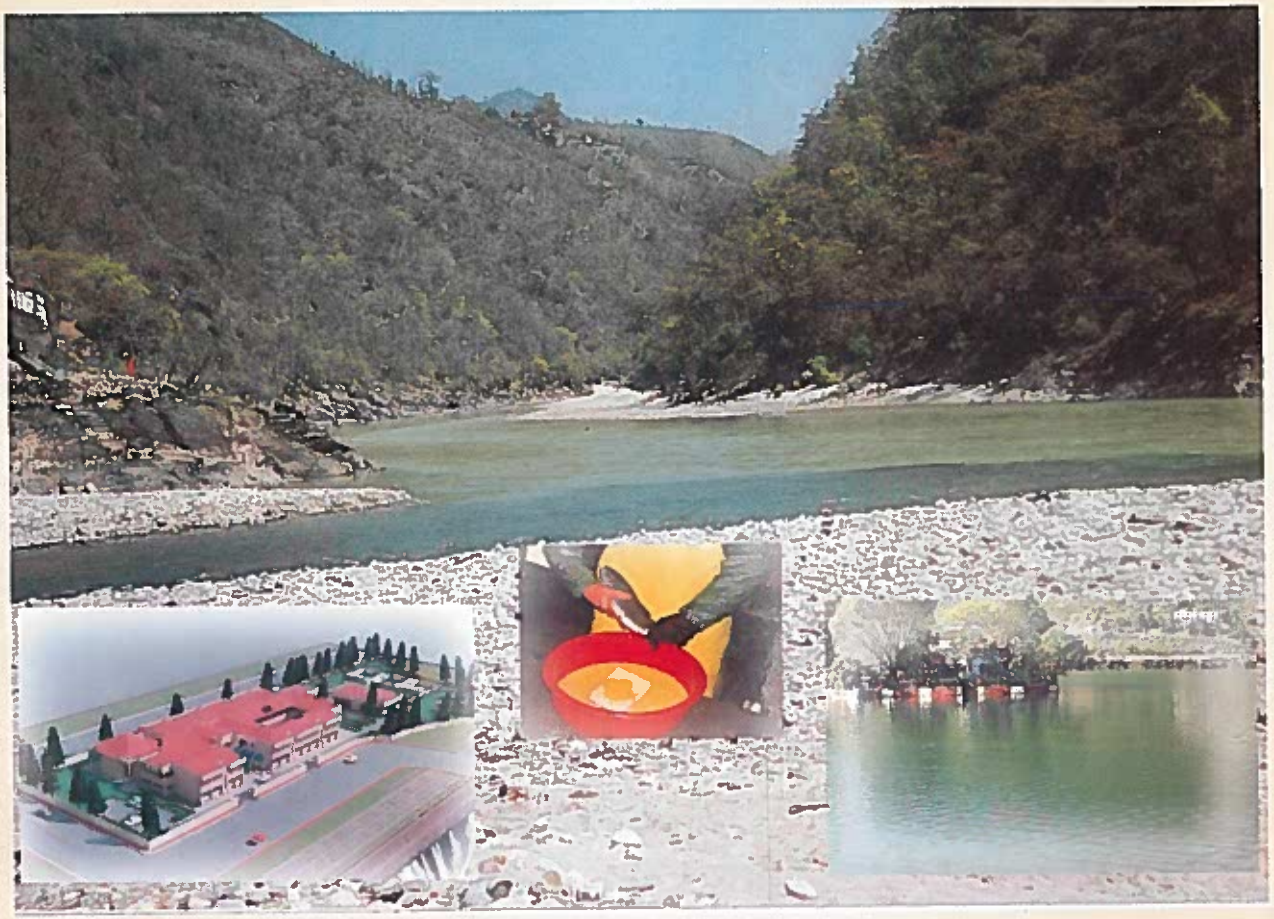
Contribution of NRCCWF in Coldwater Fisheries Research & Extension



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K.K. Vass

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FOREWORD

The country has registered significant progress in fishery sector since Independence. Our fish production globally by aquaculture has reached second position after China. Aquaculture has shown steady progress over the years and is now contributing nearly 70% to inland production. But more efforts are needed to achieve the targets fixed by the Planning Commission of 8 million tonnes by the end of X Plan. One of the strategies to enhance sustainable fish production will be to look into the areas and regions which up-to now have received less attention. In this direction our hill resources have significant potential but they need different technology, policies and support services. The hill ecology on one hand is very sensitive and on the other, less opportunities force the local population to exploit the natural resources for their economic benefit, which directly or indirectly results in ecosystem degradatron, low productivity both due to climate and potential. The potential of these regions has to be fully utilized for increased fish production to provide food and nutritional security to our population.

