



Vision 2050



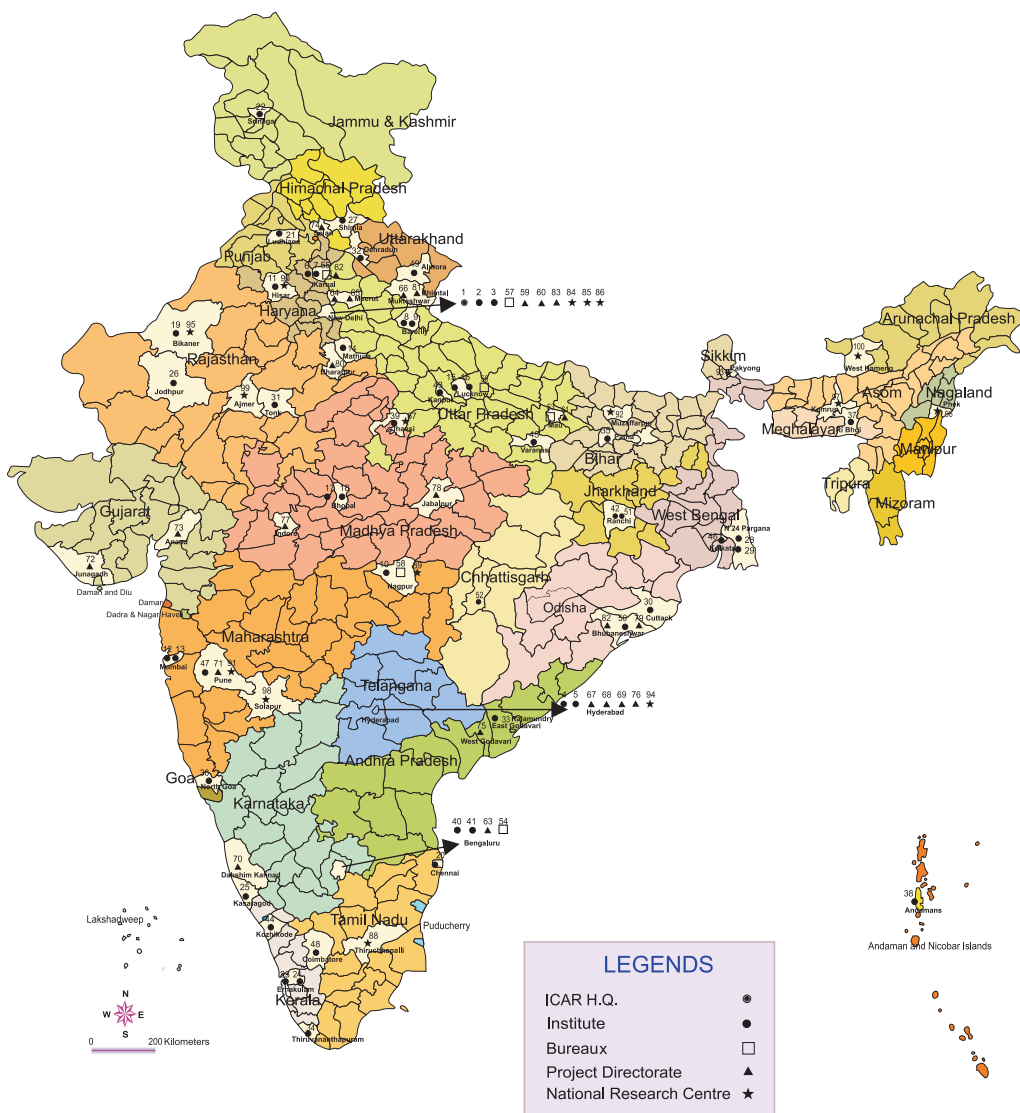
Directorate of Coldwater Fisheries Research
Indian Council of Agricultural Research





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Vision 2050



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www.dcfrr.res.in

Printed : July 2015

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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।

Ramesh Chandra Mehta

(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-Directorate of Coldwater Fisheries Research (DCFR), Uttarakhand 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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Preface

India is naturally endowed with many streams, rivers, lakes and reservoirs in the high and mid altitudes of the Himalayas and Western Ghats. The oxygen rich, cool and coldwaters of the mountains harbour a distinct group of indigenous and introduced fish fauna that form the valuable coldwater fisheries resource of the country. Since its establishment in 1987, the ICAR-Directorate of Coldwater Fisheries Research has been entrusted with the responsibility of spearheading research and imparting pragmatic inputs to enhance and sustain coldwater fisheries and hill aquaculture production in India. From a humble beginning, the directorate has undertaken comprehensive initiatives towards scientific management of fishery resources, safeguard of coldwater habitats, aquaculture expansion through technological interventions and knowledge transfer to uplift the socio-economic status of less privileged communities inhabiting the rugged geographic terrain.

The remarkable accomplishments of the directorate over the last three decades of its existence include meticulous exploration and documentation of fish biodiversity, aquatic ecology and hydrobiology in remote locations; geographic information system based assessment and mapping of coldwater resources; molecular characterization of coldwater fishes and their inherent variations; successful breeding, rearing and seed production of several indigenous coldwater fishes such as mahseer, snow trout and minor carps; enhancement of natural fish stocks through ranching; development of aquaculture in access restricted places; overtures like open water cage culture; customised feeds and feeding schedules for candidate species; disease surveillance and health management in farming systems; exhaustive nutrient profiling of food fishes; technological inputs for water management; environmental impact assessment services; modelling fish based ecotourism; human resource development through training programmes and workshops; and partnership mode outreach activities.

On the other hand, there are several new challenges to confront and offset in the upcoming years. Apart from the prevalent subsistence and recreational fishing, commercial fisheries are sparse and the production is low. Even so, indiscriminate fishing and deterioration and destruction of natural habitats have depleted fish populations in many coldwater streams, rivers and lakes. Climate change is another alarming concern due to its potential impact on the biology, diversity, distribution and abundance of native fish fauna in the coldwater ecosystem. In farmed fishes, the shifting thermal regimes may impair growth;

aggravate stress; and cause disease outbreaks and mortality. Hill aquaculture is progressively recognised as the primary source of nutritious and healthy animal protein in the uplands, but a major constraint for culture expansion is the reduction in land holdings and the imminent scarcity of water and other inputs. Lack of proper infrastructure further hinders the evolution and development of aquaculture practices in the harsh landscape. Also, intrinsic characteristics such as slow growth and low fecundity of the highly preferred indigenous fish species (snow trout and mahseer) impede their farming prospects. Lastly, the natural disasters that occur often have forlorn consequences on hill aquaculture and the ecosystem.

Given the ever increasing demand for fish and the changing food habits of the upland inhabitants, the above challenges have to be addressed with a science driven systematic vision. Hence, utmost care has been taken in drafting the vision 2050 document to envisage a rational course of research and development activities to be pursued by the Directorate. This document will provide the stakeholders an outlook of the perceived solution oriented approaches. It further emphasizes the significance of ongoing research programmes with respect to planned future endeavours that would keep pace with the emerging challenges.

Some of the focal points of our vision are identification, development and maintenance of resource centres for endemic fishes in different hill states; generation of aquaculture site suitability maps and a complete package of culture practices specifically suited for different regions; domestication through closed life cycles; broodstock improvement programmes with biotechnological basis; development of climate resilient fish and resource efficient culture systems; promotion of post-harvest value addition and market intelligence; setting up disaster management systems; fostering international cooperation among neighbouring countries with common resources; capacity building and women empowerment. By and large, the primary goal is to augment fish production in Indian uplands through manifold measures that will withstand the test of time.

I would like to express my sincere gratitude to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR for his continuous support and visionary guidance in this endeavour. I am also grateful to Dr. B. Meenakumari, Deputy Director General (Fisheries) and Dr. S.D. Singh, Assistant. Director General (Inland Fisheries) for their valuable suggestions and astute supervision while drafting the “Vision 2050”. My sincere thanks and appreciation are also due to my colleagues Dr. Prem Kumar and Dr. Biju Sam Kamalam, Scientists, for their untiring efforts in preparing and bringing out this document.



