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Vision 2050

Central Institute of Fisheries Education

Indian Council of Agricultural Research

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

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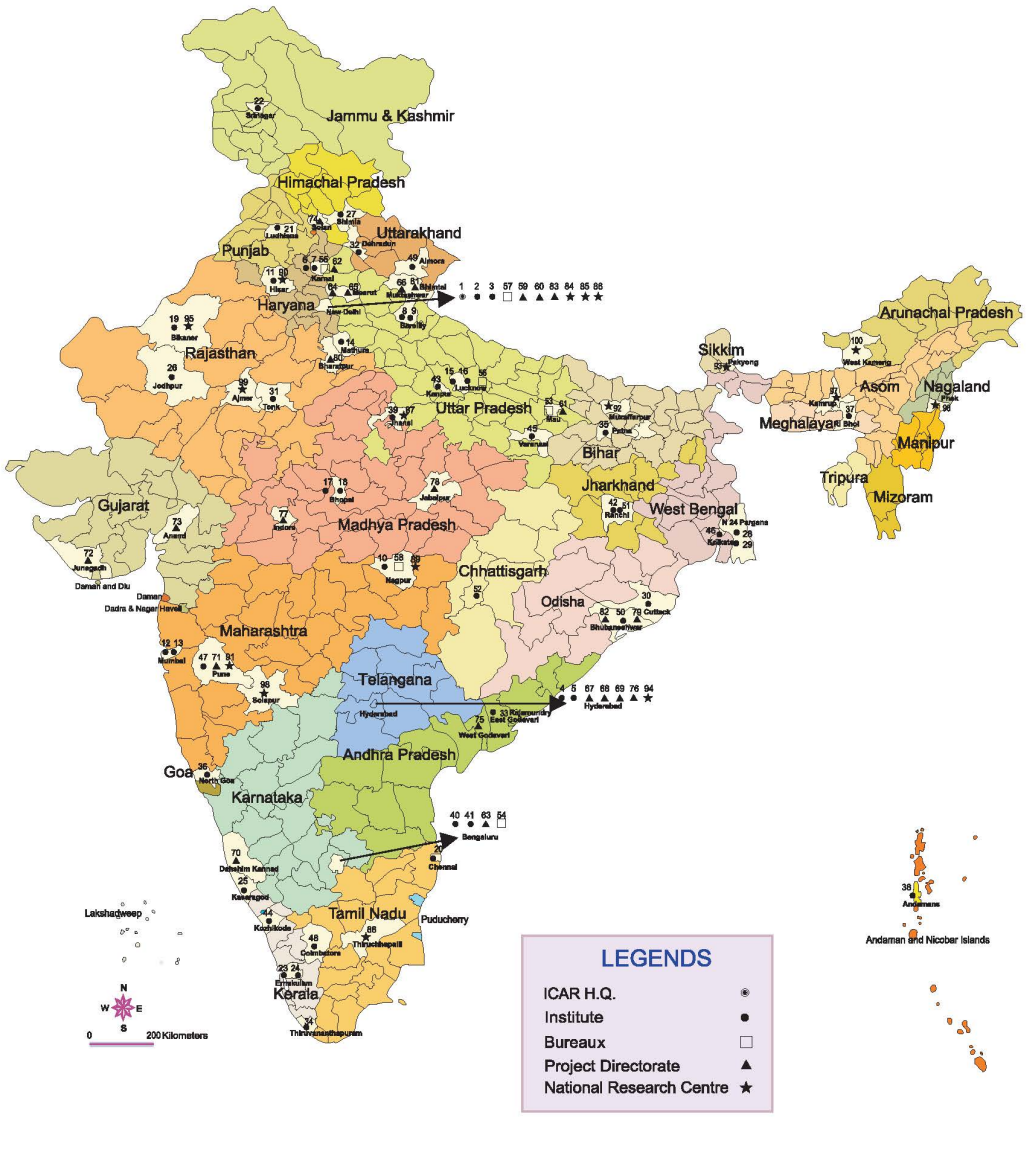

LEGENDS

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- Bureaux
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Vision 2050

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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 programmes 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 Fisheries Education (CIFE), Mumbai 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)
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and Director-General, Indian Council of Agricultural Research (ICAR)
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Preface

The Central Institute of Fisheries Education has emerged as a premier organization for fisheries research education in Asia and the African region. Since its establishment in 1961 and recognition as a Deemed University in 1989, the Institute has been playing a pivotal role in the development of qualified and trained human resources incorporating various new dimensions into its academic curricula to suit the needs of the stakeholders. In recent years, several new courses have been initiated with emphasis on specializations in basic and emerging areas of fisheries science.

The major research focus of the institute broadly relates to diversification in aquaculture including development of new strains, developing technologies in which salt-affected unproductive lands can be transformed into productive aqua farms, management of aquatic resources and biodiversity, climate change, post-harvest and value addition, newer aquafeed resources, increased emphasis on biotechnology and nano-technology, fish vaccines and ecosystem and extension services. With the upcoming state-of-the art infrastructure and modern laboratory facilities, the institute is marching ahead to become a global player and a Centre of Excellence in higher fisheries education and research.

Keeping in view the challenges and opportunities in fisheries education and research, CIFE has prepared a perspective plan as Vision 2050 highlighting vision, mission, achievements and future scenario along with a road-map encompassing the proposed strategies, action plans and activities to realize the goals and mandate of the institute. The document incorporates various innovations integrating ICT into academic programmes, networking and outreaching through multi-institutional and multidisciplinary approaches to produce quality human resources in the fisheries arena for coming years. While laying the path, efforts have been made to balance both the global development and standards.

I express my sincere gratitude to Dr. S. Ayyappan, Secretary, DARE & Director General, ICAR for his foresight and continuous guidance in bringing out this Vision 2050 document and support in its realization. My thanks are due to all my colleagues at the Institute for their valuable inputs

namely, Dr. K.V. Rajendran, Dr. A.K. Pal, Dr. N.P. Sahu, Dr. N.K. Chadha and Dr. P.S. Ananthan in the preparation of this document.

