Vision 2030

CENTRAL INSTITUTE OF FRESHWATER AQUACULTURE

(Indian Council of Agricultural Research)

KAUSALYAGANGA, BHUBANESWAR – 751 002

Odisha, India

Vision-2030

Central Institute of Freshwater Aquaculture
(Indian Council of Agricultural Research)
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PRINTED : June 2011

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Kausalyaganga, Bhubaneswar 71002

Published by the Director, Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar-751002,

Printed at M/S Capital Business Service &Consultancy, B-51, Sahid Nagar, Bhubaneswar-751007

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Foreword

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

Indian Freshwater Aquaculture has evolved itself from the stage of a domestic activity in Eastern India to that of an industry in recent years. Indian subcontinent is endowed with a rich diversity of fish/shellfish species as also freshwater aquaculture resources. With an average annual growth rate of 6%, the freshwater aquaculture produce alone is contributing to over 30% of the total fish production in the country. From its modest beginning as a Pond Culture Division of CIFRI in Cuttack, through its metamorphosis into Freshwater Aquaculture and Training Centre (FARTC) and as a central institute in 1987, Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar has made significant contributions towards enhancing fish production in the country, and thereby assuring food and nutritional security to the growing Indian population and livelihood option to millions of small-scale farmers and also as an organized industry through several epoch-making technologies, including multiple carp breeding and grow-out production of catfish and prawns, portable carp hatchery, pearl culture, wastewater aquaculture, development of improved rohu '*Jayanti*', development of balanced diets for carps, catfishes and freshwater prawns, development of diagnostics and therapeutics for important fish pathogens, etc.

It is expected that the analytical approach and forward looking concepts presented in the '*Vision 2030*' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

(S. Ayyappan)

Dated the 12th July, 2011
New Delhi

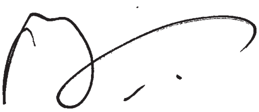
Preface

Population growth, increasing affluence and changing dietary habits have led to rapid rise in global demand for food, and a report of FAO (2009) forecasts the need to increase food production by over 40% by 2030 and over 70% by 2050. However, the agriculture sector at global level is facing stiff challenges with decelerating profitability and reduced annual growth rate. In Indian context, Indian Council of Agricultural Research (ICAR) is taking all out efforts to enhance agricultural production and productivity through science-led and technology-driven approach. There is need for the agriculture sector to continuously evolve to remain ever responsive to manage the change and to meet the growing and diversified needs of different stakeholders in the entire production to consumption chain. According to latest statistics, global fish production stands at 143.6 million t, of which about 40% is contributed by aquaculture sector. Global capture fishery is at crossroads, with over 70% of the resources being exploited.

Indian fisheries sector has made great strides in the last five decades showing eight fold increase, from 0.75 t in 1950-51 to 8.1 t in 2008. Inland fisheries contribute to over 50% of this production, of which 84 % of the production comes from aquaculture. Growth rate of this sunrise sector is almost 6 per cent, and could certainly make good stagnating production trends shown by capture fisheries. Fisheries contribute significantly to our national economy, with about 1.5% of national GDP and 4.6% of agricultural GDP. Food and nutritional security, employment & livelihood support, and uplifting the economic status of fishers are the cardinal services offered by Indian fisheries. Having said that, commensuration with the increasing population and demand for fish, a real-time analysis of the scenario is required along with a mission-mode approach to realize our available vast potential as a means of enhancing fish production in the country.

Indian Council of Agricultural Research in its own wisdom has made a systematic effort to envision the challenges and opportunities to chart the strategy for taking agriculture forward in the 21st century through the preparation of 'Vision 2020'. The Central Institute of Freshwater Aquaculture, Bhubaneswar also made effort under the caring guidance of ICAR to prepare visionary document for 2020 which was upgraded to "CIFA Perspective Plan – Vision 2025" to address the challenges those had taken place. The present document, 'CIFA Vision 2030' is based on scenario planning, and it enlists the priorities and strategies envisaged in the coming 20 years to overcome the challenges and harness the power of science and technology to address issues on increasing fish production and productivity, tackling the decreasing natural resource base, encountering the impending climate change, and above all providing food and nutritional security to the populace.

I am grateful to Dr. S. Ayyappan, Secretary DARE and DG, ICAR for the invaluable guidance and encouragement in preparing this document. I am thankful to Dr. B. Meenakumari, DDG (Fy.) and Dr. S.D. Singh, ADG (I.Fy.) for constant encouragement and valuable suggestions. I appreciate the efforts of my team of specialists, notably Dr. P. Mukhopadhyay, Shri. N.K. Barik and Dr. P. Das in developing this document. I am convinced that 'CIFA Vision 2030' document will be a strategy document to enlist the skills and capabilities, knowledge exchange and translation, and promoting innovation in freshwater aquaculture research.



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July 13, 2011
Bhubaneswar

Preamble

Aquaculture which accounts for 50% of the total fish production has been providing food and nutritional security to millions of people at affordable price as well as contributing to the livelihood support to a large member of rural population in the country. Its growth rate (over 6% a year) is the fastest among all other food production systems. It is also considered as the most efficient form of animal production system. Of the total inland fish production, almost 84% is contributed by freshwater aquaculture amounting to 3.9 million tonnes. The potential of the vast freshwater resources covering 6.7 million hectare is yet to be fully realized. The contribution of this sector to the gross domestic product is about 0.75 % in 2007-08. Similarly, the share of fisheries to agricultural GDP (Gross Domestic Product) has increased from 2.17% in 1980-81 to 4.56% in 2007-08 and thus boosting the agricultural growth since last several years. The freshwater aquaculture which began as small scale activities of stocking ponds with fish seed collected from riverine sources during early fifties in rural Bengal has now transformed into a major economic activity in almost all states with the common objective to double the production. This is essential or else it would be difficult to achieve the targeted per capita fish availability of 15 kg by 2030. Since the last three decades, freshwater aquaculture has also been compensating the loss in the fish production due to decline in the capture fisheries as well as increasing overall fish availability in the country. Now, the quality fish protein supply, nutrient security of consumers, livelihood security of producers and traders are all linked with the growth and development of this sector.

The Central Institute of Freshwater Aquaculture is a premier Institute in freshwater aquaculture in the country under the administrative control of the ICAR, New Delhi. The present Institute has had its beginnings in the Pond Culture Division of Central Inland Fisheries Research Institute, which was established at Cuttack, Orissa in 1949 with a view to finding solutions to problems of fish culture in ponds and village tanks.