It is well known that development in any sector has been enhanced by the available R&D support and extension back-up. The progress in inland aquaculture is a testimony to this concept. Our high altitude aquatic resources in the past did not receive the adequate R&D support which it deserved. Whatever technology support and scientific informations have been available were mainly through the sustained efforts of National Research Centre on Coldwater Fisheries established under the aegis of Indian Council of Agricultural Research in 1987. The scientists of this centre, despite constraints have many technologies and scientific database to their credit but those are scattered in different reports and articles. Now that hill sector is receiving due attention from the planners in the country, it will be useful if the available information is presented in one compendium.

The efforts put in by the author, Dr. K.K. Vass and his colleagues, deserves appreciation. This document will be useful to those concerned with the fishery development in our highland regions.

CONTENTS

1. DEFINITION

The term " Coldwater Fish" vaguely refers to the members of the family Salmonidae, much sought after by the anglers all over world. In India, however, Cyprinids belonging to sub-family Cyprininae which inhabit streams, lakes and reservoirs receiving snow-melt water directly from their water-sheds are also included in this definition. There are a large number of indigenous and a few exotic species of fish which frequent the rivers, brooks, lakes, ponds in the uplands. Of these trouts, snow-trouts, mahseers, common carp and minor carps are important as sport and food fishes. These species are widely distributed both in the Himalayas and the Peninsular plateau.

2. COLDWATER REGIONS

STATES HOLDING COLDWATER FISHERIES

3. THERMAL LIMITS

The temperature tolerance of coldwater fish lies at lower levels of the thermal scale, which is of critical significance and plays a crucial role in their dispersal in the uplands. The thermal regime limits, the very existance of fish species and other aquatic life, which greatly alters the composition of the biotic communities in upland streams, and wetlands. On the basis of temperature tolerance, we may distinguish coldwater fishes as eurythermal (having broad temperature tolerance range) and steno-thermal (having a narrow temperature tolerance range). *Schizothorax richarsonii, Cyprinus carpio*, and *Barilius bendelisis*, which can withstand a wide spectrum of temperature, can be categorized as eurythermal. The brown trout (*Salmo truta fario*), the eastern brook trout (*Salvelinus fontinalis*) and the Tibetian snow-trout (*Diptychus maculatus*) are examples of steno-thermal species which tolerate only a narrow range of temperature nearly up-to the freezing point of water. It is the upper level of tolerance limit that determines the survival, occurrence and distribution of the fish in time and space. The thermal limits are indicated in the table as under:

Table 1. Temperature range of important coldwater fishes

Main Fish species of economic importance	Water temperature (°C)
Snow-trouts	
Upper limit	20-25
Lower limit	5.0
Good growth performance	15-20
Mahseers	
Upper limit	25-30
Lower limit	10.0
Good growth performance	15-25
Exotic trouts	
Upper limit	15-20

4. ECOLOGICAL ADAPTATIONS

The coldwater fishes are often endowed with great powers of locomotion such species have stream-lined bodies. The trouts and schizothoracids find their way farthest up the high streams. Mahseers and Glyptosternid cat fishes among others are inhabitants of the lower reaches of the hill streams. The occurrence and distribution of coldwater fish, in addition to temperature, are also dependent upon the swiftess of the current and nature of the substratum including the plant and animal communities available at the bottom. Majority of the coldwater fishes possess structures especially adapted for clinging, burrowing or otherwise to withstand fast water currents.

These variable features of the environment have induced remarkable modifications among the coldwater fishes both externally and internally. Normally, there is very little food availale in the hill streams for the resident fish species. Coldwater fish species have acquired modifications of the mouth suitable for rasping the encrusted organisms and removing algal slime off the submerged or emergent rocks and boulders. The modification of the lips for removing periphytic organisms is well seen in snow-trout, mahseer, certain minor carps. The coldwater species are ill-adapted for feeding in deep and muddy waters.

Table 2. Oxygen tolerance range in some important coldwater fishes

Main Fish species of economic importance	Critical dissolved oxygen values (mg/l)
Snow-trouts	
Upper limit	8.0 and above
Lower limit	5.0
Mahseers	
Upper limit	7.0 and above
Lower limit	5.0
Exotic trouts	
Upper limit	8.0 and above

5. FISH DIVERSITY

There are 258 fish species both indigenous and exotic, belonging to 76 genera, reported from Indian uplands which are spread over in Himalayas and the Peninsular plateau. However, the list of some of the important species is tabulated below:

Table 3. Some important Coldwater fishes both indigenous and exotic

Snow-trouts	**Minor carps**
Schizothorax richardsonii	*Labeo dyocheilus*
Schizothoraichthys curvifrons	*Labeo dero*
Schizothoraichthys longipinnis	*Crossocheilus latius latius*
Schizothoraichthys esocinus	*Garra gotyla gotyla*
Schizothoraichthys niger	**Loaches**
Schizothoraichthys nasus	*Botia birdi*
Schizothoraichthys hugelii	*Noemacheilus botia*
Schizothoraichthys planifrons	*Noemacheilus multifaciatus*
Schizothoraichthys micropogon	*Noemacheilus montanus*
Schizothoraichthys progastus	*Triplophysa stoliczkae*
Diptychus maculatus	**Exotic trouts**
Lesser barils/Minnows/Catfishes	*Oncorhynchus mykiss*
Barilius bendelisis	*Salmo trutta fario*
Barilius barila	**Other exotics**
Barilius vagra	*Cyprinus carpio specularis*
Raiamas bola	*Cyprinus carpio communis*
Danio aequipinnatus	*Tinca tinca*
Danio devario	*Carassius carassius*
Glyptothorax pectinopterus	
Glyptothorax conirostre conirostre	

6. FISHERIES

Majority of the coldwater fishes are caught individually by local fishermen in the rivers and streams and do not form fisheries of commercial importance. A few, however, such as the snow-trout (*Schizothorax* spp. and *Schizothraichthys* spp.), large-scaled barbels (*Tor* spp.), common carp (different phenotypes of *Cyprinus carpio*) and a few minor carps (*Labeo dero* and *Labeo dyochelius*) are some of the commercially important food fishes dwelling in uplands. Truly speaking, even these species do not form fisheries of appreciable magnitude. The reasons attributed to this situation are many but most important ones being, first due to slow growth and small size, the fishes fetch less price, second is the cast net used as gear which is basically one man unit so community fishing is hardly prevalent, thirdly the terrain in uplands having meager transport facilities makes transporting catches from production/collection site to nearby markets difficult. Therefore, fisherman invariably does not get the remunerative price for his catch, which forces him to sell the catch as one or two units in nearby villages/towns.

An important aspect of coldwater fishery of the uplands is the opportunity the species provide for sport. Brown trout (*Salmo trutta fario*), rainbow trout (*Oncorhynchus mykiss)* and certain species of large-scaled barbels are the principal species of sport value in Kashmir, Himachal Pradesh, Uttaranchal, North-Bengal, Nilgiris, Kodai hills and Munnar ranges where the Indian and Foreign tourists annually visit in large numbers. In certain regions, sport fishery constitutes an important source of revenue. In Jammu & Kashmir, trout alone contributes to about 40-50% of the State's revenue from sport fisheries.

7. RESEARCH SUPPORT TO THE SECTOR

The research support to the hill fisheries even at national level started very late in comparison to the warm-water sector. The efforts at individual levels in the universities were undertaken by number of persons to workout the academic problems related to some important coldwater fishes in the Himalayan states. But research with focus on the fisheries science started with involvement of ICAR system during late sixties which subsequently culminated in creation of National Research Centre on Coldwater Fisheries in 1987.

NRC ON COLDWATER FISHERIES

7.1 Establishment & Growth

7.1.1 Historical Background

While reviewing the work of erstwhile CIFRI, the Estimates Committee of the fourth Lok Sabha (1976-68) emphasized the need for intensive research to provide a scientific basis for development of trout and other hill fisheries. The committee further suggested that vigorous attempts be made by the CIFRI for development of trout and other high altitude fisheries in hilly areas of Uttar Pradesh, Karnatka, Kerala and Tamil Nadu. Subsequent reviews of research programmes of the CIFRI by the achievement audit committee in 1972 and 1978 and quinquennial review team in 1983 repeatedly stressed the urgent need to intensify research on coldwater fisheries by creating infrastructure and providing additional scientific, technical and other research support staff. During mid-term appraisal of the VI Plan, the ICAR decided for intensification and strenghening of coldwaer fisheries research. In spite of various recommendations made by different committees, the coldwater fisheries research under the aegis of CIFRI remained limited due to lack of infrastructure facilities. Even the manpower support for coldwater fisheries remained same since 3rd five year plan. Subsequently the Working Group on Agriculture Research and Education for the VII plan suggested that the research in this area be strengthened by having a separate NRC.

under ICAR control with its temporary headquarters at Haldwani in the then Uttar Pradesh State. Subsequently, from May 1997 the temporary headquarters of the institute was shifted to Bhimtal about 30 km from Haldwani, where the main complex of NRCCWF is under construction and is likely to be ready be the end of 2002. Lack of institutional capability has been one of the major constraint in slow pace of technology development in this sector.

Dr. Dehebendra Pradhan , MOS , DARE, (ICAR), Shri B.D. Bhagat, Agriculture Minister, Govt. of Uttranchal at the foundation stone unveiling ceremony of NRCCWF complex on 12.3.2001 at Bhimtal

The NRC on coldwater fisheries is the only national facility in the country where research investigations are undertaken both on capture and culture aspects with a focus on exotic and indigenous coldwater fish species. Since its inception, NRC-CWF inspite of limited scientific, technical manpower and meager insfrastructural facilities, has made significant contribution for proper appraisal of coldwater fishery resources and evolve suitable technologies to propagate important coldwater fish species in hills.