W. S. Lakra
Director,
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Context

Global population is expected to reach 9.6 billion by 2050, an estimated increase of more than 2.0 billion from the present stage. Though meeting the food demand of the growing population is a challenge, the steady growth in global fish production is a silver lining, as the average annual growth rate of fish production (3.2%) has outpaced the population growth (1.6%). However, on the other hand, world per capita consumption has been registering an increase from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 (FAO, 2014). And, globally fish continues to be the most-traded food commodities. Besides being a source of health as well as wealth, fisheries and aquaculture provides jobs and livelihood to millions and the employment in the sector has shown tremendous growth surpassing the world's population growth.

Situation in India is not different from the world scenario. The country will be the most populous in the world, with 1.69 billion people, by the year 2050. At the same time, the economy will continue to grow and per capita income will increase many fold resulting in a significant increase in the per capita consumption of fish. As the second largest producer of fish in the world, fisheries sector contributes about 1 percent to the overall GDP and 4.6% of the agricultural GDP. However, as the production from marine capture sources has almost reached its peak, greater emphasis will be placed on aquaculture to meet the growing demand. Globally, the share of aquaculture is projected to rise to 62% of the total fish production by 2030. The demand on aquaculture will not only be on the quantity but also on the quality, safety and diversity of the fish produced. This can be achieved through expansion, intensification and by improving the resource-use efficiency with greater emphasis on minimising the environmental impacts. Further, as in any other branch of agricultural sciences, demand-driven technology will be the key to the future growth of fisheries. Nevertheless, looking beyond food production, searching below the sea will be an opportunity the country needs to harness.

Highly specialised quality human resources will be one of the central engines which drive the research and development essential to enable fisheries and aquaculture to meet the future demands. Globally, fisheries and aquaculture research and education has moved ahead at a rapid pace in response to the diversity and increasing specialisations. Central

Institute of Fisheries Education also witnessed a dramatic transformation from a training institute to a centre of excellence producing specialized human resources, engaging in basic, strategic and applied research and providing policy support to fisheries development. However, a critical evaluation of the specialized courses in terms of the present and perceived impact and relevance to the sector, assessment of needs and the required skills, foreseeing the future complexity and developing a strategy/policy for designing comprehensive fisheries and aquaculture education and training programmes including faculty capacity building is essential. Further, to remain competitive, stakeholder-compliant and viable, the research and educational institutions need to engage all the key players, industry in particular, operating in the sector.

In Europe, rapid diversification of the industry mostly driven by technological development calls for highly skilled and specialized human resources. The industry expects the trained workforce to be more flexible and mobile and to comply with the labour market requirements, the qualification need to be more flexible, both in content and form (Dhont, 2008). Similar trend is becoming a reality in the Indian aquaculture sector, as it is moving from the traditional system to a more mechanized, intensive and sophisticated production and process systems where it replaces generalists with specialists. Besides the core skills, the sector also requires human assets to support developmental and regulatory processes and entrepreneurship capacity. Under this premise, the long-term objectives of the institute are:

- To develop critical mass of human resources with specialized skills in diverse areas to meet the growing demands of the sector.
- To engage in research that appreciates and absorbs the knowledge- and information-intensive advancements to ensure long-term sustainability of the sector and to maintain environmental integrity.
- To integrate the research and development advancements in the academic programmes to make it relevant and competitive.

Central Institute of Fisheries Education has been in the forefront of providing demand-driven and need-based educational and training programmes for human resource development and capacity building. CIFE is engaged in the basic and applied research in frontier areas of fisheries science and has generated and disseminated several technologies for field use successfully. Important technologies in the field include: utilization of inland saline soils for shrimp (*Litopeneaus vannamei* and *Penaeus monodon)* production; hatchery seed production of scampi using inland saline water, and artificial sea water; cage culture and pen culture in open water system; standardization of protocols for indigenous

ornamental fish; natural breeding of *Clarias batrachus*; Carp hatchery models D-80 & D-85; organic aquaculture through biofertilizers; anti-stress formulation for fish seed transport and value-added, ready-to-eat fish products.

CIFE, in collaboration with NFDB and various state fisheries departments, is conducting a number of training programmes for fish farmers at various locations including its centers. The Institute has conducted several training programmes for women and has helped them to organize the cooperative societies for manufacturing and marketing the fish products. CIFE has been playing a significant role in developing aquaculture specially the high-value freshwater prawn culture in the North Eastern States of Assam, Tripura, Mizoram and Manipur by setting up hatcheries using artificial seawater. The institute has initiated several programmes in collaboration with departments of fisheries of different states for capacity building of extension personnel and other stakeholders in the areas of participatory and cost-effective extension services and fisheries co-management. The cage culture programmes undertaken by CIFE for developing fingerlings to stock the reservoirs has tremendously improved the production of reservoirs specially the Dimbhe reservoir in Maharashtra. The innovative programmes on saline aquaculture taken up at CIFE Rohtak Centre has demonstrated the possibility for productive utilization of salt-affected inland areas. Attempts are being made to transfer the technology in inland salt-affected areas in Haryana, Maharashtra and other States which are not suitable for agriculture. As a part of the intensive research and development efforts, two flagship programmes: (1) Inland saline aquaculture: Diversification and technology demonstration; (2) Ornamental fish resources: Utilization and conservation with a focus on NEH region are underway at the institute.

In this context, the Vision 2050 is a continued effort to visualise the future against the perceived challenges and potential opportunities after a critical assessment of our present capabilities and relevance. As any sectoral development plan must go hand-in hand with the human resources development programmes, the quality of fisheries education will be the deciding factor in making fisheries and aquaculture sector competitive, acceptable, viable and sustainable. In this direction, this document provides a roadmap for fisheries education and research in the country.

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Challenges

Fish contributes ~17% of global animal-based protein supply. However, demand and consumption pattern of fish in future will be driven by factors such as population and income growth, demographic shift towards urbanization and dietary diversification. Another factor driving the demand for fish will be the increased awareness about the nutritional quality of fish. According to the United Nation, by 2020, an additional 657 million people will be urbanized to the existing 3.6 billion (52.1%) people living in urban areas. The increased urbanization would result in fewer people available to produce more protein food to meet this demand. To meet the projected demand, a study estimates that aquaculture production will need to be doubled from its current level (67 million tonnes in 2102 to ~140 million tonnes in 2050). The scenario will not be different in India. By 2050, increasing population (by ~37%), accelerated economic growth and increased per capita income (~8 times of the present level) will contribute to increased domestic fish demand. Currently, the country's fish production stands at 9.58 million tonnes with an average annual growth of 5.96% (2013-14) and contributes 0.83% of national GDP and 4.75% of agriculture GDP (The Handbook on Fisheries Statistics, 2014). This translates to ~11-fold increase in production in just six decades.