Later, the Central Inland Fisheries Research Institute, based at Barrackpore, West Bengal in a major effort to give emphasis to freshwater aquaculture research, initiated steps on establishing the Freshwater Aquaculture Research and Training Centre (FARTC) at Kausalyaganga, Bhubaneswar, Orissa. The Centre blossomed into its full capacity and became as an independent Institute during 1987 as Central Institute of Freshwater Aquaculture. The Institute is also the Lead Centre on 'Carp Farming in India' under Network of Aquaculture Centres in Asia-Pacific. The Institute has four regional centers, and KVK/TTC is located at the headquarters.

The rapid expansion of the freshwater aquaculture sector across all parts of the country has been visibly demonstrated. But, the increasing role played by the sector in the poverty alleviation, livelihood support and nutrition security has often been ignored due mainly to lack of information on them. This sector provides direct or indirect employment to as many as 14 million people of the country. About 1.3 % of the landowning households are reported to be involved in the aquaculture activities and estimated 1.1 million farming households are involved in aquaculture. Aquaculture generates income and employment opportunities across the chain of seed production, fish culture, fish harvesting, input supply, trading, marketing as well as processing. Globally, aquaculture is being seen as antidote to fight poverty and malnutrition. Many developmental programmes like MGNREGS, Watershed development etc. look aquaculture as a means to enhance the overall impact on the poverty alleviation in rural areas.

CIFA has been conducting research in the areas of contemporary interest with major emphasis on the welfare of the fish farmers, consumers and other stakeholders in the freshwater fish production and supply chain. The institute, with its core competence and comparative advantage can deliver the required services through the pursuit of research and development agenda - most relevant to our stakeholders. All efforts are being directed towards becoming the leading freshwater fish research institute in the world.

Contents

Freshwater Aquaculture Scenario and SWOT Analysis

Vision of freshwater aquaculture

In the back drop of reclining land and water resources, exploding population and stagnancy in production from capture fisheries sources, the importance of aquaculture has become crucial in the national perspective. There are, therefore, great expectations that freshwater aquaculture in India holds promise to produce high quality and large volume of healthy fish stock for human consumption. The present production level of 3.9 million tonnes will be targeted to rise in a sustainable manner to about 8.0 million tonnes by 2030 applying holistic principles in tune with the increasing per capita availability. CIFA's vision is, therefore, to first prioritize the research to suit the need and aspirations of our stakeholders and conduct hands-on training with the proven technologies to make freshwater aquaculture truly remunerative and a panacea for the future growth of the sector.

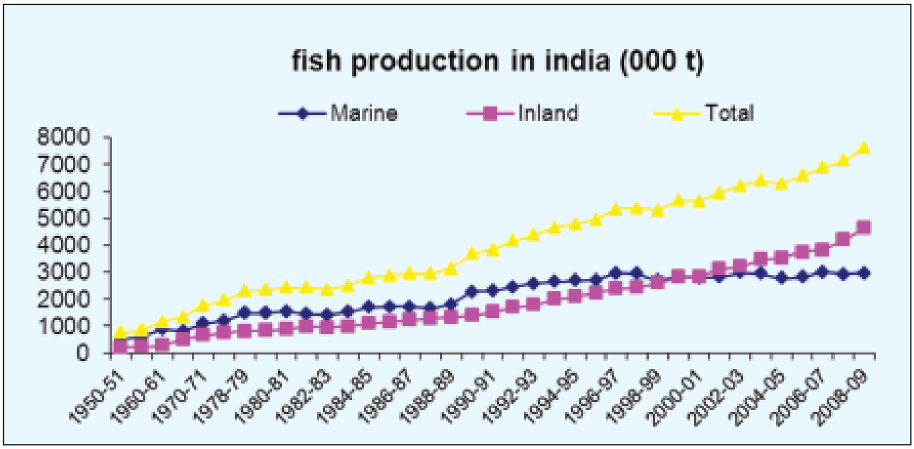

Fig 1. Trends in marine and inland fish production in India.

Aquaculture and economy

Aquaculture, a subsector of agriculture in India, has increasingly been asserting its positive contributions. The real development of the aquaculture sector in India started from late seventies and from then the sector has been growing steadily. From the onset of the green revolution, the agriculture sector grew at about 2.36 %, but the aquaculture growth was remarkable at about 6.2 % per annum. During this period aquaculture production in India increased from 0.2 million tonnes in 1973 to 3.48 million tonnes in 2008. India's total fish production increased from 0.75 million tonnes to 7.61 million tonnes from 1950-51 to 2008-2009. Within this period the share of the inland fish increased from 28.9 % to 60.1 %. Within the inland sector the capture fisheries has stagnated or declined depending the major growth in the inland sector to be driven by the freshwater aquaculture. Even though the aquaculture and agriculture did not follow parallel development pathway, both the sectors complement each other in a significant way as the dynamics in each of them are interlinked. In recent time, the spectacular growth in the aquaculture sector has contributed significantly to increased growth rates. Late start of the sectorial development compared to agriculture as an advantages of the faster growth as well as significant portion of the underdeveloped segments in the sector. Freshwater aquaculture sector thus provides a unique opportunity to further accelerate to support to the economic growth of the country.

A total GDP from fisheries is in the tune of 35.65 thousand crores contributing about 0.75 % of national and 4.56 % of agricultural GDP. The share is on the increase over a period of time indicating the realization of the potential of the fisheries sector as driven by the freshwater aquaculture.

World annual inland fish production is 41.6 million tonnes. India is second largest in inland fish production with 3.8 million tonnes and first one being China (20.8 million tonnes). In last 15 years, China's inland sector has grown about 3.7 times and India by about 2.3 times but other countries like Vietnam grew by 5.2 times. In other words, China took about 11 years, India 14 years and Vietnam 5 years to double their inland fish production. India contributed about 4.86 % of the global fish production in 2006, the third largest but gap between India and China is very high (China 35.87% of global fish production). In terms of the inland fish production India's contribution is 9.25 %.