(A.K. Singh)

Director

DCFR, Bhimtal

Contents

<i>Message</i>	<i>iii</i>
<i>Foreword</i>	<i>v</i>
<i>Preface</i>	<i>vii</i>
1. Context	1
2. Challenges	13
3. Operating Environment	17
4. Opportunities	19
5. Goals and Targets 2050	21
6. Way Forward	29

Context

The expanse of coldwater fishery resource in India is spread across mountainous areas of the Himalayan range extending from Jammu & Kashmir to Arunachal Pradesh in the north (approx. 2500 km east to west) and along the Western Ghats in the south, comprising an overall area of 5,33,604 km². The geographical area and the population inhabiting this region accounts to about 16.2% and 4% of the total land area and population of the country, respectively. The coldwater resources are distributed mainly in the form of upland streams, rivers, lakes and reservoirs that are located in high and low altitudes of different hill states such as Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, Assam and West Bengal. As of now, these coldwater resources are known

Resource management, species & system diversification in aquaculture, human resource development and combating climate change are the highlights of the vision 2050.

to harbour a diverse group of fishes belonging to 258 species, 76 genera and 21 families, constituting approximately 17% of the total fish fauna of the country. Out of these, 203 species have been recorded from the Himalayas and 91 from Deccan plateau. Among the recorded species, schizothoracids and mahseer support sizable capture and sport fishery in rivers and lakes. Aquaculture is restricted mostly to carp culture in mid-hill coldwaters and rainbow trout in comparatively higher altitudes. Presently, trout farming is in developing phase and would be a good venture of lucrative business in future. The Directorate of Coldwater Fisheries Research has made significant contributions towards documentation of fish fauna; assessment of resources; breeding and culture practices of selected species; and technology transfer. On account of population upsurge and urbanization the demand for fish has significantly increased over last decades. The coming decades are expected to pose newer and greater challenges for livelihood and nutritional security in the hills. To fulfil the impending gap between supply and demand of fish, the challenge ahead is to develop complete package of practices of fish farming that can be disseminated in the field. Presently, coldwater sector contribute about 75,000 MT which is about 1.5% of total inland fish production. The mission of the directorate is to enhance the production level up to four fold by 2050 through judicious

and technological management of coldwater fishery resources, efficient production technologies and models of hill aquaculture in the context of climate change, and providing training & consultancy services for holistic growth of the sector. The vision 2050 mainly emphasises on the following points:

- Scientific assessment, evaluation and management of the Himalayan aquatic resources.
- Domestication, mass seed production and technology transfer for production enhancement of highly preferred coldwater fish species.
- To develop package of practices and climate resilient models of aquaculture system.
- Skill upgradation, human resource development, consultation and regional collaborations.

How the Institute has progressed

Central Inland Fisheries Research Institute (CIFRI) had started a unit on coldwater fisheries in 1963 keeping in view the necessity to assess and utilize the fisheries resources available in the sector. Due to the recognised importance of the hill resources, the unit was given the status of National Research Centre

The journey of DCFR started as a unit of CIFRI, became NRCCWF in 1987 and then elevated as DCFR in 2008. The Directorate has commendable achievements to its credit in resource assessment, culture practices, species diversification & technology transfer.

on Coldwater Fisheries (NRCCWF) in 1987 during the VII five year plan. The working area primarily includes the Himalayan region right from Jammu & Kashmir to Arunachal Pradesh and part of Nilgiri and Munnar hills. Since its inception, the NRCCWF faced constraints in terms of manpower and infrastructure to expand its activities in the huge and complex geographic area. This was subsequently addressed during the XI plan, when the NRCCWF was given the status of Directorate of Coldwater Fisheries Research (DCFR) in 2008. The status facilitated the expansion of research and developmental activities in Himalayan states in a collaborative mode with state government and other agencies. The emergence of the Directorate was mainly to develop location, situation and system specific technologies by utilizing and augmenting the available resources in all the Himalayan states. Over the years, the Institute has carried out commendable work in basic and applied areas, which includes fisheries resource management, hill aquaculture, extension programmes, consultancy services and human resources development. The Directorate has been working in partnership with state fisheries department and

universities on several location and situation specific issues. This has resulted in valuable ecological and fishery database generation in lotic and lentic waters of upland regions, and culture techniques of various important upland endemic and exotic fish species. Chinese carps based aquaculture has been brought under the diverse carp culture through number of demonstrations in mid hills. Low volume high priced trout culture has been taken up and commendable progress has been made. Jammu& Kashmir, Himachal Pradesh and Sikkim are the leading states in trout farming. The Directorate has reframed its target for enhancing the production through expansion and intensification of aquaculture by developing package of practices and models for judicious management of open water bodies. The other important target is skill development of farmers to enhance their pivotal role in production.

Mandate

The Directorate has the following mandate:

- to conduct basic, strategic and applied research in coldwater fisheries and aquaculture
- to develop stock management models and culture technologies for major fish species
- to create awareness and provide training and consultancy

Vision

Coldwater fisheries and aquaculture should be an important socio-economic activity in upland region for livelihood security, especially through fish culture and eco-tourism.

Mission

To become a “Centre of Excellence” with the responsibility to assess and manage coldwater fishery resources, develop technologies and models of hill aquaculture and formulate strategies for holistic growth of the sector.

Achievements

The Directorate is working in a mission mode for the overall development of coldwater fisheries, in order to make the sector a sustainable livelihood option that provides nutritional security to the people inhabiting the hilly terrain. With a humble beginning, the Directorate has made significant contribution in documenting fish fauna and understanding the biology, nutrition, culture, breeding and management practices of selected species. Moreover, it has also

contributed in the assessment of existent coldwater resources. The achievements of the Directorate are summarized below under the following major thematic areas:

1. Resource assessment and management

- A digital database has been generated for the 258 fish species falling under 76 genera and 21 families, which are reported from the major river drainages. This tailor made software on coldwater fish species will assist in storing, retrieving and updating information.
- Field surveys have been conducted in high altitude rivers and lakes of Jammu & Kashmir, Arunachal Pradesh and Himachal Pradesh for exploring the possibilities of developing aquaculture and sport fishery.
- Exploratory surveys have been conducted to study the aquatic ecology, fish biodiversity and hydrobiology in various lakes and reservoirs situated in high altitude areas such as Nubra valley, Leh-Ladakh, Arunachal Pradesh and Sikkim.
- Resource map databases for Sikkim, Jammu & Kashmir, Uttarakhand and Himachal Pradesh have been developed using GIS and remote sensing.
- GIS based aquaculture suitability maps were prepared for selected areas in Uttarakhand and Sikkim to assist in site selection, planning and development.
- Molecular markers like RAPD, mitochondrial DNA and microsatellite markers have been developed for different fish species like *Tor putitora*, *Tor tor*, *Tor khudree*, *T. chelynooides*, *Schizothorax richardsonii*, *S. niger*, *S. progastus*, *S. plagiostomus*, *S. esocinus*, *Barilius bendelisis*, and *Garra gotyla*.
- A total of 2591 nucleotide sequences (524 mtDNA, 173 microsatellite, 1031 ESTs and 5 complete CDS) have been isolated and deposited to NCBI GENBANK. These markers were successfully used in characterization of species and population, and will support future molecular breeding and genetic selection programs.
- ICAR-Directorate of Coldwater Fisheries Research has described a new nemacheilid loach, *Schistura obliquofascia* from Uttarakhand by molecular and morphological characterization.

Fish & fishery resources have been assessed for their management, resource map database developed using GIS & remote sensing and molecular markers have been developed for species-population characterisation.