Although the growing significance of aquaculture is undeniable, the concerns about its environmental and social impacts are also critical. It is estimated that directly and indirectly, together, aquaculture already occupies 1% of global agricultural land and consumes approximately 2 percent of global agricultural water (Waite et al., 2014). Therefore, another significant constraint to the sector will be resources scarcity which could result in competition over scarce inputs leading to conflict with other sectors and users. The situation would further aggravate due to the global climate change. This would lead to the greatest challenge to the sector to produce more from less, and this will be extremely relevant to especially Asian countries.

Quality human capital will be one of the engines which drives aquaculture forward in a sustainable way. FAO estimates show that aquaculture provided ~19 million on-farm jobs in 2012 and 96% of which were in Asia. The projected growth in fish production will boost the employment opportunity, not only in the primary sector

but also in the secondary sectors like processing and marketing etc. In India, though the sector has witnessed spectacular growth during the last few decades and attained a status of an industry, a comprehensive database on human capital in aquaculture and allied sectors is lacking. It has been reported that the lack of database is due to the dispersed nature of resources and non-availability of a suitable mechanism for data collection. A report by Rao et al., 2011 has projected the demand supply scenario of human resources in fisheries sector in 2020 (Supply: 6,705; Demand: 31,215 Gap: 24,510 (78.5 per cent of the demand) based on the assumed growth rate of outturn levels of 2.6% during 2006-10. Therefore, one of the challenges to the organization responsible for human resources development is to carry out a realistic need-assessment, develop futuristic need-based curricula and design appropriate skill development programmes. CIFE, as an organization involved in higher fisheries and aquaculture education, will also face enormous challenges in the future to remain relevant as the flagship institution in the country which can play a significant role in the region, if not at the global level.

Maintaining Leadership in Fisheries Education

The anticipated issues in academic programmes would be industry-led fisheries education, developing e-courses for fisheries professionals, modifications in infrastructure, distance education and virtual classrooms, innovative teaching/learning tools, novel assessment systems, etc. The widening of gap between educational institutions and the industry needs would be another great concern in the coming decades. Enhanced efforts are required to provide hands-on experience, skill development and student exchange programmes to make them "Student Ready". Attracting and retaining talented students in fisheries profession would be another challenge in modern vibrant economies dominated by IT and service sectors. According to estimates, post-secondary enrollment rate of age 18-23 years in India is only 18%, compared to 41% in USA. Further, lack of students' interest to pursue fisheries higher education is a clear sign to call for re-assessment of the academic programmes and re-designing strategies for strengthening as well as enlarging the scope of existing programmes. Vertical (in terms of different levels of programmes) as well as horizontal (new fields i.e. fish behaviour, ocean and atmosphere science, marine engineering) spread of fisheries higher education would provide both opportunities and challenges simultaneously. Developing competent human resources in such scenario, who can effectively address the challenges faced by Indian fisheries sector,

while remaining a leader in fisheries education, would be the task cut out for CIFE in coming years.

Further, developing core faculty strength in diversified areas of specialization will be an immediate task for the institute to achieve the long-term objectives. Improving the quality at the undergraduate level by undertaking vigorous faculty improvement programmes for the fisheries colleges of the country will be a priority area for CIFE. Setting harmonized standards to the fisheries education through proactive involvement in every step of conceptualization to implementation of academic and training programmes is another challenge for the organization.

As academic programmes cannot stand alone without the constant enrichment of advanced knowledge emanating from research and development programmes, knowledge development through education and research will be a continuous process. Further, it is also imperative that the institute identifies broad areas of challenge that impact the sustainability of the sector. These include the following:

- Produce more fish with minimum reliance on inputs and minimum impact on environment.
- Aquaculture productivity verses environmental sustainability.
- Improving quality and safety of fish and developing efficient ways to reduce waste.
- Effective implementation of regulatory measure with minimum regulatory burden on small farmers.

Water Scarcity and Deterioration of its Quality

In 2010, aquaculture consumed an estimated 201 cubic kilometers (km3) of freshwater, equal to approximately 2 percent of global agricultural water consumption (Waite et al., 2014). Water has become scarce in the recent years due to irregular monsoon pattern and climate change. In addition to these factors, aquatic pollution is deteriorating the available water resources and making unfit for use in various economic activities such as for human consumption, aquaculture, etc. By 2050, water scarcity will be one of the major concerns for fisheries development. Hence, enhancing the productivity and production by using minimum water would be a great challenge. Further, it is necessary that the required skilled manpower to take the developed technologies further for fisheries and aquaculture development.

Ensuring Quality and Safety of Fish Products

Quality and safety of fish products are of concern throughout the

harvest, handling, processing, distribution and marketing supply chain. Factors which contribute to potential hazards in foods include improper fishing practices; poor hygiene at all stages of the supply chain; lack of preventive controls in fish processing and preparation operations; misuse of chemicals; contaminated raw materials, ingredients and water; inadequate or improper storage, etc. In this background, the most important challenge is to develop hygienic fish product with efficient surveillance of food-borne illnesses and food product traceability.

Climate Change and its Impact

Climate change could affect all aquaculture production systems through many fold effects such as availability of resources, extreme weather patterns, changes in physical and chemical changes in water which can lead to serious impact on water quality and productivity. Climate change also poses a new challenge to the sustainability of fisheries and aquaculture system by modifying fish distribution and productivity of marine and freshwater species. As a result, the distribution, productivity, and species composition is changing which generates complex and inter-related impacts on inland and marine ecosystem as well as the fragile ecosystems like estuaries, coral reefs, mangroves and sea grass beds that provide habitats and nursery areas for fish. Develop effective strategies to minimize the impact of climate change and to harness the potential production opportunities which will be opening up in certain areas should be a priority.