Seed production scenario

Fish seed is the most critical and prime factor and considered the main lever of the aquaculture development in the country. The blue revolution started with the development of seed production technology through induced breeding (hypophysation) during early sixties. Initially started with carps, presently at least two dozens of fishes are being induced to breed. At the beginning, the technology was considered as highly knowledge-based and skill-demanding but has now become a popular technology across the length and breadth of the country. A large number of hatcheries have been set up in both public and private sectors in many states. The seed production technology developed by CIFA (earlier under CIFRI) helped creating the well-developed seed production industry in the country. Total seed production increased from 409 million fry during 1973-74 to 24,144 million fry in 2007-08. West Bengal has been a major producer of the fish seed however, over a period of time almost every state is producing a major part of their requirements as the technology spread to whole of the country by now. With the availability of hypophysation techniques and inducing agents, carp breeding in particular has now become very common and popular.

CIFA took a further lead in broadening the scope of hatchery seed production and brought into its orbit, the air-breathing and non-air-breathing catfishes, freshwater prawn to meet the growing seed requirements and diversification of aquaculture. Techniques of breeding species of regional importance are now available and diversification of aquaculture is now possible on a regional basis. Despite the fact that country produces at present over 22 billion carp fry , non-availability of desired size of stocking fish species still remains a constraint. Similarly, production of 200 million seeds per annum from 35 freshwater prawn hatcheries in the country is not also adequate to cater to the need of prawn farmers.

Growth of production

The average aquaculture production during 2007-08 was reported to be 2.6 tonnes per ha/yr. But there are wide variations across the states and production environments. The commercial farmers of Andhra Pradesh and Punjab have achieved more than 6 t/ha/yr whereas it was less than 1 t/ha/yr in case of the community aquaculture. The research farms of CIFA have demonstrated production as high as 17 t/ha/yr. It underlines that actual production is quite low and a wide yield gap exists which can be bridged through the development of different disciplines under the umbrella of freshwater aquaculture accompanied by aggressive dissemination. Production growth can also be achieved through improvements in the productivity of cultivated organisms per unit of input, either through technological modifications to the inputs or through modification of the cultivated organism itself. In future, aquaculture will be more technology and input based with greater intensification per unit water bodies to produce more fish per unit area. In this context setting up of more fish feed production units at suitable locations along with mapping the potential agro-based feed ingredient availability in various zones of the country and a database on their nutritive values and nutrient digestibility would be a major step ahead.

Table 1. Aquaculture production systems and interventions

	Systems	species	seed	Feed	Fertiliser	Aeration	Production t/ha
1	Polyculture	IMC	Fry	-	-	-	0.1-0.3
2	Polyculture	IMC	Fry	-	Partially	-	0.3-0.6
3	Polyculture	IMC	Fingerlings	-		-	0.6-1.0
4	Polyculture	IMC	Fingerligs	-	Partially	-	1.0-2.0
5	Polyculture	IMC	Fingerlings	Fully	Partially	-	2.0-3.0
6	Polyculture	IMC	Fingerlings	Fully	Fully	-	3.0-5.0
7	Composite Fish culture	IMC, Exotic carps	Fingerlings	Fully	Fully	-	3.0-10.0
8			Fingerlings	Fully	Fully	Fully	10.0-15.0
9	Air breathing fishes	Murrels, magur	Fry	RB + OC+ Fish meal	Fully		1.0-2.0
10	Prawn monoculture	Rosenbergi, malcomsoni	Post larva	Formulated fee		partially	1.0-2.0
11	Carps and prawn poly culture	Carps, prawn	Fingerlings , post larva	RB + OC	fully		3.0-5.0 fish 0.3-0.5 prawn
12	Rice-fish	Carps/catfish	Fingerlings	-	-	-	0.1-0.3
13	Fish-livestock/birds	carps	Fingerlings	-	-	-	3.0-5.0

Consumption and protein security

Freshwater fish constitutes the main source of animal protein food in most parts of rural India and more so in the land locked states. Almost half of our population is fish eaters and average fish consumption by the rural and urban population is 7.02 and 9.06 kg/capita/yr, respectively, whereas ICMR recommends 11 kg per capita consumption. There are wide variations across the country for example; Kerala, West Bengal, Odisha and Northeastern states have a larger percentage of the people consuming fish. In major fish consuming state like Kerala the percentage of protein from non-veg sources is more than 22% and that of West Bengal more than 10% whereas it is less than 1% for the north Indian states. Average per capita per day intake of protein should be 1g/kg body weight per day but there is a wide disparity between the rural and urban population. The meat, fish and egg together contribute about 4% of protein in rural and 5.5 % in urban areas. But it is still miserably low in the poorer section. Across the country again it is as high as 22 % in Kerala and about 10% in West Bengal and Assam but as low as 0.6 % in Punjab. Therefore, the relative importance of the fish is higher for the fish consuming states. Per capita per day intake of protein in India is 57g. Out of which egg, fish and meat constitute 3.98 and 5.47% of total protein intake for rural and urban areas respectively. The poor households are particularly deficient in their protein intake as per capita protein consumption of the poor household is very low (37g against 57g of national average). Percentage of protein from non-veg sources for the poor is very low (2-3%) compared to 7-8 per cent for the rich households. Therefore, the poor has lesser access to animal protein. The average protein intake from non-veg sources is 4% for rural and 5.5% for urban areas. Therefore, the fish is an important source of protein and more so for the poor households in the poorer region of the states. With the increase in the fish production, the poor will have a greater access to the quality animal protein with a significant improvement in the protein security of the country.

Demand and supply

Fish account for 20% of animal-derived protein in low-income food deficit countries compared with 13% in the industrialized countries. It has been shown that animal product consumption grows fastest in countries with rapid population growth, rapid income growth, and urbanization. This pattern is also observed with fisheries products in particular. Consumer theory suggests that as individuals become wealthier, they tend to substitute higher-priced calories for lower-priced ones, once basic food needs are met. The demand for fish products at the household level, as at the national level, is quite responsive to changes in income. In case of India, the percentage of households consuming fish has been increasing over the years and percentage of the fish consuming population is higher than meat, egg and chicken. Per capita consumption has also been increasing. The income elasticity for fishes is 1.66 indicating that with the increase in income people tend to spend more on fish and relatively less on other types of meat. The fish demand is sensitive to price changes except IMC (Indian Major Carp). There is a higher demand for IMCs and other freshwater fishes like minor carps, catfishes and murrels. These fishes are cheaper and sensitive to price as well as income. Therefore, a greater part of the demand of the fish needs to be realized from these species. Among the fish species the higher demands projected for IMCs and other freshwater species at about 3.98 and 3.96 % per annum respectively. Additional fish demand required for India by 2020 is about 3.21 million tonnes. Out of which about 90% of the demand is to be met from IMC (52%) and other freshwater fishes (38%). With this demand growth, at national level of the fish consumption, will reach 6.3 kg (2020) from 5.6 kg (2011). For the fish eating population it will be from 16.8 kg to 18.5 kg. In this scenario the share of the IMCs and other freshwater fishes will increase by about 9.5% and 6.8 %, respectively. In other words IMCs and other freshwater fishes will play a greater role than even today in meeting the demand of the country. By 2030 it is expected that there will be a need to increase aquaculture production by three times from the present level to meet the demand. Fish constitutes 6% of total food budget in India but in the country like Bangladesh it is as high as 20%. Poor households respond more positively to the higher income indicating a significant shift in the demand as more and more people. Therefore if supply does not commensurate increase in income of the poorer section there will be raise in the price which will obstruct the consumers and consumption. The low value carps determines the price and consumption of the sector and play a major role.