2. Aquaculture

Culture and breeding protocol for important fish species

The Directorate's accomplishments on different promising coldwater fish species are:

- Culture and breeding protocol have been developed for mahseer, snow trout and minor carps to maintain their abundance in the natural system and as part of conservation and aquaculture initiatives.
- Technical support for rearing and seed production of rainbow trout has been extended to the state fisheries departments of Arunachal Pradesh, Sikkim and Uttarakhand.
- Our field centre at Champawat has standardised the culture and breeding technology of rainbow trout and its mass scale seed production is carried out. The seeds are being supplied to private farmers and other state Govt. fish farms.

Breeding protocol for snow trouts, mahseers and minor carps have been developed. Composite carp culture and integrated fish farming in mid hills using low cost feed are propagated.

Species diversification in aquaculture

Species diversification in upland aquaculture is necessary for enhancing fish production. In order to meet the challenge, the Directorate has identified certain new candidate species and breeding protocol have been developed for chocolate mahseer (*Neolissocheilus hexagonolepis*), *Labeo dero*, *Labeo dyocheilus*, *Osteobrama belangeri* and *Semiplotus semiplotus*.

Culture and breeding of improved strains

Two new strains of common carp, namely, Ropsha scaly carp and Felsősomogy mirror carp were imported from Hungary in the year 2007 and reared in our experimental field centre at Champawat. Breeding and seed production have been successfully carried out, and the fry are being cultured at different locations as the evaluated performance strongly encouraged further propagation.

System diversification in aquaculture

- Fishery enhancement in open water bodies like lakes and reservoirs is of much significance to enhance the overall fish production.
- To address this issue, we have conducted studies to develop *in situ* seed rearing protocols in floating cages in Bhimtal lake.

Feed for aquaculture

Efforts have been made to develop feed for cultivable species like mahseer, snow trout, rainbow trout and carps. The feeds developed so far are:

- NRC-1, NRC-2 and NRC-3 for indigenous coldwater species like golden mahseer, *Tor putitora* and snow trout, *Schizothorax richardsonii*.
- The larval feed NANHE MAHSEER for golden mahseer.
- Feed formulation for rainbow trout has also been developed.

Fish Health Management

- In order to have an effective disease reporting and surveillance system, the Directorate has initiated studies to investigate fish pathogens that could potentially harm the coldwater farming sector. The outcome of the study would be used to combat infectious diseases by developing molecular diagnostic tests and vaccines, in the near future. So far the study indicates that coldwater fishes are safe from common viral diseases.
- The Directorate also envisages a referral disease diagnostic laboratory for coldwater sector.
- Clinical-epidemiological survey have also been conducted in different hill states to evaluate the health status of farmed coldwater fishes.

Potential fish pathogens are investigated under disease surveillance programme. Low cost grit filter have been developed for water recirculation. Nutrient profiling of food fishes are carried out. Cold tolerant genes have been characterised. Multi-tier culture system developed for mitigating water scarcity.

Fish as Food

- The whole body nutrient composition including profiles of fatty acids, amino acids, selected vitamins and trace elements have been studied for *Tor putitora*, *Neolissocheilus hexagonolepis*, *Oncorhynchus mykiss*, *Schizothorax richardsonii* and *Cyprinus carpio*, so as to determine the health benefits accrued for human consumption.

3. Adaptive response strategies

Temperature tolerance

- In order to elucidate the role of Glycerol-3-Phosphate Dehydrogenase (GPDH) gene in cold acclimation process in snow trout during winter months, GPDH gene was cloned from two snow trout species (*S. richardsonii* and *S. niger*). Among the congeneric species of *Schizothorax*, the highest expression was found in *S. richardsonii*.

Moreover in *S. richardsonii*, the qRT PCR showed highest expression in muscle followed by liver.

Water management and conservation

- The Directorate had standardized fish culture in polytanks which equally holds good for water harvesting, conservation and judicious utilization.
- A multi-tier model for fish culture using polytanks has been developed, which is suitable for small scale-farming systems in the mid hills.
- A low cost grit filter has been developed to recycle the pond water. It was found to be efficient in removing 70% physical impurities, alleviating ammonia build-up and improving dissolved O₂.

Numbers of trainings and demonstrations have been organised, mainly for north eastern region. DCFR has assisted State Govt Fisheries Departments for producing mahseer and trout seed, and is truly behind the Sikkim's success in trout farming.

Environmental impact assessment

It is well known that the ministry of environment and forest (MoEF) owns the responsibility of regulating and ensuring environmental protection; formulating environmental policy framework in the country; undertaking conservation & survey of flora, fauna, forests and wildlife; and planning, promoting, co-ordinating and overseeing the implementation of environmental and forestry programmes in case of hydro electric projects on river basins. For the latter purpose, the Institute provides consultancy concerning impact assessment on fish fauna and thereby assists in framing the environmental management plan. To name a few, the Institute has contributed in Keshang - Kerang integrated project, Kutehr project, river Alaknanda, river Sutlej, river Yamuna and Tons.

4. Human resource development

In fulfilling the mandate, the Institute has contributed significantly to human resource development through training programmes, seminars, workshops and exhibitions. The Institute publishes and distributes technical bulletins and pamphlets in English, Hindi and other regional languages on different aspects of fish farming and fishery management to help the stakeholders.

Research in partnership mode

In order to harness the coldwater fisheries potential of the country, the Directorate is working with five hill states in partnership mode,

a programme initiated during the XI five year plan. Comprehensive work has been initiated in the areas of resource assessment, expansion of trout farming, culture and breeding of indigenous coldwater species and identification of suitable sites for sport fishery. In collaboration with different state fisheries department and universities the Directorate has carried out the following works:

- Scientifically renovated state Govt. trout hatchery at Shergaon and Nuranang in Arunachal Pradesh and at Memenchu in Sikkim, for seed production.
- Established mahseer hatchery at Rowing in Arunachal Pradesh, Eco-camp, Nameri National Park, Tezpur in Assam and Bagua fish farm in Sikkim, for culture and ranching purposes.
- Reared brood stock of rainbow and brown trout at state fish farm, Bairangana and experimental fish farm at Champawat.
- Health monitoring and disease diagnosis in farmed trout stock from different coldwater states.
- Technical and financial support was provided to the department of fisheries, Sikkim, for brood stock development of rainbow trout. Brood stock of rainbow trout at Uttaray and Yaksum trout farm has been maintained. Through the joint initiative of DCFR and state fisheries department of Sikkim, around 200 farmers have adopted trout culture.

Research and development in north-eastern region

An extensive programme has been carried out in the north-eastern region of the country to extend the available aquaculture technologies to farmers for improving their farming practices and socio-economic status.

- Composite carp culture technology was demonstrated with three exotic carps namely grass, silver and common along with chocolate mahseer in Ziro and Dibang area of Arunachal Pradesh.
- The composite carp culture was popularised among the farmers of Dirang block in Bomdilla districts of Arunachal Pradesh.
- Community based paddy cum fish farming was popularised in Ziro district of Arunachal Pradesh.
- Studies have been conducted on the breeding behaviour and culture protocols of candidate species such as *Osteobrama belangeri*, *Semiplotus semiplotus* and *N. hexagonolepis*.

IPR cell was established during XI plan and working for protecting intellectual rights. Fish based eco-tourism model can be used for community development.

Protection of Intellectual Property

The institute has constituted a separate IPR (Intellectual Property Rights) cell to address IPR issues. Under the XI plan, the IPR cell was further strengthened to constitute the Institute Technology Management Unit (ITMU). The ITMU conducts workshops to keep the scientists updated on IPR issues and helps in protecting their Intellectual Rights.

5. Socio-economic contribution

Fish based ecotourism

Fish based ecotourism represents a non-consumptive use of biological resources that provides socio-economic benefits to the people. The hills naturally attract tourists due to their spectacular scenic beauty. Many picturesque valleys, riverbanks, mountains are available for trout or mahseer based sport fishery development. The directorate has worked towards developing suitable models for fish based ecotourism. Moreover, important sites having the potential to develop sports and angling facilities have been identified and worked upon.