Aquatic Animal Health Issues

As international trade of aquatic animals and their products increase, aquaculture practices get further intensified and diversified and new exotic species introduced, problems associated with animal pathogens and diseases will also get expanded and intensified. This along with the expansion of the geographical range of diseases and change in virulence of pathogens due to changing climate is going to be a reality and great challenge. To deal with this, new disease management measures and advanced and highly sensitive pathogen detection techniques as well as better tools for understanding of the cultured animals need to be evolved. Though disease impact in 2030, through simulation of shrimp diseases, showed the ability to recover, socio-economic impacts at the national and local levels will be considerable (FAO, 2014). This impact will be more pronounced if the affected fish has direct human consumption and food security value. In this scenario, effective implementation of biosecurity measures to minimize the disease occurrence will be a serious challenge.

Aquatic Environment and Ecosystem Sustainability

Aquatic ecosystems are facing the problem of over-exploitation and non-sustainability, pollution and bio-invasion. These problems need to be managed through a holistic approach. Every stakeholder shall be made aware of the problems faced by the aquatic ecosystems as also the measures to be undertaken to sustain on a long-term. Ecosystem-specific approaches to attain sustainability by focusing on innovative and efficient green technologies in the areas of resource utilization and recycling of used resources, minimization of generation of wastes and management of pollution are needed. There were many attempts to develop green technologies for cleaner environment and healthy ecosystem, but they have not seen the light in the field due to the issue of feasibility. The challenge for the institute is to develop feasible eco-friendly technologies to bring ecosystem sustainability. The thrust would be to incorporate microbial power to attain sustainable production and to provide solution to the problems of the aquatic environment.

Operating Environment

Efficient and proper planning can provide optimum operating environment for fisheries to overcome the future challenges in the food sector. By the year 2050, the main challenges will be caused by population growth, demographic factors, urbanization, income changes and resource use patterns. The marine fisheries sector needs to overcome the problems of overexploitation and handle efficiently the question of sustainability of its resources through management interventions. Public private investment can be envisioned to play a lead role in mariculture. Inland fisheries which include riverine, confined pond and reservoir systems are also envisioned to be transformed into efficiently managed and sustainable systems of fish production. Coldwater fishery will grow at an exponential rate both in terms of fish production and income generated from recreational fishery. The expected overhaul of the brackishwater fish and shrimp farming systems in the next two decades via policy and efficient private investments will yield substantial pay back in terms of sustainable production to meet increasing demand. The demands for processed foods including value-added fish products would be substantial. It will be necessary to develop value-added fish products in environment-friendly, low energy consuming packaging and ready-to-eat format. The shift in demand for semi-processed or ready-to-eat food would likely to change the market structure as well.

The role of private sector is expected to be substantial both in research and education and the large private investments would be determined by the market and by resource scarcity. Consumerism would be more oriented towards health and hygiene and ready-to-eat food. Therefore, the demand for fish can be expected to be substantial. Exploration of new areas for fishing grounds such as deep sea fishery and innovation in craft and gear technology will enhance the fish production. Fuel efficient craft will help in reducing greenhouse gas effect and thereby decelerate the process of global warming. Minimizing post-harvest loss would result in augmenting food security in future. Alternative resources like seaweed, aquatic plants and other non-traditional resource utilization would uplift the livelihood of marginal fishers and farmers. Environmental concerns would be determining the type of process to be adopted for preservation of fish and fishery products. Development of innovative technologies and their demonstration and transfer will be in

key areas of aquaculture such selective breeding, management and control of aquatic animal diseases, developing efficient feeds, developing efficient production system which causes minimum environmental impact.

To equip future generation to face the future challenge, the educational institution has to recognise the three pillars of sustainability viz. environmental, economic and social, and address the complex interaction of all these factors and assimilate in the academic and research programmes. As in the case of the whole sector, fisheries education also would be operating in a resource limiting environment and, therefore, resource-use-efficiency will be key in human resource development and the supporting R&D. This will also likely to result in private investment in the sector. This environment will lead to stringent scrutiny of technology development and innovations for the impact, economic returns and the social benefits and calls for more involvement of social scientists in the sector. Fisheries education would be inter-disciplinary, inter-sectoral and need-based. It would have to orient itself to admitting students belonging to multiple disciplines and of different age groups. Internationalisation of education through distance mode using information and communication technology will likely bring in "borderless education" in the sector.

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New Opportunities

Fisheries and aquaculture make crucial contributions in meeting the food and nutritional requirement of the growing world population and in providing livelihood and income to millions of people. Although the world fish production in the past five decades has outpaced the population growth, the challenges faced by the sector is multidimensional. These include the volatile world economy, climate change-related uncertainties and extreme weather patterns, besides the shrinking natural resources. Malnutrition is a worldwide problem and it is estimated that 842 million people, or about one in eight people in the world, are under the grip of this malady. According to FAO, the vital contributions from fisheries and aquaculture to global food security and economic growth remain constrained by an array of problems. These include poor governance, weak fisheries management regimes, conflicts over the use of natural resources, the persistent use of poor fishery and aquaculture practices, a failure to incorporate the priorities and rights of small-scale fishing communities, and injustices relating to gender discrimination and child labour. However, it is predicted that aquaculture will remain as the fastest growing animal food- producing sector in the coming decades as well, and along with capture fisheries the fish production would exceed that of beef, pork or poultry. Therefore, the future of fisheries and aquaculture depends on how we address all these issues in a pragmatic manner. The challenges which we envisage today and for the future also give us tremendous opportunities in charting our research priorities and designing and refocusing on human resources development programmes.

Fish genetics, fish nutrition, fisheries engineering, fish environment and fisheries and aquaculture management would have to play a complementary role in the years to come. The dwindling stocks of healthy brooders and advances in hatchery technology in terms of re-circulatory systems and renewable energy sources and water use efficiency would be both a challenge as well as a platform for new opportunities. The onus of sustaining agricultural growth could rest squarely with the fisheries sector. Such opportunities could be currently visualized as a function of green field opportunities identified by NFDB. Spectacular opportunities exist in tuna fisheries and mariculture of select species in the next 50 years. Similarly, ornamental fisheries could offer a truly

integrated linked-up value-chain opportunity that has both vertical and horizontal growth prospects. Fisheries management would essentially imply intensive culture practices both inland and marine by 2050. Professionally managed companies with high levels of economies of scale would require highly skilled professionals. In addition to high levels of proficiency in specialized fields, fish business management would play a very important role at the post-graduate level. This scenario could arrive even in the next 10 years.