Micronutrient security

The fish has high nutritional value is well known. Less well-known is that the significant contribution it makes to the diet of many fish-consuming communities in both the developed and developing world not only with respect to high quality protein but also a wide variety of vitamins and trace elements. Fish provides high quality protein and a wide variety of vitamins and trace elements including vitamins A and D, phosphorus, magnesium, selenium, and iodine. Fish is also a valuable source of essential long chain fatty acids and its fillet protein is easily digestible. Even in small quantities, fish can have a significant positive impact on improving the quality of dietary protein intake by complementing the essential amino acids that are often present in low quantities in the rice-and-vegetable diets. In particular, fish is a rich source of lysine which is an essential amino acid that is often deficient in rice diets with little animal protein.

Recent research shows that fish is much more than just an alternative source of animal protein. Fish oils in fatty fish are the richest source of a type of fat that is vital for brain development in unborn babies and infants. This makes all fish and especially fatty fish, such as tuna, mackerel and sardine, particularly good components of the diet of pregnant and lactating women. It is therefore apparent that fish makes a valuable contribution to the nutritional quality of the diets of the populations of many developing countries in the Asia-Pacific region.

Freshwater aquaculture sector can play a greater role in promoting nutritional well-being by balancing malnutrition including multiple micronutrient deficiencies that hit the generations of women and children in India. Increasing the availability of fish in the daily diet enhances palatability thereby increased intake leading to overall improvement of nourishment and boosting up host immune competence. Thus it can protect the vulnerable population including the growing children with respect to multiple micronutrient deficiencies thereby ensuring their desirable physical and intellectual development.

Diets deficient in micronutrients are relatively high among populations whose intake of foods is predominantly cereal–based but low in consumption of food like fish. Micronutrient deficiencies impair cognitive development and impair immunity as well as increases susceptibility towards infectious diseases. While fortification of food items in the daily diet is a successful intervention strategy, food-based approaches aimed at improving micronutrient status by increasing availability of fish for example is a very simple and sustainable approach to tackle the issue. Given the vast water resource availability much of which still remains unexploited, increased fish production through the wide scale adoption of aquaculture technologies generated at CIFA to combat nutritional deficiencies becomes highly imperative for national development.

Smallholders' and community aquaculture

The debate over the small versus large holders for aquaculture is often non-conlcusive. While the large holders' commercial aquaculture from states like Andhra Pradesh or Punjab produces for the market, the smallholders' aquaculture is for the family and local consumption. Therefore, the social impact of the smallholders' aquaculture for the food and livelihood security is quite high. Over a period of time the number of operational holdings has doubled from 51 million in 1960-61 to 101 million in 2002-03 and during this period the average size of the farm declined from 2.63 ha to 1.06 ha. Therefore, a large numbers of people have the access to the smaller patch of land. Among the landholding class the average size of water bodies is about 0.1 ha. In addition to water bodies like community ponds and leased ponds etc are also very small in the range of 1-2 ha. Therefore, the aquaculture in these ponds can be considered as smallholders ponds as the small and marginal farmers are increasingly being involved in the aquaculture operations. In future many of these small ponds operated by the small and marginal farmers will shoulder major responsibility in the aquaculture development. It has been shown that the poor in developing countries get a higher share of their much smaller animal protein consumption from fish than do better-off people in the same countries. Access to the small aquaculture resources, technology and fish with reduced price has a welfare effect of aquaculture. In this context CIFA can take the lead to teach the farmers to do the scientific farming by providing them with quality inputs and technology.

The community based aquaculture is an emerging area of the fish farming in the rural areas. There are many forms of water bodies like common property resources, small irrigation tanks, water harvesting structures, community ponds etc. being held by the collective body like Panchayat, government or other public agencies. There is an increasing awareness of the value of these water bodies for aquaculture purpose, and therefore interest increases to develop aquaculture. In most of the cases, these water bodies are being leased to the collective or community based organizations like cooperatives, Self-help-groups, youth clubs or others bodies for aquaculture. Such community aquaculture has provided significant social benefits to the community and therefore this has been promoted by many governments. In the context of the future developments, the fine tuning of the technology as well as policy development suitable to these water bodies are critical for development of fish farming in these water bodies. The lease policy, technology transfer and Freshwater Fish Farmers Agency (FFDA) input support etc will be required for the community aquaculture development.

Biosecurity aspects

An important challenge to the future expansion of aquaculture is the outbreak of diseases. Biosecurity which is a system of cumulative steps for the prevention, control and eradication of infectious diseases to protect the farm stock requires to be stringently implemented from the hatchery to the grow-out stage. Over the past several decades, the expansion and intensification of aquaculture production has been accompanied by increased movements of live aquatic animals and aquatic animal products, including brood stock, seed, and feed. This process of expansion, along with globalization, has made the accidental spread of diseases into new aquatic populations and more likely geographic regions. Disease is a major constraint in aquaculture development, often significantly diminishing pond productivity. High stocking densities and poor water as well as seed quality can lead to disease outbreaks in ponds; these can subsequently spread to other ponds through water exchange.