How the Institute can help the system

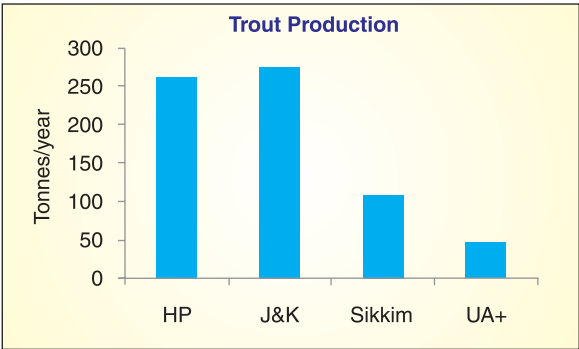
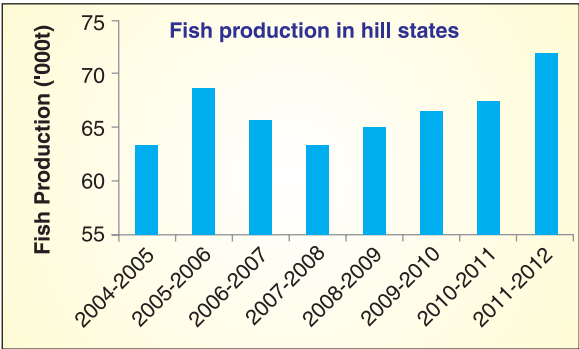
It is expected that the population of the country would increase to nearly 2.5 billion by 2050. Thus there is a big challenge to feed the anticipated growing population. Research and

development in coldwater fisheries and aquaculture has great potential for horizontal as well as vertical expansion. In the hill regions, fish represents an essential, often irreplaceable source of high quality and inexpensive animal protein, crucial for the balanced diet of the marginally food secure communities. Keeping in view the global, national and ecological changes, the Directorate is committed towards enhancing fish production in hills through intervention measures such as research, technological support, awareness programmes and frontline demonstration activities. In this milieu, the Directorate is continuously striving to document aquatic biodiversity in hill states and generate research information that helps in developing ecologically sustainable strategies for fish yield enhancement. It is also responsible for activities such as ranching in the deprived ecosystems and to develop model for sport and eco-tourism.

Providing nutritional security to the increasing upland resident population is our concern. Capture fishery has reached its potential, while aquaculture offers a lot of scope to increase the production.

In coldwater sector, capture fisheries occurs as subsistence

or recreational fishing, therefore the production is low and small size fish are prevalent. In hill state reservoirs, fish catch ranges from 27 to 149 kg per hectare. Aquaculture, on the other hand, is often an allied activity where fish are grown in irrigation ponds for additional income. On the whole, the total fish production in hill states accounts for merely 1.5% of the country's inland production. This scenario highlights the immense untapped



potential for fish production in the coldwater sector. For instance, production of high value farmed rainbow trout is nearly 700 tonnes and offers plenty of scope to be increased at least ten times by 2050. Popularization and commercialization of trout culture has to be taken up on priority basis, along with technological advances to enhance per unit productivity. Development of closed life cycle and culture protocol for indigenous fish species having good market value and consumer acceptance is also warranted. Moreover, sustained investigations should focus on enhancing the productivity of open water bodies through managerial interventions and *in situ* conservation and culture. Overall, the target is to increase the current total fish production up to four folds by 2050 and this will provide food security as well as employment opportunities.

Reason of 2050

Directorate of Coldwater Fisheries Research is identified as the premier Institute for undertaking research on hill fisheries. Its multi-dimensional and innovative efforts to manage the natural resources in hill states for sustainable fish production have been commendable. Besides,

improvement and management of aquatic resources through holistic approach and improvised research efforts, DCFR has been playing a vital role in livelihood security. India witnessed eleven fold fish production in six decade which

Climate change will be projected through documentation of impact broadly across ecosystems including fisheries and aquaculture. Aquaculture assumes much importance in view of increasing population and depleting land resources.

could meet domestic demand and provide livelihood to 14.5 million people. It will be our endeavour to keep pace with the emerging challenges of the sector. Climate change is projected to impact broadly across ecosystems including fisheries and aquaculture. Aquaculture assumed much importance in view of increasing population and depleting land resources. The availability and access to fish supplies will become an increasingly critical issue. In view of the long-term perception and implications, it would be appropriate to put VISION 2050 to action for harmonizing the ongoing research programmes. This would definitely result in developing need based, location, situation and system specific technologies. The document would be useful for different stakeholders and planners of the coldwater sector. There is a vast scope and potential of improving fish production in hills. This can be achieved by bringing natural Himalayan lakes located at different altitudes, newly created and existing upland reservoirs under scientific management for fishery enhancement and, by bridging the gap between actual fish yield and production potentials. Through application of modern technologies, significant scope exists for promoting trout farming which, in long run, will have a demand in both domestic and export markets. Directorate has incorporated the present realities, potentials and future prospects in the coldwater fisheries of the country. The present vision aims to provide a solutions-oriented, systemic approach for closing research gaps. It is experienced that the low input composite carp culture in hills mainly is carrying out by the women. The institute will focus on women empowerment through capacity building and enhancing opportunities for women development. It will be our endeavour to keep pace with the emerging challenges of the sector. In view of the long-term perception, it would be appropriate to put VISION 2050 to action for harmonizing the ongoing research programmes. This would definitely result in developing need based, location, situation and system specific technologies. The document would be useful for different stakeholders of the coldwater sector. VISION 2050 emphasizes the importance of high value trout species that could be popularized among progressive farmers, industrialists and entrepreneurs for commercial production. The

vision of DCFR stresses upon judicious and scientific management of the Himalayan aquatic resources to overcome the impact of developmental activities in these fragile ecosystems. DCFR also has a noble vision of making coldwater fisheries and aquaculture into an important economic activity for upland regions for livelihood security and eco-tourism. However, in order to translate this vision to reality, the Directorate would require support in the form of finance, manpower, infrastructure and policy. Jacques Diouf, DG (FAO) sought that the animal protein consumption is expected to double in the first half of this century and expects strongest growth in the consumption of farmed fish and chicken. Therefore, there is a need of enhancing the production at least to four times from the sector by 2050 considering the demand and adversities of future.



Challenges

The Himalayan ecosystem will face the great impact of changing climate such as loss of species, changing in thermal regime and biology of the fishes. Reduction in land holdings and water availability change in farming system and change in food preference which are needed to be addressed through appropriate technologies and extension system to mitigate the implications. Ever increasing demand of electricity will have more impact on river biodiversity, which needs to be balanced with effective environmental management plans. The Himalayas region will face water stress, which is already being felt in some of the hill states, especially Uttarakhand, Himachal and Kashmir, where large number of underground spring water resources has either dried up or flows have drastically diminished. This problem is further aggravated in hills through injudicious water abstraction for various activities. In addition, the natural lakes in majority of Himalayan regions have become eutrophic with deteriorating water quality resulting in loss of fishery. Environmental and anthropogenic issues coupled with excessive fishing pressure and increasing demand is serious threat to total coldwater fishery sector. The following challenges are needed to be addressed:

Climatic stresses, water scarcity, reduction in land availability would be the challenges for coldwater fisheries.

Climatic Stresses

The Himalayan mountain ranges rise sharply from 200-300 m to over 8800 m and include world's highest peaks. Mountains are said to be the early indicators of climate change. Peaks above 5000 m are generally covered with glaciers. Besides hundreds of glaciers and permanent snow covered peaks, there are several of glacial lakes, and many large rivers and their hundreds of tributaries originate from glaciers. The impacts of climate change range from the direct effects of increasing CO₂ concentration and the consequent rise in the temperature and to the indirect effects through alterations in the hydrology caused by the melting of glaciers and ice covers, and the change in the precipitation regime. The impacts will differ along the altitudinal gradients with cascading influence at successfully lower elevations. According to a new study by Natural Resources Defence Council (NRDC) and Defenders of wildlife, global warming is likely to spur the disappearance of trout and

salmon from as much as 18 to 38 percent of their current habitat by the year 2090. Changing climate may also aggravate the disease outbreaks in coldwater fishes for which we have to be prepared in advance in developing molecular diagnostic kits and vaccines. Considering these facts, coldwater sector will have responsibilities of expansion of sustainable aquaculture activities for livelihood and nutritional security for uplands in context to water scarcity due to climate change. The expectations from the Directorate are judicious and scientific management of the Himalayan aquatic resources to overcome the impact of developmental activities in these fragile ecosystems.

