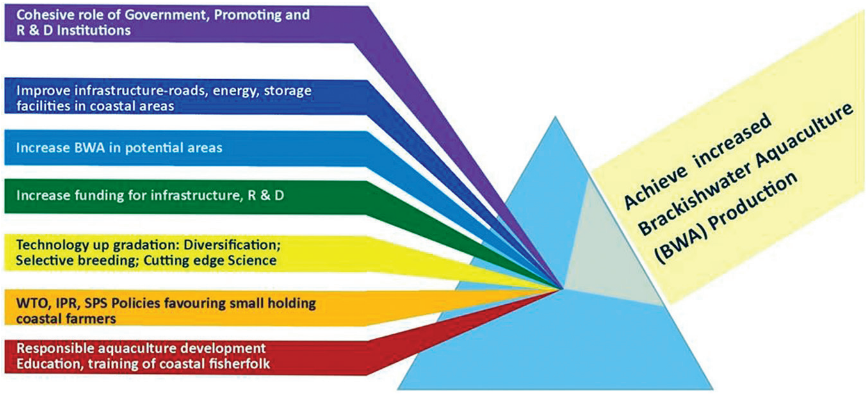
With the continuous expansion of aquaculture industry, a worldwide requirement for a reduction of full-dependence from natural fish meals and fish oil, dominates. Dietary nutraceuticals for improving the health of brackishwater species and substances such as pheromone which can be directly applied in water to induce maturation and spawning may have to be explored. A strong need for nutrigenomics approach is emerging for examining the biochemical physiology of fish growth with the aid of transcriptomics. Genes that are related with metabolism of proteins, energy metabolism, apoptosis and immunogenic functionality, protein synthesis, stress and digestion of proteins are subjects to be thoroughly evaluated. These studies would unravel the biochemical, molecular and metabolic response to nutritional interventions and help in optimization of feed formulations. A variety of novel nucleic acid-based molecular and immunodiagnostics such as loop-mediated isothermal amplification (LAMP) are currently in use in health sciences and also in aquaculture, and would continue to play an important role in pathogen exclusion from aquaculture systems. However, newer versions of diagnostics have to be developed that make these tools farmer/field friendly. Multiplex tests to simultaneously detect a number of pathogens such as the bead array and microarray have huge potential. Nanotechnology is also being used in conjunction with proteomics and would help to identify markers of disease and vaccine antigens. Immunoproteomics, also known as 'reverse vaccinology' and has great potential in containing mortality problems in aquaculture. Additionally, research thrust needs to be given for development of sensor-based diagnostics that would cater to automated aquaculture systems. New vaccine delivery tools for nucleic acid vaccines such as nanoparticles or use of bacteriophages have to be harnessed. Use of new approaches such as virotherapy, which uses viruses to treat infections would be highly useful in the treatment of parasitic diseases in finfish. Bacteriophage therapies are already under development and proved useful in the prophylaxis and therapy of bacterial infections in aquaculture. Bioactive compounds from sea could be explored to find novel molecules to treat diseases.

Automation and Energy

By 2050, one would envision considerable mechanization and automation of brackishwater aquaculture system with regard to feeding, vaccination, harvesting etc., and sensors for online monitoring of water quality parameters, pathogens, pollutants, toxins, etc., and also for taking up mitigatory measures. Use of sensors and radio frequency identification (RFID) tags and other tracking technologies have to be incorporated wherever needed. Life cycle assessment of aquaculture supply chain (hatchery and production systems, transportation, refrigeration etc.) to identify the hotspots responsible for global warming and develop measures to decrease the energy use and mitigate the emission of greenhouse gases (GHGs) should be continuous inbuilt process of aquaculture activity. Aquaculture activity should primarily focus on the use of renewable energy including solar, wind and wave energies to bring down carbon emission to zero levels.

Empowerment of Coastal People and Betterment of Their Livelihood

Despite the phenomenal success of the brackishwater aquaculture sector, concerns for the economic conditions of coastal people still need to be enhanced in the context of rising environmental concerns, the new economic order following establishment of World Trade Organization (WTO), intellectual property regime (IPR) and sanitary and phyto-sanitary (SPS) issues, compliance of several multilateral agreements. By 2050, livelihood of coastal people would have to be transformed and equivalent to modern city standards. This transformation would be possible through empowerment of coastal people by educating them and sustained capacity building program and associated development to restructure aqua farms with improved road connectivity and also by developing aquatourism such as sport fishing of cobia or similar species for game fishing. Developing live fish marketing in conjunction



with aquatourism supported by aesthetic live fish transportation and holding facilities would help farmers to fetch higher value for their produce. Provision of aqua silviculture livelihood projects to fisher folks will not only help in restoration of mangroves but also further the cause of sustainability. Facilitating the up-scaling of farmer groups as producer companies would help in minimizing operational costs and accessing premium markets. These goals could be achieved through strong linkages with State Government departments, NGOs, finance and market institutions. Public-private partnership approaches in on-farm research and extension outreach, capacity strengthening of fishery extension personnel and farmers through innovative extension methods such as ICT tools for instant information exchange.

Domestic market, which is a sleeping giant generally relies on low-value fishes. Additionally, a large section of middle and high-income people's need of high-value fish products requires to be taken care. Innovations in product diversification, venturing into the preparation of ready-to-eat food and networking with fast food centres, would strengthen the emerging domestic markets, leading to higher demand for aquaculture products, giving new growth trajectories to brackishwater farming.

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NOTES

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