Climate change and aquaculture

Temperature rise is the major effect of global warming and the effects are likely to continue in the foreseeable future. The Inter-Governmental panel for climate change (IPCC) report indicated that many of the developing countries tend to be vulnerable to extreme climate disturbances and thus may have an adverse impact of a gradual climate change on animal production system including fish farming through aquaculture. Fish, being poikilothermic in nature, are prone to physiological changes pertaining to global warming. Given the importance of climate in the aquaculture production system, it is essential that concerted research efforts be carried out to assess the vulnerability of aquaculture towards the impact of climate change, prioritize the strategies and also to identify the stakeholders' response. One of the important occurrences may be the hypoxic conditions in the water bodies. Hypoxia can lead to derangement in the oxidative pathways, impairment in the reproductive performances by affecting the neurotransmitter biosynthesis, disruption of normal functioning of endocrine secretions particularly the secretion of hormones-testosterone and estrogen. Embryonic development is a temperature sensitive phase when, there may be possibilities that cell differentiations and proliferations get affected due to the impact of temperature changes. Global warming is likely to create favourable climate conditions for the growth of causative organisms and thus increased ambient water temperature is likely to cause a rise in the responses of disease occurrences spread by vectors. Similarly alterations in other sensitive water quality parameters such as ammonia, air and water temperature may have pronounced effect on feed utilization efficiency, growth and even on the sensory qualities of the cultured fish species. Concerted efforts in aquaculture research to reduce the vulnerability of aquaculture due to the impact of climate change (variables like solar radiation and air temperature) are therefore vital to make aquaculture more resilient.

Production system diversification

Till now most of the aquaculture developments has taken place in the perennial as well as well-maintained ponds across the country. But such quality of the aquaculture resources is becoming scarcer with the time. The increasing demand of the fish needs to be produced from the difficult production environments like multiple use ponds, irrigation bodies, irrigation channels, water harvesting structures, seasonal water bodies, farm ponds etc. The extent of the water available in these water bodies is huge but the challenges for the aquaculture development in them are quite significant. Both technological as well as policy support are required to develop these water bodies particularly in the context of the developing multi-stakeholders management system. The technology like stunted fingerlings, portable hatcheries, minor carps culture, small cat fish like magur and murrel culture, pen and cage culture etc. are the options that will be increasingly used to develop aquaculture in these water bodies. Therefore, the diversification of the production system is the bell of the day.

Wastewater recycling and reuse in aquaculture

Water (next to air) is the most indispensable resource for ecological sustenance and everything on earth needs water as it has no substitute. A tiny fraction of our planet's abundant water resource is only available to us as freshwater. Increasing pressure on freshwater resources and real water requirements necessitates sound water management in order to ensure sustainable use. The expansion of freshwater aquaculture will certainly be difficult unless water resource management through reuse, wastewater recycling for increasing productivity by obtaining more values per unit water used are considered mandatory and water should not be withdrawn from groundwater sources faster than it is replenished through natural hydrological cycle. As the population grows, there will be a proportional reduction in the per capita availability. Again, on the other side, because of improvement in living standards and rise in agricultural and industrial growth, India is likely to approach a regime of water stress in the foreseeable future .To be able to combat such a situation, increasing water productivity by obtaining more value per unit water need to be ensured. Water productivity broadly denotes the outputs (goods and services) derived from a unit volume of water. One of the greatest potentials for increasing water productivity lies in the judicious management of surface water and groundwater resources for conjunctive use provided this leads to better distribution of water. Wastewater offers assured source of water supply to otherwise water-stressed urban hinterlands for production of human food of very high biological value through aquaculture.

It is not only the people who are threatened by water shortage and environmental degradation, but also freshwater ecosystems like seasonal wetlands which harbour the world's greatest concentration of species. These are the most vulnerable on the earth. Sewage-fed aquaculture which has been practiced in Kolkata since long without prior chemical or biological treatment play a great role in water quality improvement. With the increasing population in the country, the quantity of wastewater generated has been increasing beyond the treatment capacities, apart from host of industrial effluents and solid wastes in recent years. Intense efforts are being made at treating the domestic sewage to make the effluents suitable for discharge into the natural waters. Technology for treatment of raw sewage involves mechanical, chemical and biological process. In mechanical process, there is an involvement of huge finance and in chemical process; there is a chance of harmful effect on the environment. On the other hand, biological treatment involves systematic use of natural activity of the bacteria for biochemical reactions. The mechanical and chemical processes are widely used for treatment of domestic sewage; the latest one is the Up flow Anaerobic Sludge Blanket (UASB) process. The traditional practices of sewage recycling through agriculture, horticulture and aquaculture, being basically biological processes, have been vogue in several countries. The emphasis in these practices has been on the recovery of nutrients from the wastewater for fish and prawn production.

In this context, low value water from various sources such as dairy, brewery, rice mill, food and beverage plants, silk reeling industries have immense relevance and are preferred for incorporation in fish production through aquaculture in realizing the water productivity. Considering social and environmental consequences, the package of practices could well be implemented to modify the present form of traditional practices adopted in several locations especially in urban fringes (peri-urban) to solve the problem related to higher land and energy requirements for treating the wastes. A large share of water to meet new demands must come by saving water from existing uses since this will have considerable use and interest in developing countries in the tropics in realizing the water productivity on human food production, crop diversification, environmental hygiene and finally poverty alleviation programme. Pilot scale on farm and on station researches on the efficacies of wastewater utilization in aquaculture indicated promising results vis-a-vis conventional feed-based fish production with added advantage of harvesting more crops per drop of wastewater.

Aquaculture, in particular, has a major role in providing basis for better human health. It is important that wastewater be recycled for production of fish wherever possible since fish raised in such a system may be the cheapest and best source of edible animal products thereby imparting economic, biological and environmental benefits accrued from waste recycling.

Genetic and biotechnological interventions

Modern developments in genetics and biotechnology have great potential to increase food production efficiency in the context of aquaculture. It has already been proved that selective breeding procedures can improve economic traits, such as growth, disease resistance etc. in fish. DNA marker-based approaches have shown high potential to support the conventional selective breeding system in augmenting genetic up-gradation of cultured stocks. Further, efforts are also in full swing to identify, characterize and isolate abiotic stress (such as high temperature, low oxygen and high salinity) tolerant genes from fish. CIFA has already made a mark in most of these modern approaches, and by the turn of 2030, the institute is expected to dish out technologies for field applications.