Water availability

The forecasting studies conducted as a part of the World Water Vision, predicted that by 2025, water stress in entire world will increase to more than 60%. The report also indicates that entire India (except Brahmaputra basin) will be under mild to severe water stress. This implies that the Himalayas, too, will face water stress, which is already being felt in some of the hill states, especially Uttarakhand, Himachal and Jammu & Kashmir, where large number of underground spring water resources has either dried up or flows have drastically diminished. This problem is further aggravated in hills through injudicious water abstraction for various activities. Water conservation and management is an important area of research and development in the uplands. Therefore, due emphasis has to be given on water budgeting, management with closed culture system.

Reduction in land holdings

The agriculture in the hills is having limitations with a number of factors such as small land holdings, dependency on rain for irrigation and temperate climate. These factors force

Disease management, growth promotion and amenability to food preferences are the researchable issues for nutritional and livelihood security in hills.

the human resource to migrate from the hill to plain areas for earning their livelihood. To check this migration among the hill community for development and sustainable livelihood is the priority area. The per capita availability of land has declined from 0.89 hectare in 1951 to 0.37 hectare in 1991 and is projected to slide down to 0.20 hectare in 2035. As far as agricultural land is concerned the per capita availability of land has declined from 0.48 hectare in 1951 to 0.16 hectare in 1991 and is likely to decline further to 0.08 hectare in 2035. This decline in per capita land availability in the country is mostly on account of rising

population. In context to hill region the average land holding is 800 m² which is going to be reduced further due to developmental activities and land degradation. It is estimated that about 5,334 million tons of soil is eroded annually from the cultivable land and forests of India. Our rivers carry nearly 2050 million tons of silt, depositing approximately 480 million tons to the reservoirs causing eutrophication and reduction in water holding capacity. Multi-phasing fish farming, aquaponic and biofloc systems are capable ways of minimizing the land requirement.

Slow growth of coldwater fishes

In the coldwater sector, most of the hill states are at different levels of development with regard to fisheries and aquaculture. The States like Jammu & Kashmir and Himachal Pradesh during the last two decades have made significant progress in capture fisheries such as sport fishery, aquaculture especially of trout, and fishermen welfare and support services to the sector. In spite of these efforts the production is still very low as compared to the all India average. Therefore, in the planning process the fishery in hills needs to be given due importance in terms of financial, infrastructure and modern institutional back-up facilities. Majority of the coldwater fishes are caught from the rivers and streams in small quantity thus do not form fishery of commercial importance but they are indicator of river ecosystem. Breeding techniques of indigenous snow trout and mahseer were developed and were tried to introduce in culture practices but as they have shown very slow growth. Genetic improvement programme in these species are to be taken up using genomics and transcriptome profiling. The institute has taken up work on molecular genetic characterization of snow trout and mahseer from different geographical locations to identify the population with high genetic diversity which would be used in genetic improvement programme in future. This gives great opportunities to develop improved strain to enhance their growth in hill regions.

Fish Health

There is a possibility that due to rise in water temperature, in future, we may not encounter the existing viral diseases like infectious pancreatic necrosis, infectious hematopoietic necrosis, viral hemorrhagic septicaemia, koi herpes virus, spring viremia of carp etc. that usually occur at temperatures below 15°C but the possibility of emergence of new viruses cannot be ignored for which we need to be prepared. In order to have a healthy fish produce and to keep the fish diseases at bay, regular, strict disease surveillance and reporting programme has to

be strengthened. National Referral Coldwater Fish Disease Laboratory at DCFR Bhimtal would lead the disease investigation centres in different coldwater regions/ states to enable quick response to the disease besides effective sampling and diagnosis.

Food Preferences

Changing trend of the food habit of the Indian population may increase the demand of fish as cheap and best source of protein. Initial findings of network project over nutrient profiling of the fishes has proved that the fishes have quality protein, fatty acids and micronutrients which are essential to human health and brain development. Therefore, the fish would be used as nutrient supplement as well as nutritional therapy in the near future. With refined package of practices, culture of high value trout would be popularized among progressive farmers, industrialists and entrepreneurs for commercial production for local market and export purposes to earn foreign exchange. Development of harvest, post-harvest and value addition package for the coldwater fishes could open new vistas for processed fish and employment avenues. Increased productivity will meet nutritional security besides socio-economic improvement of the people in hills.



Operating Environment

In the context of rising temperature linked to climate change, it is expected that the glaciers will melt and the hill area there would be wide range of mid hill coldwater that would change the altitudinal range for coldwater. Trout zone will be shifted to higher altitude. The lower range of the Himalayan region would be conducive to culture Indian major carp and minor carps. The mid hills area will be highly productive due to increments of water temperature. Presently high altitudinal area is unexplored but there are chances of having integrated fish farming in future. There would be following changes in the operating environment.

Increased water temperature, habitat destruction and change in water quality will impact the biological behaviour of fish. Higher cost of feed ingredient will enhance the cost of production

Rising water temperature

Rising water temperature may not have much impact on warm water species but it will have lots of implications for the coldwater species dwelling in the uplands. In many areas, fishes are already living at their upper thermal limit, meaning even modest warming could render streams uninhabitable. The lost of coldwater species will have long term implication in terms of loss of recreation, sports, food and employment as well as regional culture. The changing climate in the Himalayan region has also affected the ecosystem of the region. The climate change and land use degradation has accelerated water induced hazards such as flash flood, river line flood, erosion, land slide in monsoon period and drought in summer. Several anthropogenic factors that may contribute to this acceleration, including poorly managed agriculture, forest fire, overgrazing, and substandard construction of roads and buildings. Increasing population and demand of land for agriculture has resulted pressure in the watershed of the Lesser Himalayan region. The ecological changes happening in the Himalayan region has led to the changes in the riverine and stream morphology thus altering the habitat for coldwater fishes. The changing course of rivers/streams, destruction of spawning and feeding grounds has further threatened the very survival of the coldwater fishes. Some of the documented impacts on mountain ecosystem that are linked with climate change in the Himalayan region are:

- Scarcity of water resources in hills due to receding glaciers

- Siltation and eutrophication in natural water bodies
- Fish kill in winter and increase in blue green bacteria in summer

Habitat destruction

The natural lakes in majority of Himalayan regions have become eutrophic with deteriorating water quality resulting in loss of fishery. It is worth to mention that mahseer has drastically depleted in Nainital lake. The unregulated mining and destructive methods of fishing in hill streams have resulted in significant decline in major fishery such as mahseer and snow-trout while other important species have become endangered viz, *Raiiamas bola*

Locally available new feed ingredients would be required to reduce the cost of production.

(Indian trout). Environmental and anthropogenic issues coupled with excessive fishing pressure and increasing demand are serious threats to total coldwater fishery sector. Further, in many hill states, the Fishery Department cannot have any intervention in fishery resources that flow through forest areas, which are totally controlled by forest people for managing the fish stocks but they do not have the expertise. Siltation from the catchment areas, besides changing the ecology due to construction of dams, has destructed the feeding and breeding grounds of many fishes. Habitat alterations in Himalayan waters have affected distribution and abundance of native fishes in mountain streams of India. Power dams and reservoirs have dramatically changed the fish habitats and local fish communities. The migration routes of important native fishes like mahseer and snow-trouts have been blocked. Excessive withdraw of water from the river courses for agriculture, domestic and industrial uses leaving inadequate water for comfortable fish life is also a major factor responsible for the depletion of fisheries resources.