The gap between demand and supply of animal protein requirement for the burgeoning human population can only be addressed through 360 degree research, technological innovation and intervention. In that background, the institute envisages the following R&D approaches/ opportunities for sustainable fisheries and aquaculture:

Aquatic Environment and Ecosystem Sustainability

To minimize the environmental impact due to aquaculture production as well exploitation of natural resources and ensure ecosystem sustainability, the research efforts in the coming decades would focus on following two areas: ***Reduction in pollution levels*** through alternative and efficient production systems, efficient recycling of aquaculture waste through agri-horticulture, integration of systems on a vertical dimension (multi-level integrated production systems) for reduction in earth's surface area for production, microbe-based technologies for nutrient recycling, re-use of water and waste reduction in post-harvest processing and portable microbial reactors for bioremediation; and ***Prevention of bio-invasion*** through research on biological species both native and exotic, and efficient policies and policing on the introductions of exotics.

Fisheries Resources Management

Making the technologies like GIS/PFZ user-friendly, fishers can boost the fish production. Vessel-based programmes for exploration of deep sea resources and spatio-temporal distribution should be intensified for exploration of fisheries resources. Application of ecosystem models for stock assessment studies will not only help in monitoring ecosystem health and biodiversity, but also regulate the exploitation of commercially important resources. As an alternative method of improving production from the sea as well as freshwater bodies, sea ranching and reservoir stocking may be attempted. Coral and mangrove ecosystems provide variety of resources that are overexploited. Sustainable resource utilization would result in conservation of these fragile ecosystems. Algae are another aquatic resource for food and energy and projected

as future fuel resource. Hence establishment of culture collection and cultivation of micro and macro algae for conservation, utilization and carbon crediting will be a priority. India is bestowed with a variety of seaweeds that can have food and industrial applications and there are tremendous opportunities to utilise these untapped resources.

Aquaculture

As traditional inland agriculture practiced in Asia, integrated aquaculture, having many attributes of natural ecosystem functions which helps in reducing waste and utilize scarce resources effectively, will be one of the important ways the aquaculture will be progressing in future. Integrated multi-trophic aquaculture (IMTA) is an integration of culture practices of different species occupying different trophic levels in the same culture environment depending on the compatibility of various species. The biological and chemical waste material from one culture system will be the input for the other culture system and this will make environmentally neutral production cycle. The compatibility and synergistic relation among species of different trophic levels will make the system under natural bioremediation. It will help us to culture feed-based organisms along with organisms which extract inorganic and organic particulate matter from the natural environment. It can be applied to coastal, marine and land-based systems by creating a simplified natural ecosystem which is in well balance with the surroundings to provide sustainability to the culture environment and the farmer. The system works on environmental sustainability, economic diversification and reducing the environmental and economic risks. Commercialization of IMTA has to overcome potential challenges of multiple uses of water bodies and unintended interaction between systems. To develop IMTA and to exploit its potential as natural bioremediation measure and a method which reduce the environmental cost, various frame works and policies need to be established with a broader vision.

India has vast resources of untapped open water bodies, which are exploited only through capture fisheries. These water bodies which have an average production of 15-20 kg/ha/year, offer immense potential for enhanced fish production through implementation of cage farming practice for raising high-value aquatic species. Since these water bodies are common properties, this technology will give best results if implemented through community participation. This will not only increase the fish production of these water bodies but also impart to the livelihood and food security of the community. Availability of desired quantity or quality water at desired time is very essential for any

aquaculture venture. Therefore, it is essential to estimate the quantity of water required for any of the proposed venture before its inception. Developing re-circulating aquaculture systems designed for intensive culture of high value aquatic species, and where water is scarce and species need constant maintenance of various environmental conditions, will be an area where intensive research is required.

In the recent years various new candidate species entered into Indian aquaculture system on experimental and pilot-scale level either through the efforts of various research organizations or by importing the technology. In addition, various species have entered illegally into the system and attracted the aquaculturists due to fast growth rate and consumer preference. Also the Central Government has officially permitted introduction and culture of few new candidate species like tilapia, *Pangasius*, and Pacific white shrimp in India which, has necessitated more hatcheries for production of quality seed. Cobia, mullet, sea bass, groupers are also being bred in captivity and seed is produced on pilot-scale in India. In order to meet the seed demand of these high value species for diversification of aquaculture, hatcheries need to be established at selected places. Nevertheless, species diversification needs to be looked at very critically in the light of limited research resources available and also of trophic status of the candidate species.

Various technologies have been developed for culture of freshwater, brackishwater and marine species of finfish and shellfish by using ground saline water in the inland saline soils. These technologies can be refined suitably to use in various agro-climatic conditions of the country to utilize vast inland saline resources (8.62 million ha). This will help in utilization of vast fragile agriculture lands of the inland states. Further, climate change may also open up new production opportunities, as more area unfit for agriculture but can be fit for aquaculture may be created due to salinisation of coastal land.

Aquatic Animal Health Management

Develop and apply innovative technologies to detect, monitor and minimize the impact of aquatic animals pathogens and better understanding of aquatic animal health: Concomitant with the expansion and intensification of aquaculture, introduction of exotic species, trade in aquatic animals and their products have opened up potential new and accelerated pathways of pathogen incursion, expansion and enhanced virulence on a global scale for the movement and spread of pathogens. Intensified aquaculture practices and global climatic changes support the emergence of new pathogens and the movement of the

aquaculture products results in the spread and establishment of these agents in new hosts as well as new regions. Though we have achieved spectacular growth in aquaculture production, especially shrimp culture, this has occurred despite the fact that we have only relatively poor basic knowledge about the cultured species. This is the overall context in which we currently address aquatic animal health issues. It is anticipated that this premise would not change much in the years to come except for the strategies and approaches which we adopt to address the issues. In this context, minimizing the impact of aquatic animal diseases and better understanding of the cultured aquatic animal health will remain as a challenge as well as a priority area in the coming decades. The following areas will be continued to be the thrust areas for research:

- Development and application of highly sensitive and specific diagnostic tools for rapid and cost-effective detection of emerging, exotic and endemic aquatic animal pathogens which can be used as a tool for an integrated disease management database at national, regional and global level.
- Development and application of innovative technology for treatment and prevention of aquatic animal diseases.
- Application of advanced techniques to understand the host immune mechanisms and host-pathogen interaction.