SWOT analysis

Strengths

The country has rich freshwater aquaculture resources in terms of 2.36 million hectares of ponds and tanks and 1.30 million hectares of beels, jheels and derelict waters, in addition to 0.12 million km of canals and 2.05 million hectares of reservoirs, that could be put to different fish culture practices or even culture-based capture in case of large water sheets. At least 25-30 species of freshwater fish are ready or potentially ready for culture. In addition to Indian major carps, minor and medium carps, air breathing fishes, freshwater prawns and bivalves have strengthened the freshwater aquaculture species base. There is a host of standardized technologies to augment fish production in different water bodies. Mono culture, polyculture and integrated farming systems enable the fish farmer to achieve high production according to system requirements. CIFA has proven track record in multidisciplinary approach for increasing fish production – the institute is involved in research on aquaculture production systems, nutrition, physiology, genetics, biotechnology, microbiology, pathology, pond environmental monitoring, aquaculture engineering and social sciences, and has developed a host of technologies through multidisciplinary approaches. The institute has well-developed infrastructure facilities including large experimental fish farms, scientific and technical expertise, Regional centres in different ecological regions, large number of externally-funded projects including substantial funding from the international organizations, as well as KVK for dissemination of technologies.

Weaknesses

At national level, some of the prominent weaknesses include: Non-availability of proper database in freshwater aquaculture resources and systems, domination of freshwater aquaculture by only a few low-valued fish species, weak linkages & networks between research and development machineries in the freshwater aquaculture sector, weak extension network for transfer of technology and provision of feedback mechanism, non-availability of leasing policy for community water bodies, social issues hindering the aquaculture development, inadequate infrastructure facilities and input availability, non-availability of adequate credit facilities, and non-Availability of aquaculture insurance schemes. Further, there is no well established value chain-based aquaculture system in the country. At Institutional level, CIFA is facing manpower shortage, and it is becoming increasingly difficult for the Institute to meet the growing demand of different states for technological support, besides carrying out envisaged research programmes. Lack of adequate farm mechanization is another weakness, given the fact that the institute has vast area and several fish ponds to be managed almost exclusively by man.

Opportunities

The country has the potential to increase fish production from the present level of about 2t/ha/yr to 5t/ha/yr through technology-driven and mission mode approaches & strategies. There is great scope for species and system diversification. CIFA has proven track record of increasing production efficiency through selective breeding, a good example being *Jayanti*, the improved variety of rohu, which exhibits about 85 % gain. The traditional breeding programme can be complemented with marker-assisted selection at whole genome level with the advent of technologies. Other opportunities include integration of freshwater aquaculture with other farming systems and livelihood enhancement for marginally small and poor farmers and providing nutritional security.

CIFA is a premier Institute in freshwater aquaculture which has evolved several epoch-making research contributions for development of freshwater aquaculture in the country. As a Lead Centre in carp farming of the Network of Aquaculture Centres in Asia-Pacific (NACA), the Institute has also shown its presence felt globally. With improved facilities and implementation of innovative programmes, the Institute possesses every potential to become a centre of excellence for tropical aquaculture. The Institute has been organizing several international training programmes for the developing countries of South-east Asian Region. With the facilities and expertise, the Institute can be a Lead Centre for research, training and consultancy in different aspects of aquaculture, especially for the tropical Afro-Asian and Latin American countries.

Threats

The nation faces threat from unauthorized introduction of exotic species into culture systems. For example, entry of African catfish, *Clarias gariepinus*, which is known to be highly predatory and also cannibalistic, into our water systems can lead to disastrous consequences on natural biodiversity. Contamination of natural water bodies, inbreeding depression in fish stocks due to faulty hatchery management practices, emergence of diseases, habitat destruction and the consequent depletion of natural fish resources, excessive application of antibiotics and chemicals, natural disasters, etc. pose serious threat to aquaculture development in the country. CIFA faces threat from inadequate human resources to manage its vast infrastructure facilities as well as research and extension programmes.

CIFA 2030

In view of the increasing demand of fish foreseen for the future in the backdrop of changing global trade scenario, decreasing natural resource base and impending climate change, aquaculture research for the next 20 years needs to be reshaped and reoriented to convincingly meet the emerging challenges. Advent of the latest scientific technologies in the field of genetics and biotechnology would effectively support such endeavours.

The present document on Vision 2030 with the vision and mission as follows has taken note of all the above aspects for prioritization and reorientation of the research programmes of the Institute.

VISION

Making Indian freshwater aquaculture globally competitive through eco-friendly and economically viable fish production systems for livelihood and nutritional security.

MISSION

Excellence in research for developing sustainable and diversified freshwater aquaculture practices for enhanced productivity, quality, water use efficiency and farm income.

MANDATE

The mandates of the Institute are as follows:

- To conduct basic, strategic and applied research in freshwater aquaculture;
- To enhance production efficiencies through incorporation of biotechnological tools;
- To undertake studies on diversification of aquaculture practices with reference to species and systems; and
- To provide training and consultancy services

FOCUS

With a view to accomplish the vision and mission of the institute, CIFA emphasizes several programmes to enhance fish production through system & species diversification and technology interventions. National broodstock upgradation, quality seed production, national dissemination programmes, round the year production of fish seeds, fish feeds made from locally available cheap ingredients, disease surveillance & remedy to crippling diseases, such as argulosis, harnessing recent developments in fish genomics, impact assessment, etc. are among the future research priorities of the institute. Capacity building of human resources including scientists, farmers and other stakeholders is always a priority to us, so as to be globally competitive and ensure food and nutritional security of the country.

Harnessing Science

It is essential to harness the available fish knowledge to enhance the fish productivity, tolerance of abiotic stress factors, broodfish and seed quality to meet the future demand of freshwater fish in the domestic and international markets. Issues related to input use efficiency, sustainable management of fish-based production systems, health management, feeds & nutrition and value addition would continue to be addressed with the availability of newer research techniques, tools and technologies. The growing population demands a reorientation of the research efforts in aquaculture production systems to ensure high productivity with less water and labour, with environment-friendly technologies that are more resilient to climate change and minimize environmental footprints.

Aquaculture – a multidisciplinary subject would strive to enhance productivity, production, input use-efficiency, reduce cost of production, improve quality of eatable products as well as minimize risks/hazards and post-harvest loss etc. It would further user to realize diverse interests of various stakeholders involved in production and supply chain of fishery products. Demand is more due to rapid population growth when production and supply sources are in declining phase as such technological challenges become more complicated than earlier days. Science is also changing very fast with emergence of new techniques, methodologies and tools etc.