Aquaculture Inputs

To date, aquatic feeds have depended heavily on fishmeal and fish oil as their source of protein and lipid. However, the feed industry is encountering shortfalls in the availability of these ingredients because of a decline in the number of fish captured in the wild and the increased human demand for some of the species currently being used for fishmeal and oil production. Therefore, efforts are now being directed in different parts of the world to finding alternative quality ingredients, which ideally are less expensive and readily available for use in practical diets. The data accrued have shown that a large proportion of both fishmeal and fish oil can be replaced by other locally available protein and lipid sources.



Opportunities

Geoinformatics and bioinformatics will act as decision support system. The water temperature regime will also be changed. There is a need of developing the model for thermal range using GIS. The water temperature will be increased creating opportunities to select the suitable species for enhancing production using bioinformatics. There are opportunities to develop thermal tolerance strains that may thrive in wide range of water temperature. Increasing water temperature and pollution may impact on the fish health management and nano and picotechnology may be used in drug delivery and nutrient absorption. There is a vast scope and potential for enhancing fish production in hills by bringing natural Himalayan lakes located at different altitudes, newly created and existing upland reservoirs, under scientific management for fishery enhancement by bridging the gap between actual fish yield and production potentials. There is a significant scope of applying modern technologies as are discussed hereunder:

GIS and bioinformatics would support the decisions to enhance the productivity and production. Biotechnological tools could be used for producing high growth, thermal tolerant strains of fish resilient to climatic stresses.

Geoinformatics

Geoinformatics can support in making authentic decision, which are purely based on realities on the ground. Site selection is a key factor in any aquaculture operation, affecting both success and sustainability. The tools have become of increased significance for environmental planning and assessment mainly because of the need to compare a great number of spatially related data, and because it can be used to couple these spatial data with their attributes and overlay them for making location specific decisions. The spatial database can be attributed as repository for the country besides being a resource for developing scientific management and action plans for fishery development.

Bioinformatics

The growth of Bioinformatics accelerated new technologies that produce huge data sets like high throughput genome sequencing projects. The mining of data and analysis of such large data and extraction

of information from this data is possible only with the help of new algorithms and computation techniques which can be run by well trained personnel to use these environments.

Molecular Genetics & Biotechnology

India has rich and diverse ichthyofaunal genetic diversity. Technological advancements made within the last few decades reduced the barriers for transferring the genes across the biological kingdom. In the light of this technological revolution, it becomes important to take documentation of our fish genetic resources by extending beyond description of population and stocks to the level of genes. At present, genome research in Indian fish species is limited to few species. There is a need to develop capability and infrastructure that is equipped for large-scale genomic exploration of our vast ichthyofaunal resources. More initiatives are necessary to generate genomic information focus on comparative genomics and their phylogeny. Traits are not easy to trace through phenotypic manifestation as it may be labile to change through environmental conditions. Molecular polymorphism at the genomic DNA can be effectively utilized to tag these regions and to map them to specific chromosomes to enable the mobilization and pyramiding of these genes/QTLs through marker assisted selection (MAS). Such procedure will certainly add efficiency and precision to breeding for improved expression of the traits concerned. The development of maps and markers are of global economic importance since these can be used as knowledge base for precision breeding and targeted trait improvement. Genetic progress in animal breeding could increase by more than 50%.

Nano/Picotechnology

Coldwater fisheries can be revolutionized with the application nanotechnology tools like rapid disease detection, targeted delivery of drugs and hormones, DNA base vaccines and nutrients etc. At present, there is a need to do research to develop nanotechnology tools which can apply to aquaculture in relation to water treatment in aquaculture system, fish health management (clinical diagnosis and therapeutics), animal breeding, harvest and post harvest technologies etc. Some of the well known applications of this technology in aquacultures are DNA nano vaccines, aquatic environment management of phosphates by using lanthanum base compound, enhancement of fish growth by feeding nanoparticles of iron etc.

Nano/picotechnology should have great scope in fish nutrition, health and breeding.



Goals and Targets 2050

The primary task of the Directorate is to scientifically contribute and enhance the current volume of coldwater fish production up to four fold by 2050. It is to be noted that this has to be done in the context of environment-climate changes and scarcity of natural resources. In the following section, we have outlined solution-oriented approaches for bridging the gaps.

The mission of the Directorate has to enhance the production and productivity level up to four fold by 2050.

1. To increase the productivity of open water bodies

- Rivers, streams, reservoirs and lakes support the major fishery resource of hill states. The hill region has diverse fishery resources which are mainly used as food, while few of them are used for recreational and ornamental purposes. The normal distribution of coldwater fish biodiversity extends from north-eastern to north-western Himalayan ranges and parts of Western Ghats. Some of the fish fauna can withstand extreme cold climate in very high altitude lakes, which are generally found frozen for three to six months in a year. This makes the fish genome unique for valuable traits.
- Information on water quality, primary productivity, fish biodiversity, abundance and distribution are required to be maintained in view of climate change. The other challenges that coldwater fisheries is facing today is dwindling water supply followed by aquatic pollution. Further to add injuries to the wound, climate change has led to situations like drought and flash floods, thus severely affecting the aquatic environment. Therefore, bioremediation of lakes and reservoirs would be required to restore the water bodies that have been polluted and eutrophicated. Further, metagenomic studies would help in identifying prospective environmental bio-markers and to investigate interactions with host fish in natural coldwater habitats.
- Similarly, habitat destruction has further deteriorated the productivity

Maintaining repository of important endemic fish, temporal mapping of resources, bioremediation of degraded resources, CEIA & CEMP are vital to enhance the productivity of open waters.

of the aquatic resources. Temporal resource mapping of diversified natural resources that experiences a wide range of climatic diversity is warranted to frame strategies for enhancing their productivity and conserving the fishery resources. Statistical models of simulations and forecasting can also help in predicting changes in the ecosystem and carrying capacity of coldwater bodies.

- Mahseer, snow trout and minor carps form the major fishery in streams and lakes. Game and sport fishing is one of the most fascinating outdoor physical activities which satisfies diverse tastes and pursuits. Trout and mahseer are known as the best game fishes because of their magnificent qualities to quench the angler's fishing thirst by providing thrills and excitement while hooking. Sport fishery has immense significance in today's world to develop tourism industry and growth of a region through employment generation and allied activities. The institute has a vision to develop location specific fish based eco-tourism model.
- With the ever increasing electricity demand, rivers are diverted for hydroelectric projects. This would impact the physical and biological realm of the rheophilic aquatic diversity. The impact assessment, planning proper water flow and remedial measures are under the purview of the directorate to conserve the native fish biodiversity. The directorate also has to play a vital role in developing breeding protocol and surrogate brood stock technology for the potential endemic species that can lead to productivity enhancement through ranching programmes. Overall, the Directorate is committed to community development in hills using fisheries resources as a source of food security.

2. To increase the aquaculture production

In comparison to the plains, animal protein is more expensive in the hills due to the added transportation cost. In this context, locally farm produced fish

Planning for aquaculture set up using GIS and water recirculation are prelude to modern fish farming

is suggested to be the best substitute. Coldwater aquaculture may thus play an important role in providing protein nutrition and improving socio-economic status of the people dwelling in the mountainous zones of the country. Moreover, fish culture in the hills encourages conservation of water as well as indigenous fish biodiversity. A wholesome approach in culturing fish includes the use of appropriate feeding standards that are aimed not only at improving economic returns but also at developing a lasting cohabitation of sustainable aquaculture and a cleaner environment.