Feed, Nutrition and Physiology

Technological innovation for development of nutrient concentrates from the unutilized resources along with basic understanding on growth and reproductive physiology for enhancing vertical aquaculture productivity: Feed used in aquaculture accounts for 50% or more of the production cost, besides being the source of pollution caused by the unutilised feed in the system. Reliance on fish meal and fish oil as feed ingredients also makes the feed and nutrition in aquaculture as the focus of great attention. Developing alternative quality feed ingredients (low-carbon), understanding the digestive physiology and nutritional requirement of candidate aquaculture species with the objective of maximising the feed efficiency and minimising the waste will be the priority areas. Further, under intensive production systems, fish and crustaceans are exposed to various stressful conditions leading to growth reduction, immuno-suppression and susceptibility to infectious diseases resulting in major economic loss for farmers. In this context, it is a challenging situation, especially in a climate change environment, for the aquaculture nutritionist to make a balance between fish health and growth as well. Fish being poikilothermic in

nature are more vulnerable to environmental changes and physiological changes affecting the reproductive performance. Basic research including molecular neuro-endocrinology and investigation of complex processes of germ cell development and differentiation is curial to understand the problems associated with gonadal growth and maturation and their control through environmental cues.

Considering diversification in aquaculture practices in near future, the present art of seed production techniques may not be able to produce some commercial species of food and ornamental values, which are difficult either for inducing spawning or to obtain gonadal maturity under captive condition. Therefore, alternative seed production techniques need to be developed to address three major problems related to reproduction and conservation of valuable traits: lack of gonadal recrudescence suitable for induced spawning under captive condition; long puberty period in some cases; and conservation and production of the species carrying genetically valuable traits. In this context, appropriate physiological intervention complemented with feed and nutritional strategies will be the priority area for the coming decades.

- Germ cell transplantation (GCT) for developing surrogate brood fishes for producing donor derived functional gametes of valuable food and ornamental fishes will be significant.
- "More from less" is the ideal strategies needs to be followed for enhancing the aquaculture production. Selective extraction of protein/lipid/carbohydrate for formation of concentrates from the unutilized or underutilized feed ingredients may solve the crisis of ingredients unavailability.
- Understanding the molecular mechanism of growth by nutrigenomic study to quantify the magnitude of growth that can be manipulated.
- Studies on immuno-nutrition and nutraceuticals for stress mitigation and growth enhancement.

Genetics, Breeding and Biotechnology

Development of high yielding and disease resistant strains of fish species: Improved varieties developed by both selective breeding and transgenesis are likely to be the future. The current surge in high throughput technologies for genomics and proteomics are indicative of further technological improvements to come. This would lead to development of large databases that can be harnessed for genetic improvement. The division is likely to continue using molecular and nano-technological approaches to address issues related to captive maturation, induced breeding, sex reversal, disease prevention,

monitoring environment pollution, etc. It is expected that fish seed distribution will become more organized and the division will focus on developing molecular markers for seed certification. The institute could also network with other institutes for *ex situ* and *in situ* conservation of aquatic species from western/ NEH regions. Most importantly, developing human resource capable of promoting genetic management of fish/shrimp hatcheries and working at the cutting-edge of biotechnology and nanotechnology will remain the primary goal.

Harvest and Post-harvest Management

The focus area will be to develop innovative technologies to reduce post-harvest loss and produce value-added, ready-to-eat fish products. To ensure quality and safety, focused research will be carried out to develop rapid and sensitive methods for identification of seafood pathogens, toxins and spoilage organisms employing biotechnological and molecular approaches. Nanotechnology will be a potential area which will be applied in the process of developing different types of value-added products. Development of effective methods of fish food certification and labelling while harmonising with the international food safety standards and requirements would be a priority area, as this would help protect domestic consumers and help the producers to get access to international market.

Social Sciences

Challenges in fisheries and aquaculture are vast and hence increased research efforts are needed to develop appropriate technologies and solutions for existing problems. In country like India where financial resources are limited and opportunities to invest are unlimited, investment from government for fisheries research will be limited and may decline too. In such scenario, we need to undertake research prioritization to maximize the return out of our research investment/ endeavour for maximizing social benefits. Thus research prioritization for fisheries sector of the country as a whole will be imperative. Again, upon huge investment of public money in fisheries research will require ex-ante and ex-post evaluation of such investment. That should also form the researchable issues for fisheries economics to justify the optimal use of scarce resources in the country. During the period, a large number of technologies in fisheries will be developed which will require investigation of economic viability before recommending them for adoption by end user. This should certainly form the part of research agenda in fisheries economics.

In addition to these, we have vast Inland natural fisheries resources which require valuation for proper planning of these resources and hence provide opportunities for the division to valuate these resources. Though, export from fisheries has been growing rapidly in recent years, we have not been able to achieve the potential due to number of constraints in domestic market as well as in foreign market like progressively evolving food safety measures and also the dynamic nature of rules and regulations. In such scenario, we need to keep watch on changes in foreign market and take necessary steps to prepare ourselves to match the demand in foreign markets. This will require research in the area for making suitable policy suggestions.

Domestic market is also changing rapidly due to changes in consumers' awareness and income level and hence requires suitable changes to meet the domestic demand. This, again, requires study of domestic market to suggest appropriate infrastructural changes and investment requirement to make domestic marketing system more efficient and suitable for the year 2050. Further, with increased fish production and processing, fish business will require more number of fisheries economists who can meet the human resource requirement of fisheries business and also to take up the research and teaching activities. Along with this, programmes for developing skilled and experienced fisheries and aquaculture extension services for effective knowledge/information exchange and enabling technology development and dissemination will be a core component.