The coming decades are expected to pose newer and greater challenges to coldwater fishery sector both in development of aquaculture and sport fishery. Therefore, coldwater fisheries technologies already developed by the institute require further refinement and up-scaling. This sector needs adequate R & D support, improving

openwater fisheries. To achieve these objectives, the NRCCWF has the following functions:

- Evaluate and assess the coldwater fishery resources in upland areas
- Develop strategies for their conservation and management
- Conduct research leading to development of suitable technologies for farming of indigenous and exotic species in uplands
- Study the impact of environmental changes on the aquatic biodiversity in upland openwaters
- Undertake transfer of technology through training, education and extension programmes
- Consultancy services in different areas like coldwater fisheries development, aquatic ecology and environmental impact asessment

7.1.3 Manpower support

To underake the activities related to above mandate, the ICAR has approved following manpower strength but all positions are not presently filled due to various administrative reasons.

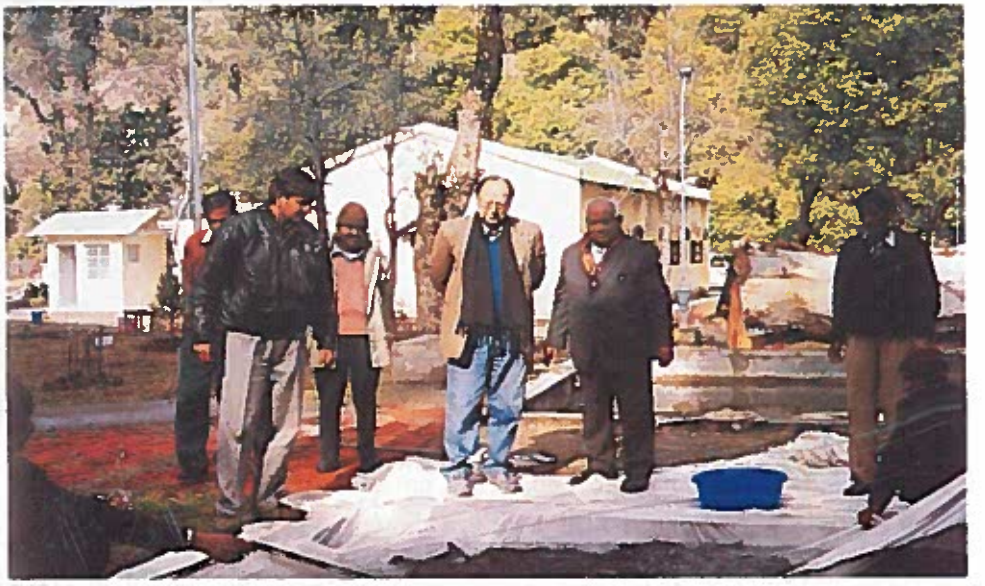
Table 4. Sanctioned Cadre Strength of the NRCCWF

MANPOWER	
Category	**Approved Positions**
Director	1
Scientists	20
Technical	14
Administrative	14

7.2 Infrastructure, Facilities & Research support services

7.2.1 Farm & Hatchery

The institute has created experimental farm facility which is located at Chirapani in the Champawat district of Uttaranchal State. All experimental trials on aquaculture with respect to both indigenous and exotic fish specis are being carried out at this farm. Many more facilities have been created at the farm in recent past. The institute also conducts different training programmes with focus on hill aquaculture at the farm site. The details of the farm are as under:

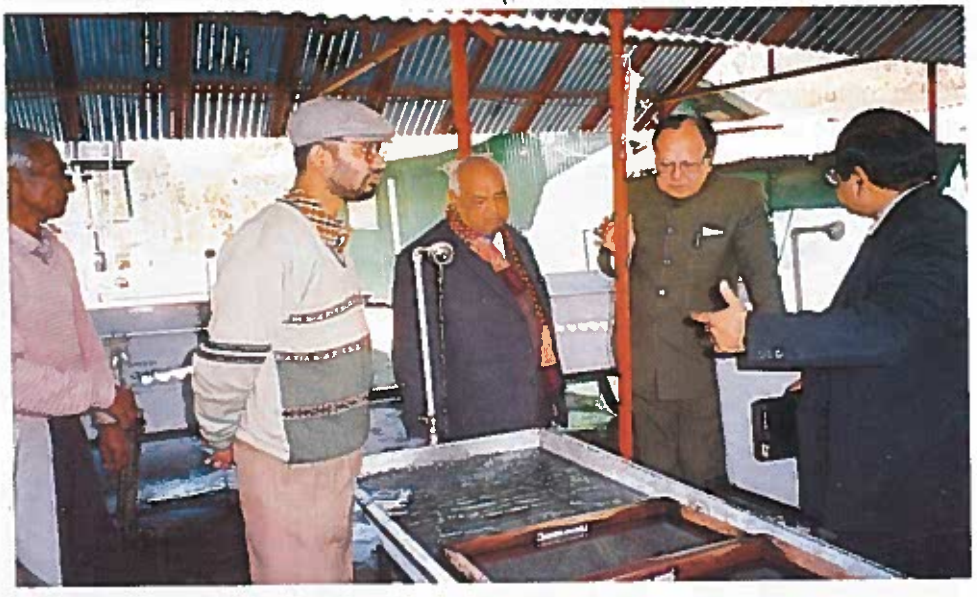


A view of the Chirapani Experimental Farm of NRCCWF at Champawat, Dr. S.A.H. Abidi and Dr. S.N. Dwevidi examining the trout stocks

Table 5. Details of Farm facilities with the Centre

Details of NCCWF Experimental farm at Chirapani in the district Champawat	
Area of the experimental farm	3.25 hectare (split in two pockets)
Nursery tanks	10 Nos; 3m x 10m size
Rearing tanks	5 Nos; 30m x 5m size
Circular tanks	20 Nos; 3.15 m^2 each

A temporary flow-through pilot mahser hatchery facility has been established at Bhimtal. The hatchery has the rearing facility to produce 0.20-0.30 million mahseer seed primarily to provide seed for undertaking aquaculture experiments, supply to select users and for undertaking ranching programmes in local lakes as part of germplasm conservation.

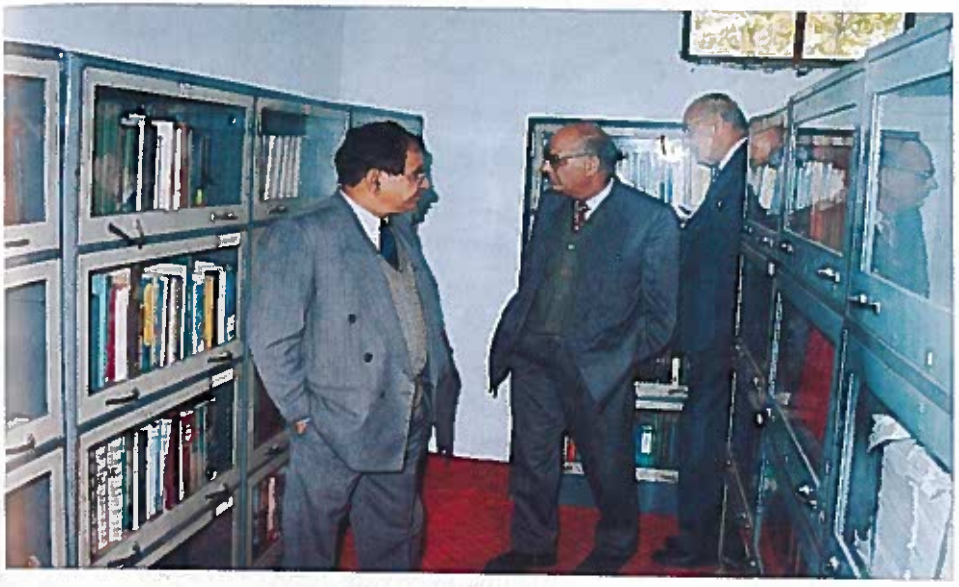


A view of Mahseer hatchery of NRCCWF at Bhimtal

7.2.2 Laboratories

Pending creation of permanent institutional facilities, the centre is presently operating from different rented accommodations located at Bhimtal (district. Nainital, Uttaranchal), this place is the approved headquarter of the institute. Different laboratories in these rented buildings have been establishd which are reasonably equipped to carry out the scientific investigations related to aquaculture, openwater fisheries, aquatic biodiversity and environmental problems specific to hill aquatic resource management.

library section also processes and diseminates the scientific/technical information to the potential users. It is computerized and CD-ROM facility has also been created.



Library facilities of NRCCWF at Bhimtal being inspected by members of QRT

7.2.4 Documentation

The section mainly looks after the publication of scientific bulletins, brochures, newsletters and pamphlets. Large number of them have been published both in English and Hindi for the benefit of cross-section of users, within and outside the institute. Some of the publications produced by the institute are indicated hereunder:

Table 6. List of Publications brought out in the recent past

Title of Publication	Language of publication	Year of publication
Annual Report	English with Hindi summary	Every year since 1989
NRCCWF - NEWS		
Vol (1) No 1	English	1998