- The current fish production of hill states is about 1.5% of the total inland fish production, in which reservoirs are the major contributors. The average annual growth rate of coldwater fish production is 2.5%. Himachal Pradesh (with a higher growth rate of 8.3%) and Jammu & Kashmir are the leading states in coldwater aquaculture and states like Sikkim and Arunachal Pradesh have scope of rapid development.
- Due to the kaleidoscopic topography of the mountain region, it is very difficult to assess the resources. Therefore, it is necessary to use GIS based decision support system for assessing the resources. This helps in further planning and development by improving the consistency and quality of the macro/micro level decisions.
- The hill area represents a paradoxical situation of being classed as both 'high potential' and 'water scarce'. The region faces marked water shortage during the summer months because of the unimodal rainfall pattern that limits water availability in tributaries & rivulets. Nevertheless, there are no comprehensive water management strategies. There is a need to undertake multidisciplinary research for water conservation using suitable culture models.
- Coldwater fish production has to be increased to sustain the livelihood of the people inhabiting the hilly regions, by effective utilization of the aquatic resources. Presently exotic carp based fish culture practices are in vogue in the mid hill region. There is a scope for system diversification such as polytanks based integrated fish farming technology and similar advances that can be introduced at a large scale in the mid hill regions.
- There are few cultivable species in coldwater region and a programme has been taken up on species diversification. The Institute has done a commendable work under diversification of aquaculture and has developed culture and breeding techniques for *Tor putitora*, *Schizothorax richardsonii*, *Semiplotus semiplotus*, *Neolissocheilus hexagonolepis* (chocolate mahseer) and minor carps (*Labeo dyocheilus* and *Labeo dero*). Further, the species diversification programme has mainly targeted the indigenous fish species such as mahseers (*Tor tor*, *T. mosal*, *T. khudree*), Schizothoracines (*Schizothoracichthys esocinus*, *S. progastus*, *S. plagiostomus*, *S. labiatus*, *S. niger*) and *Labeo pangusia*.
- Rainbow trout has good potential for domestic consumption as well as foreign export and is considered as a low volume high value commodity in India.

Modern tools for fish health management, production of improved cultivable strains and involving women can contribute in sustainable farming.

However, there is ample scope for further enhancement of trout production in the hill states through participatory approach. Potential success in trout production requires significant improvement in the management practices and better governance. In order to achieve the goal of enhancing trout production, it is quite necessary to focus on improving existing technologies or developing new ones for increased and sustained production. For instance, the transportation of seed is only possible at eyed ova stage. Therefore a feasible technology needs to be developed for the transportation of live trout seed at fry or fingerling stage, because trout seed is a major factor limiting the development of trout farming among the small and marginal farmers. Development of portable and concise trout hatchery designs is required in this direction.

- Feed is the largest input in aquaculture and it is necessary to provide cost effective nutritionally balanced feed to make aquaculture economically viable. In this context, it is necessary to make a catalogue of the nutrient requirement of the cultivable fishes during their life cycle and also concerning the locally available ingredients. A number of feed formulations can be developed through computer-assisted-programme to choose the best combination for field experimentation. It is emphasized that an optimal essential amino acid balance should be maintained and the n-3 highly unsaturated fatty acid requirement be satisfied. Newly developed feeds should aim at being nutrient-dense in order to reduce the output of solid, phosphorus and nitrogen waste. Other concerns are improving nutrient availability, optimizing digestible protein and replacing fishmeal with alternate ingredients.
- Fish health management plays a key role in sustaining aquaculture. Introduction of technologies like efficient water treatment systems that are capable of preventing the entry of pathogenic microbes in the fish ponds should be developed for effective water management. Moreover, to keep the pathogenic diseases at bay, sensitive, effective and user friendly diagnostic tests should be developed to enable the fish farmers in the diagnosis of fish diseases. Effective vaccines should be developed for prevention and control of fish pathogens.
- The current art of aquaculture vaccine preparation still relies on the approach of whole broth culture, in which the bacteria are inactivated with formalin and emulsified with mineral oil or other oils. The most effective delivery route is by intra-peritoneal injection. Enteric coating can be a viable alternate approach for aquaculture vaccine delivery. Future efforts should focus on the absorption mechanisms

of large proteins in the fish intestine. With a full understanding of such mechanisms, proper pharmaceutical delivery systems can be designed through a combination of available approaches, i.e. protection from proteolysis, improving permeability of the antigen and controlled/sustained release patterns for better immune-response.

- Growth and survival rate are two key traits in making aquaculture economically viable through genetic selection. With the passage of time it may become necessary to select for other traits, such as disease resistance and aspects of carcass yield and flesh quality. The economic impact of genetic improvement maybe small initially, but it becomes spectacular when it is multiplied through hatcheries, disseminated to farmers and expressed millions of times in the production system. It is this attribute of genetic improvement by selective breeding that makes it such a unique and powerful technology. Furthermore, genetic gain is permanent and cumulative, that is, the new gain achieved in each generation builds upon gains made in earlier generations. These characteristics are unique to genetic improvement and cannot be found in other aquaculture technologies. Use of gene silencing, immune-augmentation with the help of immune-stimulants, novel nutraceuticals and prophylactics, formulation of chemical and herbal remedial, nano-particle mediated drug delivery, and bio prospecting of microbes are some other challenging areas to be dealt with.
- Women in hill region can be key players in management and utilization of natural resources through active involvement in aquaculture development, but they are marginalized and face hardship. Breeding, collection, propagation and marketing of ornamental fishes is a high potential and low input enterprise for their livelihood security. Awareness and popularization of ornamental fish trade among the farmers/public is important and it needs to be diverted from exotic to indigenous species. The institute will focus on women empowerment through capacity building and enhancing opportunities for women development.
- Marketing of the fish produced is a major bottleneck in the development of coldwater sector. Farms are remotely located in difficult terrains and have poor accessibility to the markets. Often, they are not well connected either by road or rail. Under these circumstances, farmers are unable to get a reasonable price for their fish produce. Being a perishable commodity, transportation of the

Smooth transportation, organised marketing and supply of preferred products would increase profit.

fresh fish has to be done under refrigeration. It is imperative to introduce value addition techniques so that the fish products earn more profits. In this direction, the Directorate has initiated the conception of a fish processing plant.

- Another major constraint faced by fish farmers in marketing is the lack of bargaining power, market information and entry barriers in the market. The policy makers and planners of the country, of late, has recognised that a system needs to be developed and put in place for efficient domestic marketing of fish so that all the stakeholders in the entire value chain from fishermen to fish consumers can get maximum profit and satisfaction.
- Despite its immense business value, the unfolded story of Intellectual Property (IP) in India reveals more failures than success. Inputs in terms of policy measures, facilitating and enabling environment are required for nurturing the culture of commercializing technologies. Starting with the basic facets of gaining value from intellectual assets, special thrust should be given to role of technology landscaping and IP audits under the Indian context. Strategic IP management and methods of monitoring intellectual assets have to be put in place.

3. To develop mechanisms to combat climate change and resource scarcity

Climate change and shortage of natural resources are the two major long term challenges that are most pertinent to coldwater fisheries and aquaculture. Therefore, it is imperative to understand the impact of climate driven changes on the coldwater environment and fishery resources, in order to bring forth mitigating strategies. Likewise, water is becoming scarce at an alarming rate and the cost of inputs are getting higher by the day, necessitating technologies and farming systems that will maximise the use of water and nutrients to scale up productivity.

Documenting life history traits, identification of critical node of environmental control, multi-phasing and integrating culture systems, development of metabolic booster, Aquaponic and Biofloc could mitigate the climatic stresses and resource scarcity.

- Given the fragile nature of the coldwater ecosystem, the shifting climate paradigm would exert a relatively greater pressure on the ecology and productivity of natural water bodies. The extent and points of influence should be ascertained to identify critical nodes of control.
- The biological and behavioural changes that occur in fish at individual and population level will critically determine their ability to withstand the changes in the living environment. Hence,

the changes happening in the life history traits should be well documented, with respect to epigenetic, genetic, physiologic, phenotypic and behavioural adaptation. This may ultimately enable the identification of climate resilient strains of fish.