Human Resource Development

To meet the challenges envisaged both in terms of research as well as development goals, highly skilled and meticulously trained human resources with vast knowledge-base which cuts across disciplines and specializations are crucial. The Institute needs to enhance the intrinsic and extrinsic values of the academic programmes by evolving each specialized disciplines into full-fledged schools or centres of excellence. Although the international standards would be the drivers of the change in academic programmes, sustainable and inclusive development would become focal points. Highly flexible academic programmes not just based on the routine academic performances, but based on the aptitude and ingenuity of pupil would be the key markers. In the globalized world, ample opportunities would be available to open 'Off-shore Campuses' particularly in Asian and African nations. With the advent of information technology and available advanced tools of pedagogy, it would not be far to offer fisheries programmes in distance education mode which would

help in the internationalization of fisheries education. Special initiatives should be taken to attract and retain talents and youth in fisheries. Ample opportunities lie ahead in maximizing/enhancing opportunities for women in aquaculture, as the sector provides enormous employment opportunities and income besides offering protein diet. Though the participation of women in higher fisheries education is substantial, there is a need for designing innovative training programmes in diversified areas of fisheries and aquaculture targeting the disadvantaged rural women taking into account their domestic responsibilities and low literacy level.

There will be a tremendous opportunities the fisheries education in India can harness, by exploiting the unique nature of Asian aquaculture scenario. Nearly 90% of global aquaculture production comes from Asia. Correspondingly, 96% of the 19 million on-farm jobs provided by aquaculture globally are located in the region, besides the potential for ancillary employment opportunity. A challenge as well as an opportunity will be the fact that by 2050, share of urban population in Asia will be 64%. Moreover, diverse aqua-climatic conditions, aquaculture species, production systems, long history of traditional knowledge and farmer innovations and large number of educational institutions and varied programmes are a unique platform on which India, especially CIFE, can build a fisheries education hub or consortium on a country and regional level. Developing a harmonized curriculum encompassing all the diversified needs, creation of an innovation centre for local and regional needs, an effective network of academic institutions with a regional task force are all potential opportunities.

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Goals and Targets

To make future aquaculture sustainable and more productive, besides technology innovations, human capacity development which includes education and training will be critical. To meet the diversified needs of the sector, beyond just skill development, setting up long-term goals for the fisheries academic institution will be quite challenging. A holistic approach in creating vast knowledge-base in fisheries and aquaculture through advanced research, incorporating lessons from emerging research and development front in the academic programmes, recognising the local, regional and global needs of the sector, proper analysis of required legal and policy issues dealing with the future scenario will be essential to make the human resource development programmes relevant and competitive. In this scenario, as mentioned elsewhere in the document, the goals of the organization are:

- To develop critical mass of human resources with specialized skills in diverse areas to meet the growing demands of the sector.
- To engage in research that appreciates and absorbs the knowledge- and information-intensive advancements to ensure the long-term sustainability of the sector and to maintain environmental integrity.
- To integrate the research and development advancements in the academic programmes to make it relevant and competitive.

To meet the future challenges and to harness the anticipated opportunities, the institute will engage in executing well structured plans and programmes such as:

1. Making CIFE an International Centre of higher learning in fisheries and aquaculture in Afro-Asian and South-East Asian region with a focus on undertaking basic and high end research and develop quality human resources.
2. Developing Centres of Excellence in different specialized disciplines.
3. Develop capacity building and regional hub for DNA barcoding of aquatic species.
4. Climate change research and environment resilient technology for higher production and productivity.
5. Valorization of seafood processing waste, development of value-added fish products with improved functionality and enhanced shelf-life.
6. Water budgeting and urban aquaculture including aquaponics.

7. Diversification of aquaculture in freshwater, brackishwater and mariculture systems.
8. Aquaculture in inland saline soils and salt-affected areas through refinement of existing technologies and development of new ones.
9. Developing a Centre for Fisheries Education and Policy Research for aiding policy makers and planners, and ensure guided development process.

To meet the growing demands for fish as a quality food in the context of increasing human population and other factors under acute resource constraints, the vision of CIFE needs to meet the following targets:

- Doubling of aquaculture production though sustainable intensification.
- Increase the number of highly specialized human resources commensurate with the sectoral demand.
- Improve the quality of fisheries education and training to make the human resources relevant and competitive.

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Way Forward

Role of CIFE, the apex organization dealing with the human resources development in the area of fisheries and allied disciplines, is paramount to the sectoral development. The Institute serves as a centre of excellence for conducting post-graduate academic programmes in core and emerging disciplines of fisheries science; an advanced centre for basic, strategic and cutting-edge research in fisheries and aquaculture; a national training centre to impart demand-driven training and educational programmes for different stake-holders in fisheries and aquaculture sector; a centre for providing inputs for policy development, refinement and demonstration of aquaculture technologies. CIFE has demonstrated its strength and expertise in quality teaching, research and extension in the field of fisheries and aquaculture. Beyond the national boundaries, CIFE has established itself as an attractive destination to students from many Afro-Asian countries.

CIFE will continue to provide high quality human resources to meet the diverse and specialized needs of the sector both nationally and internationally. The academic and training programmes will be enriched by the advanced knowledge base generated time-to-time, research and innovation updates, farmers' and industry inputs, and national and international partnership. CIFE will remain sensitive to the local, regional and global changes to make the human resource development plan more proactive and need-based. While human resource development remains as the flagship programme, developing innovative solutions to address the emerging challenges through research will be a core component. Continued efforts to improve the resources and the institutional strengths will remain as an integral component of the vision.

Vision

- To become a globally recognized knowledge and innovation centre of fisheries and allied disciplines for providing leadership in fisheries education and research.

Mission

- To achieve academic and research excellence in order to prepare the sector to successfully respond to local, regional and global challenges.

The following key areas will be the focus to realize the vision:

Academic Excellence

- Developing highly flexible and new academic programmes including sandwich programme with overseas universities.
- Evolving each specialized disciplines into full-fledged schools or centres of excellence.
- Developing strategic partnerships.
- Introduction of distance education.
- Special initiatives to attract and retain youth in fisheries.
- National and regional harmonisation of educational programmes.
- Developing model guidelines for establishing fisheries colleges and specialized programmes for capacity building.
- Development of globally competitive faculty.
- Looking beyond border: Opening of 'Off-shore Campuses' particularly in Asian and African nations.