Climate change and bio risk cause threat or adverse impact on production target due to several factors *viz.*, Cyclone, flood and drought etc) caused by global warming. Sometime such adverse environment remains responsible for outbreak of diseases as well. Therefore effective and integrated risk and disaster management as well as institutional mechanisms are to be developed in order to save the crop and protect farmers from their financial loss incurred.

Culture and breeding technology vis-à-vis seed production is the prime and critical part of aquaculture practice needs species diversification to augment production by ideally utilizing the pond ecosystem. Therefore culture trials on minor carps, a few murrels and other small and miscellaneous fish species are to be initiated for their production, propagation and conservation too. Aquarium fishes are of utmost importance from their controlled breeding point of view for maintenance of their quality seed and also to safeguard the germplasm with seed certification.

Feed formulation and preparation need to be stressed upon specially for larval rearing with particular reference to its cost after using locally available low cost feed ingredients. Feeding strategies are yet to chalked out for different maturity stages along with quantification of requirements of indispensable amino acids, vitamins and mineral mixtures for diversified species as well as deciphering the role of gastro-intestinal hormones on feeding rhythms, regulation of the expression of genes related to increased carbohydrate utilization and biosynthesis of the highly unsaturated fatty acids.

Biotechnology and genetic engineering would play vital role in enhancement of aquaculture production. Traditional selective breeding in aquaculture can be supported by molecular genetic tools in order to reduce time, space and investment on one side and to assure sustainability on the other. This will come about from greater survival or from faster growing animals or from a combination of attributes. There has been a paradigm shift in the approach to trait associated gene identification with the advent of high throughput genomics platforms and associated technologies. Therefore, the future of marker assisted breeding schemes in fish would lie in the prediction of total genetic value with highest precision by developing and using genomic resources.

Research in immunology and virology of fishes at cellular and molecular level is an important aspect and requires much attention. This will provide information towards quarantine protocols, development of diagnostic tools, immune related genes and their roles in host - parasite interactions, preparation of vaccine, medicines etc. and thereby protecting the crop from infections and diseases caused by worms, viruses, bacteria and protozoa etc.

Biodiversity and natural resource is a wide spread concern. The natural resource is now in dwindling state where the entire aquaculture practice solely depends on the natural source. Efficient farming and judicious utilization of natural resource, organic farming, use of vermi compost, proper management of feed nutrient and water will prevent hazards and outbreak of diseases. Enhanced participation of the stakeholders and eco-friendly literacy programmes would be given priority for protection of natural resource.

Wastewater use through treatment and recycling deserves special attention as a vast wastewater resource is available in different metropolitan cities. Its utilization, perhaps, is the cheapest and best source to produce edible food products thereby imparting economical, environmental and biological benefits accrued from wastewater.

Post-harvest technology and value addition is an area that has not yet received much attention in freshwater aquaculture sector. The subject has a major role to save wastage of eatable commodities of low grade (economically less important) by converting those as value added products to serve the customers of their choice. A huge quantity of fishes and prawns are wasted while transporting and these are perishable as well. Some fishes in their original body colour and taste are not liked by many as such these need to be processed and value added for human consumption. Nano-technology has great potential to revolutionize the field of fish processing.

Human resource developments is a pre-requisite for implementation and upgradation of research programmes, developing technologies, involving institutional arrangements to the challenges ahead and harnessing opportunities. Such science is vertical in nature to improve the quality of human resource and therefore state of art infrastructure and competent faculty positions are essential.

Institutional policies are to be framed for accelerating innovations, ensuring food security, enhancing livelihood opportunities of smallholders and also for conservation of natural resources. Steps are needed in the wake of rising population trend, growing small holdings, increasing uncertainties and emerging private sectors' participation in agri-research and agri-business.

Transfer of technologies continues to strive for development of new, ideal and efficiently better technologies. Futureof this science depends on well acceptance of developed technologies by the farming communities.

Strategy and Framework

Controlled breeding after using same population over the years results in poor genetic base leading to retarded growth and low disease resistant variety due to inbreeding depression. Therefore, replacement of parent fishes should be mandatory at every two years while in use for commercial purpose. Improved stock of cryopreserved milt can be used in gamete exchange programme. Selective breeding of other candidate species like catla and mrigal as well as freshwater prawn, like *Macrobrachium rosenbergii* should be undertaken in similar fashion as that of rohu, Jayanti which has 17% higher growth per generation after seventh generation.

Emphasis needs to be given to development of modern biological tools and resources that can complement traditional selective breeding in order to produce heavier and healthier fishes. Major emphasis is to be paid for propagation and conservation of endangered fish, prawn and molluscan species including small indigenous freshwater fishes (SIFS). Despite of concrete seed production technology already in operation, country faces acute shortage of stocking material of the desired species. Such deficit of fingerlings could be over come by establishing seed bank in those areas of the country where such problem exists.

Although the intensive carp culture technology could make it possible to achieve 17t/ha/yr against the national average 2.2t/ha/yr, such technology is yet to be transferred through extension service after making proper assessment of cultivable freshwater resources. There exists still enough scope for expansion of aquaculture in horizontal and vertical ways. A perspective plan for aquaculture development is necessary and it is to be implemented with support from state, and at national level with support from the National Fisheries Development Board the National Fisheries Development Board (NFDB).

The technology of sewage-fed fish culture, though well practiced in east Kolkata wetlands since long and yet to be adopted/practiced in other cities with sewage systems after treatment of water through recycling. This requires region-wise studies as a basis for the quality of the produce for human consumption. It further demands environmental research with particular reference to wastewater utilization and application of bio-filtration in aquaculture.

In order to utilize the tropic niches of pond ecosystem the country is blessed with a lot of freshwater fish species namely *Labeo fimbriatus, L. bata, Cirrhinus cirrhosa, Puntius kolus, P. sarana* and *P. jerdoni* etc. which deserve special attention for their inclusion in aquaculture practice as already made for some IMCs and ECs (exotic carps). Diversification of culture of these species needs to be undertaken on a regional basis.

While seed production and culture technologies for some fish species viz. *Clarias batrachus, Heteropneustes fossilis, Ompok pabda, Pangasius pangasius* have already been attempted, perfected and refined but still more fish species deserve similar attention for their culture, breeding and seed production technologies which are yet to be developed and disseminated.

Freshwater prawn species having high domestic consumer preference as well as export potentials need more attention with regard to supply of stocking materials for culture. As such establishment of a chain of prawn breeding hatcheries are highly needed to meet seed demand. Therefore, high priority is to be given for such activity with public-private partnership, if needed, including development of appropriate feeds.