Title of Publication	Language of publication	Year of publication
Special Issue	Hindi	2001
Vol (4) No.1	English & Hindi	2001
Bulletins		
Artificial propagation of golden mahseer	English	1991
Eatimation of biological productivity of mountain stream	English	1992
Tourt farming	English	1992
Schizothoracid seed production	English	1992
Common carp farming	English	1992
Coldwater Research Review	English	1992
Himalayan Mahseer	English	1999
Fishes of Indian Uplands	English	1999
Kumaon Mei matsya palan evam sanrakhshan	Hindi	1999
Status Report on Coldwater Fisheries for ICAR, GB	English	1999
Biochemistry of Coldwater Fishes	English	2000
NRCCWF-An Introduction	Bilingual	2001
Technical Dictionary	English to Hindi	2001
Uttaranchal main matisyaki vikas ki sambhawnayen	Hindi	2001
Pamphlets (19 Nos.)	English and Hindi	1999-2001

7.2.5 Project implementation section

The section monitors the implementation and progress of research project programmes of the institute. It annually organizes the meeting of staff research council for evaluating the progress and according approval to fresh programmes. The section maintains project

7.2.7 ARIS cell

In order to keep pace with information technology, this cell is providing the computer related facilities to the scientists and other staff of the institute. The local area network has been established at the institute. All major sections are using computers in their work. The e-mail and internet facility has been established at the institute.

7.2.8 Extension section

The insitute has a skeleton extension section, but it has provided adequate service in terms of technology transfer programmes, farmer related programmes, exhibitions, training programmes and distribution of fish seed and technical guidance about aquaculture to farmers and other clients in the Kumaon region of Uttaranchal.

7.2.9 Hindi Cell, Administration & Audit Cell

The institute has released some publications in Hindi in addition to English. This section takes care of the required translation and preparation of such publications. It also helps the administration and other sections to do their work in Hindi. The use of Hindi at the institute has been appreciated and more than 80% use of Hindi in our Centre has been reflected in the gazette notification of Govt. of India. The two sections of administration and audit provide very crucial and critical support to entire research programmes of the institute and render required assistance in the institute management activities.

8. TECHNOLOGY GENERATION & ACHIEVEMENTS

The coldwater fisheries rsearch is nearly three decades old. Initially for nearly 20 years as part of erstwhile CIFRI, majority of work was concentrated in Kashmir Himalayas and to some extent in hill regions of Himachal Pradesh. Subsequent 10 years as an independent institute, work was undertaken on various coldwater fisheries related problems in Central Himalayas with focus on erstwhile U.P. hills.

A. Kashmir Himalayas

in their fishery management. The local academic universities did generate some basic information on local fisheries which however, did not help in developing the desired culture practices. Therefore, the work on fisheries research as such was neglected, and the local line department was concentrating only on development issues. But any planned fishery development does require scientific basis. This responsibility with a focus on research was taken up by this centre during this period when it was operating in the Kashmir valley. The scientific contribution on coldwater fisheries made by the Centre in Kashmir during that period is summarized hereunder.

8.1 Aquaculture

8.1.1 Exotic Trouts

8.1.1.1 Standardization of hatchery practices

Suitable methodology was perfected for reducing the mortality at different stages *viz.*, ova, alevin, fry and fingerling of brown trout *Salmo trutta fario* in the hatcheries and farms located in the Kashmir valley. The percentage survival could be raised to 80% from the earlier record of hardly 20% between green-egg to early fry stage. The practice of segregating spawners much before breeding commenced and feeding them on nutritive diets helped in increasing the egg laying capacity of brooders by an average of 218 eggs per kg of spawner body weight. The results of hatchery incubation of brown trout eggs in Kahsmir during 1975-1978 are indicated in table hereunder:

Table 7. Enhanced survival in brown trout due to scientific hatchery management

Trial	Treatment	No. of green eggs	Fertilization (%)	Survival at		Cumulative survival at swim up-fry (%)
				Eyed Ova Stage (%)	Alevin Stage (%)	
1	Segregated	1,86,700	98.0	93.7	90.3	88.7
	Non-segregated	82,000	95.8	70.5	57.6	53.4
2	Segregated	2,25,000	98.7	95.71	92.5	90.35
	Non-segregated	1,45,000	93.5	65.7	63.5	60.27
3	[illegible]	3,16,000	93.8	91.0	89.5	87.5

A view of trough inside trout hatchery showing newly hatched alevins

8.1.1.2 Development of artificial diet for trout

Long-term, brown trout fry rearing experiments were undertaken between 1979 to 1981 with three fromulated diets having different protein levels using local ingredients. Three feeds tested, gave FCR of 2.2, 2.0 and 1.8 which were very much comparable with any trout feeds at that point of time used in other countries. During those years, no trout feed was imported into India, therefore, this formulation was quite significant. The composition and formulation of feeds which were trial tested are depicted in the tables 8 a,b. The comparative growth performance in experimental trials indicated significant variations, the test fishes fed at 31% protein diet attained size of 55-100 mm in 300 days while those fed at 35% protein diet recorded a size range of 55-145 mm in 240-280 rearing days but at higher protein level of 48%, the size range attained in 280 days was in the range of 60-150 mm indicating that much higher protein levels did not promote better growth in comparison to medium protein level of 35%.