- In farmed fish, dietary nutrient supplements are a promising approach to cope up with the changing climate. In addition, natural compounds that can beneficially alter the metabolism and boost the adaptive response of the fish are a key element of investigation.
- Rapid changes in climate apparently lead to various natural disasters in the hill regions. Proper disaster management protocols should be envisaged researched and developed to avoid losses in terms of coldwater habitat, fish biodiversity and aquaculture production.
- The availability of water for fish culture is declining, both in quantitative and qualitative measures. So, it is very essential to develop in-situ methods to harvest and replenish water sources. Better water management practices would result in minimal loss.
- Taking further account of the short supply, water use efficiency should be progressively enhanced by multi-phasing and integrating culture systems. In this milieu, Aquaponic and Biofloc systems are capable ways of minimizing water exchange and environmental pollution.
- Another major sustainability concern in aquaculture is the amount of wild fish used in the feed (as fish meal and fish oil) of carnivorous farmed fish such as rainbow trout. Imbalance in the supply and demand of these highly priced feed ingredients necessitates the use of locally available alternative protein and lipid sources. Eventually, it is essential to evolve feeds and feeding practices that can reduce the 'Fish in Fish out' ratio in farming systems.

4. To develop networks, extension services and human resource

The true essence of the multifarious research endeavours could be achieved only through knowledge and resource sharing, and strengthening the professional competence of all the stake holders. Stewardship of natural resources is another critical aspect that requires judicious re-orientation. Support of NARS, developing domestic market for high value fish and growing interest of people in fish angling from within and outside the country is the elements favourable for future growth of coldwater fisheries.

- Marshalling resource sharing and exchange of fish germplasm/ improved strains through harmonised regional network mechanism to enhance complementary and sustainable development of coldwater

fisheries and aquaculture in the Trans-Himalayan region.

- Transferring the technologies developed by the institute to the intended recipients on priority basis through on-farm demonstrations and trainings. As a follow up activity, providing continuous technical back-stopping to the farmers through user-friendly android applications, telephonic help lines and online technical consultancy platforms.
- Upgrading the scientific and technical workforce of the institute periodically through rigorous, need based and tailored capacity building and knowledge exchange programmes. Specific focus to be laid on enhancing the capabilities for resource management. In tandem, the experimental and analytical infrastructure should be strengthened and modernized.
- Spearheading the expansion and intensification of aquaculture practices in partnership mode along with public and private enterprises, taking into consideration the local resource pool.
- Serving as the resolute authority to offer consultancy and policy guidance to the Government with respect to all environmental studies, resource management and rehabilitation pertaining to coldwater sector.

Human resource development, technology transfer, knowledge sharing through networking and need based policy are key for sustainable coldwater sector.



Way Forward

The ICAR-Directorate of Coldwater Fisheries Research would serve as a “centre of scientific excellence” capable of addressing the forthcoming challenges and realistic targets in the sector. Augmentation of fish production through scientifically proven technological interventions, optimal utilisation of water resources based on innovations and compact strategies for diversified aquaculture systems and allied enterprises are expected to ensure adequate food supply, livelihood security, sustainable use of resources and environmental protection in the hills. In this milieu, the approach envisaged by the Directorate for the next four decades are furnished here below:

Goal	Strategies	Output	Outcome
1. Open water fishery			
To increase the productivity of open water bodies	Identification of ecologically significant and species specific potential streams/water bodies for management of important coldwater fish species	Effective utilisation of open water fishery resources	Community development and socio-economic progress
	Development of resource centres for important endemic fish germplasm and their maintenance in different coldwater regions		
	Temporal mapping of coldwater resources using geoinformatics techniques		
	Maintaining repository of water quality, primary productivity, fish biodiversity, abundance and distribution in coldwater streams lakes and reservoirs		
	Bioremediation of degraded and eutrophicated coldwater lakes and reservoirs		
	Impact assessment of hydro-electric projects on fish diversity, population, biology and behaviour to make out substantial remedial measures		
	Developing statistical models of simulations and forecasting to predict changes in the ecosystem, biotic integrity, nutrient cycling patterns and carrying capacity of coldwater bodies		
	Fish germplasm restoration and rehabilitation in depleted natural habitats by ranching and comparative studies on their biological and behavioural performances		
	Evaluating the impact of altitudinal variations in hydrology and fish biology		
	Assessment of genetic variability and species characterisation of coldwater fish species using molecular marker.		
	Metagenomic studies in natural coldwater habitats for identifying prospective environmental bio-markers and to investigate interactions with host fish.		

	Developing “Surrogate brood stock technology” for critically endangered fish species		
	Optimising fish production in lakes and reservoirs using modern tools and technologies and species diversification		
	Resource assessment of brackish coldwater lakes for fishery development		
2. Aquaculture			
Enhancement of fish production	Generating GIS based aquaculture site suitability maps for coldwater region using ground data for planning and aquaculture development.	Increased productivity and production	Ensuring livelihood, and nutritional security in hill region
	Development of location and situation specific package of practices for aquaculture promotion in coldwater sector		
	Development of portable and concise trout hatchery designs for minimal use of land/water		
	Development of automated trout culture systems for more intensification.		
	Development of eco-friendly multi-tier models of integrated fish farming for sustainable production		
	Development of location, situation and species specific models of fish culture in view of water budgeting and management		
	Life cycle assessment (environmental, social and economic sustainability) of different culture species and to manipulate it using biotechnological tools		
	Development of breeding protocol for mass seed production of potentially cultivable species.		
	Domestication and brood stock improvement of candidate species exploiting usable traits		
	Exploration of potential ornamental fish species of coldwater region and to develop breeding protocol for small scale entrepreneurship involving women		
	Development of database on genome sequencing and transcriptome profiling of important coldwater species		
	Application of gene manipulation techniques to counter slow growth and low fecundity and to induce environmental plasticity		
	Thermal growth profiling of important cultivable coldwater fish species.		
	Cataloguing nutritional requirements of potential cultivable fishes and available local feed ingredients		
	Formulating balanced and cost effective feed for different stages of candidate species.		
	Disease surveillance and identification of various pathogens in coldwater environment.		
	Development of diagnostic kits, vaccines and delivery methods		
	Development of protocols for processing and value addition to prevent post-harvest losses		
	Development of market intelligence and supply chain for augmenting profit margins		
	Production of ‘designer fish’ to cater human health concerns		

3. Adaptive response strategies to climate change			
Effective adaptation to climate change and management of resources	Investigations on impact of climate change in fragile coldwater ecosystems	Mitigating climate change and resource scarcity	Climate resilience and optimal use of resources
	Development of <i>in-situ</i> methods for water harvesting and management.		
	Development of Aquaponic systems for enhancing water use efficiency		
	Development of integrated Biofloc systems to minimize water exchange, feed inputs and environmental pollution		
	Documenting the changes in life history traits and ecophysiology with respect to climate change		
	Identification of climate resilient strains of fish based on epigenetic/genetic changes, physiological plasticity, phenotypic adaptation and behavioural response		
	Development of dietary metabolic modifiers to boost adaptive response		
	Development of feeds and feeding strategies to reduce ‘Fish in Fish out’ ratio		
	Development of disaster management protocols for coldwater ecosystem		
4. Human resource development and socio-economic contributions			
	Domestic and international knowledge exchange programme for capacity building of scientific and technical personnel	Availability of trained/skilled manpower	Expansion of aquaculture
	Capacity building to enhance capability for resource management		
	Harmonisation of regional mechanism of resource sharing and exchange of fish germplasm/improved strains for sustainable development		
	Strengthening of experimental and analytical infrastructure in coldwater sector		
	Transfer of technology through on-farm demonstrations and trainings		
	Expansion of aquaculture in partnership mode involving public and private enterprises		
	Development of farmer friendly android applications; telephonic help lines and online technical consultancy platform		
	Active contribution in environmental studies, consultancies and policy matters		
	Augmenting public awareness of research and developments in coldwater sector		



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Laser typeset at M/s Print-O-World, 2568, Shadipur, New Delhi 110008 and printed at M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi 110 028.



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