Research Efforts to Achieve Sustainability

- Expansion of aquaculture by targeting the unutilized water bodies of inland saline affected areas and degraded soil for aquaculture with suitable candidate species along with efficient culture technique.
- Developing efficient re-circulatory system with water budgeting for culture of candidate species.
- Developing integrated multi-trophic models for low-impact aquaculture; Productivity enhancement in open water bodies through cage-culture.
- Qualitative and quantitative enhancement of aquaculture production irrespective of intrinsic barrier of specific habitation or environment, using functional genomic research.
- Developing fast, efficient and safety methods for production of value-added fish products to satisfy specific demand along with universal method of labeling for their traceability from farm to fork and *vice-versa*.
- Understanding the molecular basis of neuro-endocrinology and reproductive physiology to support the species diversification in aquaculture.
- Developing surrogate brooders for food and ornamental fishes for production and conservation purposes.
- Simulation study of climate change effect on fisheries and aquaculture in micro-environmental conditions and developing apposite dietary

strategies for counterbalancing the stress by befitting nutraceuticals or bioactive compounds complemented with nano-delivery.
- Improved understanding of aquatic animal health and host-pathogen interaction coupled with development and application of innovative technologies for treatment and prevention of aquatic animal diseases.
- Developing innovative and efficient green technologies in the areas of resource utilization and recycling of used resources, minimization of generation of wastes and management of pollution.

Policy and Institutional Strength

- Developing a National Fisheries Education Policy and provide inputs in the formulation of fisheries and aquaculture policy.
- Developing database on human resources availability and future requirement.
- Creating open platforms to involve all the stakeholders to design, develop and refine academic and training programmes.
- Participatory technology development and dissemination for fast tracking the fisheries and aquaculture development process multifold.

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Strategy and Framework

CIFE, unlike other fisheries and aquaculture research institutes under ICAR, has multiples roles to play: develop quality human resources; provide research and development support to the sector; act as a nodal centre for formulating policy guidelines for sectoral development including education. CIFE's influence and responsibility in the field fisheries higher education has increased manifold over the last decade after the introduction of various specialized disciplines and due to the enhanced institutional strengths in terms of infrastructure and faculty. After the introduction of specialized disciplines of fisheries and aquaculture in the Agricultural Research Service (ARS), quality of human capital produced by CIFE will determine the future research and development programmes undertaken by all the ICAR fisheries institutes. This is a great challenge as well as an opportunity for CIFE. Challenge lies in creating highly competent, research-ready graduates who will drive the sector with vigour and innovations. This is also an opportunity, as the performance of the graduates will be assessed by outside world and it can provide a genuine feedback for CIFE to recalibrate its academic and research standards. CIFE has been attracting students, including post-doctoral scholars, from many Asian and African countries reflecting the institute's reputation outside the country. Further, CIFE, with its high academic and research standards and through strategic partnership with national and international institutions, is poised to become an International Centre of Excellence in fisheries higher education in the world.

A realistic assessment of institutional strengths and ability to harness the opportunities and preparedness to face the future challenges are the ingredients of the vision. CIFE will follow a well structured agenda for developing need-based, quality human resources by incorporating the vast knowledge base and cutting-edge research and innovations for sustainable and inclusive development of the sector.

Partnership, Linkages and Networking

CIFE recognizes the significance of partnership and linkages. As an academic institution, to ensure the criterion of 'student-ready', interaction with the stakeholders and their feedback/inputs are crucial. The institute will continue to nurture productive interfaces between industry, farmers,

developmental organisations, non-governmental agencies to build and strengthen academic, research and innovation strategies. Engaging research scientists from sister ICAR fisheries institutes in CIFE's academic programmes and student-based research is a continuous process which have paid great dividends in terms of bringing varied skills and expertise to the benefit of the students and provides a platform for novel strength-sharing. Guest faculty and Adjunct Professors from Indian and overseas institutions will also continue as an academic enrichment exercise. International linkages have also been established by the institute. Besides utilizing the expertise of faculty from overseas universities, the institute envisages these linkages as an opportunity for mutual student and faculty exchange. In a resource-limiting future, duplication of research efforts by different institutes will be wasteful. To circumvent this, the institute will continue to participate in effective network projects/programmes. Besides strengthening and nurturing the existing partnerships, developing new academic and research collaborations will be a priority of the institute.

Development of Database and Policy Framework

One of the immediate priorities of the institute will be to develop a comprehensive database on the availability and future requirement of human resources of the sector both in terms of specialization and quantity. It is going to be a challenging task considering the diverse nature of different subsectors, difficulty in identifying future trends and nature of emerging technologies. Harmonisation of academic programmes across the country will be essential to ensure the quality and uniformity of skill and knowledge. It will be CIFE's immediate responsibility to bring in all the fisheries colleges and other academic institutions involved in fisheries and aquaculture education to one network and implement the harmonization process. CIFE will be able to act as a nodal centre for developing guidelines and standards for fisheries colleges in the form of 'Fisheries Educational Policy'. CIFE has been active in reviewing and providing inputs to fisheries and aquaculture policy of the country and institute shall strengthen these efforts and assumes the position of a Centre for Fisheries Policy Development.

Institutional Strengthening

To remain at the cutting edge of research, CIFE will strive hard to build superlative research facility as well as highly competent faculty. A high-end central research instrumentation laboratory and computational facilities need to be created. A mandatory faculty improvement

programme enabling the scientists to undertake their research training every three/five years in reputed laboratories will be helpful. Though the institute has farm facilities at its centres, it will be highly desirable to acquire a farm facility close to the headquarters. Externally-funded projects have been a core strength of CIFE and there will be increased emphasis on engaging in collaborative, inter-disciplinary and inter-institutional research programmes with extramural support. Besides being an opportunity for advanced research engagement, large resource mobilsation, infrastructure and capacity building coupled with professional recognition and autonomy to the scientists will be the advantages of these projects. By attracting and retaining youths in fisheries and aquaculture, a sector which is vital to the food and nutritional security and a source of livelihood for millions, by providing academic excellence and research-based innovative solutions for sustainability, CIFE will strive hard to realize its vision and accomplish the mission.

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