Organic farming practices with maintenance of sustainability and minimization of spoilage of ambient environmental quality is an area which needs to be carefully looked into and package of practices to be developed.

Farm mechanization/technicalization in aquaculture practices particularly for pond construction, water management, aeration, feed dispenser and fish harvest etc. are to be stressed further since the initiation has already been done.

Feed formulation and preparation for both shell and finfishes in commercial scale is yet to be explored after utilizing locally available ingredients suitable for various growth and maturity stages of fishes. Long term research programmes on nutritional aspects, feed formulation and dispensing on behavioral as well as digestibility patterns are to be undertaken for better input use efficiency. With regard to larval prawn feed and feed for ornamental fishes. The stake holders still depend on imported feed. Preparation of such feed indigenously should be taken up on a priority basis.

Instead of depending on application of chemicals, pesticides, insecticides and antibiotics to control fish-prawn diseases this has become imperative to study in detail the host-parasite relationships at molecular level, serodiagnosis and immunoprophylactic measures etc. to prevent and control diseases in commercial farming.

India's contribution in export market of aquarium fishes is 0.1% although the country has huge potentiality with around 300 indigenous species and there are almost equal numbers of exotic species but still we lag behind in development of their proper breeding and seed production technology especially quality one. Such lacuna is yet to be stressed upon to safeguard the germplasm and certification of seed is needed as well.

Processing and post-harvest technology in the field of freshwater aquaculture followed by value addition are absolutely lacking in India. Therefore such field of specialization should receive immediate attention as a part of research in aquaculture.

The database of freshwater potential resources, their productivity and production from different water bodies namely ponds, tanks, beels and jhils etc. are yet to be updated. Moreover, the national basis network for such purpose is lacking except some attempts have already been made by CIFRI, Barrackpore and IIM, Ahmedabad. Systematic and periodic survey of freshwater aquaculture resources is highly needed so as to fill such void. Therefore, electronic, remote searching and computer technology are to be pressed into service for such purpose.

Transfer of technology from lab to land or from experimental result to field demonstration is one of the important aspects in extension work which inspires farmers for learning by doing. Therefore viable technologies are to be transmitted to the mass through KVKs, training programme, farmers' meet, farmers' day and published manuals in local languages. A strong foothold is required by making collaborative approaches with different agencies namely FFDA, State Fisheries Departments, NGOs, and SHGs so as to extend all possible useful tips (on aquaculture) which can reach up to grass root level or village level farmers. Such programmes are to be arranged in different agro-climatic zones as well as considering farmers' need and consumers' preferences.

Further emphasis, efforts and attention are to be devoted so as to make the aquaculture activity as an organized one although appreciable development and achievement have already been made in this sector as we find in case of Punjab, Haryana and Andhra Pradesh but CIFA in collaboration with other agencies can take initiative to prepare a blue print on national basis so as to gear up national average production to 3-4t/ha/yr from 2.2t/ha/yr. Inputs and financial support is to be provided to those who remain associated with agriculture. That means aquaculturists should be at par with agriculturists in terms of facilities subsidies provided to them.

All proven technologies related to aquaculture development are to be implemented in different agro-climatic zones involving all irrespective of caste, creed or sex. All backward communities, NGOs, women and State Fisheries Departments are to be involved in specific operational and developmental projects.

Scenario on climate change over the world is a challenge or threat to all living beings including aquatic organisms whose normal life cycle is being hampered as such the challenge is to be harnessed/mitigated with the situation through study and research.

CIFA can play a pivotal role in planning and guiding a sustainable and economically viable production system in the wake of public private partnership when the entrepreneurs and large farmers of various states could be encouraged to involve themselves in different activities associated with aquaculture industry.

Epilogue

CIFA is pro-active and committed to meet the challenges ahead through the adoption of the frontier research areas including development of production system for efficient use of nutrients and water, enhanced biotic and abiotic stress due to impact of climate change, achieving rapid growth rate of cultured fish following nutritional principles, development of an integrated, cost effective marker assisted breeding plan through the application of biotechnology, concerted and integrated efforts with effectiveness and efficiency to meet the ever increasing demand ensuring the code of responsible aquaculture. These are aimed to meet the needs and aspirations of stakeholders and to strengthen the sector further.

References

CIFA (1999) National Freshwater Development Plan. Central Institute of Freshwater Aquaculture (ICAR). Bhubaneswar

Delgado, C., N. Wada, M. Rosegrant, S. Meijer and M. Ahmed, 2003. *Fish to 2020: Supply and Demand in Changing Global Environments*. International Food Policy Research Institute and WorldFish Center: Washington, D.C. pp. 226

FAO 2009. The State of World Fisheries and Aquaculture. *FAO*, Rome. 176 p.

ICAR. 2006. Handbook of Fisheries and Aquaculture. Indian Council of Agricultural Research, New Delhi.

NCAP. 2008 Exploring market opportunities for fisheries sector in India: A Report of the Research study funded by National Fisheries Development Board. National Center for Agricultural Economics and Policy Research (ICAR). New Delhi

Annexure 1: Strategic framework

Goal	Approaches	Performance measure
System and species diversification and prioritization	National brood stock up-gradation programme	Technology packages
	Quality seed production & national dissemination	
	Grow out technology packages	
Genetic up-gradation of prioritized cultivable stocks	Selective breeding programme in more number of species	Genetically improved stocks
	Development of genomic resources towards MAS	
	Seed certification & quality evaluation	
Availability of cheap farm made fish feed for prioritized cultured species	National feed testing and referral system	Feed samples
	Development of larval, grow out and brood stock feeds	Formulations
	Molecular & biochemical approaches to study carbohydrate utilization and biosynthesis	Genes regulating carbohydrate utilization and biosynthesis
	Neuroendocrine regulation of reproduction	Multiple spawning
Fish and shellfish health management	National disease surveillance programme	Locations and frequency
	Development of cellular & molecular approaches for disease diagnostics and vaccines	Diagnostics and vaccines
Water and wastewater management	Waste water treatment and bioremediation	Diversified waste water aquaculture systems
	Water budgeting	Efficient utilization of water
Farm mechanization and automation	Harvesting and feeding mechanization	Mechanical implements
Socio-economic impact and policy research	Impact assessemnet of developed technology	Number of technology assessed
	National and regional consultations	Number of consultations made

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