Table 8. Details of feed formulations and composition of test diets

a) Different ingredients used in making feeds (%)

Ingredients	Feed-A	Feed-B	Feed-C
Fish meal	55	30	-
Silk worm pupae	-	30	70
Soybean meal	20	-	-
Wheat bran	05	15	15
Wheat starch	05	-	-
Mustard oil cake	-	10	-
Skimmed milk	04	05	05
Yeast	3.5	04	07
Shark liver oil	03	04	01
Mineral mixture	03	01	01
Vitamin mixture	1.5	01	01

b) Chemical Composition of formulated feeds (%)

Parameters	Feed-A	Feed-B	Feed-C
Crude protein	31.06	35.0	48.12
Crude fibre	1.89	0.51	1.92
Ether extract	5.38	6.54	10.12
Ash content	28.22	23.97	11.02
Nitrogen-free extract	21.44	29.55	24.74
	12.04	4.45	2.76

Two types of balanced artificial diets developed by the centre given to trout stocks

8.1.1.3 Brown trout rearing for table

Rearing trials were conducted during 1979-1982 using low and high protein diet (28% and 47%). The brown trout fingerlings with an average weight of 20g were stocked at 4-5 m^2 in raceways and reared for 300 days. The growth experiments revealed that fishes grew to size range of 215-315 mm in length and 165 g in weight when fed with 28% protein diet. In comparison, growth with 47% diet was better with size range of 245-330 mm in length and 325 g in weight during the same rearing period. The estimated production with high protein diet could be around 8 tonnes per hectare while it was estimated to be only 3 tonnes production with low protein diet. The low protein diet gave a feed conversion ratio of 3.7, feed efficiency of 28.3% and survival of 50% while high protein diet recorded the values for these indices at 1.7, 57.2% and 64%, respectively. This formulated feed and other management practices involved will help in raising the brown trout for table under farm conditions which is presently used mainly for sport.

8.1.2 Exotic Carp

compatibility of indigenous and exotics. Initially the *Cyprinus* found the new habitat quite favourable in terms of availability of natural food and congenial ecology. This resulted in more fish catch to the fisherman and its availability in market. The local consumers did not initially accept this fish but through years, the sales picked up. But this introduction had adverse impact on the indigenous varieties, their catches dropped to nearly 30% by eighties and average size of *Cyprinus* also declined. Further, out of three strains initially stocked, the *nudus* variety got eliminated and of the remaining two, *communis* variety became more dominant. On the whole, this introduction did not help the lake fishery, infact an opinion was expressed to eliminate *Cyprinus* from the lakes, which biologically was rather difficult. In fact establishment of *Cyprinus carpio* in local lakes had direct bearing on fishermen of the valley. In Kashmir all fishermen depend on capture fisheries either from the river systems or the natural lakes and other wetlands. There was no concept of fish culture with local fisherman or the farmer, this activity was restricted only to seed production and brood stock maintenance of brown trout in government controlled hatcheries. Thus fishery enhancement through *Cyprinus* generated more income for fishermen. Therefore, a need was felt to evolve a fish culture package for the poor fisherman in rural areas. The coldwater research centre in valley between 1982-1984 evaluated the feasibility of *Cyprinus carpio* culture in a village pond. By exploiting the natural productivity of rural pond and regulating the kitchen refuse and other run-off from a village into the pond, an estimated production in the range of 2.5-3.0 tonnes per hectare was achieved in a grow out period of 12 months. This simple technology could be profitably utilized in Panchayat ponds in the rural areas of Kashmir valley but needed required support from the local administration to promote the activity. This carp based marginal aquaculture did not receive support because the State administration was more focused on the propagation and development of sport fishery.

8.1.3 Indigenous Snow-trout

Different species of snow-trouts are indigenous to Kashmir inhabiting both lacustrine and riverine systems. Most of the species are endemic in the valley and through the years of anthropogenic and environmental stresses, their fishery is on the decline which has been documented by the NRCCWF. Therefore, to restore this fishery, evaluating the feasibility of its farming under controlled conditions was an important approach. In this

70-90%. The fertilized eggs of *Schizothoraichthys niger* could be incubated both under still and flowing water conditions while in other species, the larval hatching was possible only under flowing water conditions. On the basis of analysed data, the cumulative survival from egg to swim-up fry was 80% in case of *Schizothoraichthys niger*, 60% in case of *Schizothoraichthys micropogon* in a specially designed incubator with flowing water facility. However, the percentage survival in case of *Schizothoraichthys esocinus, S.curvifrons* and *S.richardsonii* ranged between 35-55, 25-30, and 30-35, respectively. The breeding details are tabulated hereunder:

Table 9. Artificial propagation of different Schizothoracid species

Species	Percent fertilization	Incubation period (days)	Water temperature (°C)	Cumulative survival from egg to fry (%)
S. niger	70-92	8-15	9.5-20	55-80
S. micropogon	75-85	15-18	10-20	40-65
S.esocinus	80-90	15-20	13-18	35-55
S. curvifrons	70-75	8-15	14-18	25-35
S. richardsonii	75-80	8-12	14-18	30-35

8.1.3.1 Development of Field incubator

In the absence of full-fledged hatchery at the field site, a portable incubator was designed for production of Schizothoracid seed at the stream site. The devised incubator consists of an outer metallic circular jacket (circumference 85 cm, height 35 cm and diameter 25 cm) with an inlet (dia 1.5 cm) at the bottom and an outlet (dia 1.5 cm) at the top. The incubator is zinc painted inside and provided with a handle. Inside the jacket, six metallic circular hatching trays are arranged in a row one upon the other. Each tray (circumference 60 cm, height 5 cm and diameter 20 cm) has a base fitted with nylon netting (approximately 196 mesh/cm^2). The metallic walls of the trays are coated with rust proof paint. The lowermost tray rests on a small triangular stand permanently fixed to the last tray. The bottom of incubator contains a layer of sand and gravel in order to trap incoming silt with water.

The incubator can conveniently be installed

the eggs is kept and dead eggs, if any, can be picked up with a tweezer. The treatment against any possible infection can be given by flowing the desired concentration of the chemical through the inlet pipe, this process will bathe all the eggs uniformly. The chemical will pass out from the outlet at the top of incubator. After the required incubation period of 8-15 days, the newly emerged hatchlings can be collected from the trays for further rearing in nursery troughs/tanks.

The working of the designed incubator has been tested on the artificially stripped eggs of Schizothoracids and those collected from nature and in both cases encouraging results were achieved. The incubation period ranged from 8-15 days with 60-65% survival. Regarding survival rates, no significant difference was recorded in hatching trays stocked @ 2000-2500 eggs and kept at different tiers inside the main incubator. Within a period of two weeks, this small sized incubator can produce 10,000 hatchlings, this capacity can be increased by suitably changing the size of the incubator. The advantages of this incubator are (i) it is handy and economical (ii) can be installed in the field by the side of a stream (iii) there is no possibility of oxygen depletion inside the system as it can be placed near to a running water stream (iv) the size of the incubator can be changed depending upon the availability of brood stock and quantity of seed to be produced. The details of experimental trials conducted are given hereunder :

Table 10. Average survival in various field trials of the designed incubator.

Tray No.	No. of eggs	Hatchlings produced	Percent survival	No. of eggs	Hatchlings produced	Percent survival
1st tray (bottom)	2,000	1,180	59.5	2,500	1,528	61.0
2nd tray	2,000	1,264	63.2	2,500	1,507	60.3
3rd tray	2,000	1,228	61.4	2,500	1,525	61.0
4th tray	2,000	1,306	65.3	2,500	1,575	63.0
5th tray	2,000	1,240	62.0	2,500	1,527	61.0
6th tray (top)	2,000	1,262	63.1	2,500	1,502	62.0

This miniature hatchery will greatly help in seed production acivity of snow-trout thus facilitating the rehabilitation of this species by ranching it at suitable sites in the

8.2 Openwater Fisheries & Aquatic Resource Management

8.2.1 Impact Evaluation of Exotic over Indigenous fish species

The exotic carp, different phenotypes of *Cyprinus carpio* were introduced in Kashmir waters in late fifties. It was in eighties that impact evaluation studies were taken up by the Coldwater centre. Till then no scientific studies on these lines were initiated by any other agency in the State. From the investigations conducted on the Dal lake in Kashmir and its fish population dynamics, it was possible to identify three main impacts which contributed to the population shift in the lake system. The population of about 70% in favour of *Cyprinus carpio* was the most significant impact of this introduction. In comparison, the indigenous species of Schizothoracids in the lake were reduced to nearly 20% in total catches. The investigations were continued to assess main reasons which led to this population shift. The main reasons identified were food, fecundity and spawning behaviour. The details are indicated as under :

Food : The common carp (*Cyprinus carpio*) is mainly detritus eater and omnivorous with affinity towards phytoplankton and same is the feeding pattern of snow-trouts in the lake. The feeding overlap is indicated from the data generated during the study and details are set in table below:

Table 11. Competition for food between Common carp and Snow-trouts in Dal lake, Kashmir

Fish	Decayed organic matter (%)	Phytoplankton (%)	Zooplankton (%)	Miscellaneous (%)
Common carp	73.81	23.43	2.76	-
Snow-trouts	61.56	27.98	1.75	8.71

Fecundity : The fecundity of mirror carp was estimated at 1,97,403 eggs per kg of body weight. On the other hand, the average fecundity of Schizothoracids was estimated at 26,420 eggs per kg of body weight. Therefore, mirror carp produces seven (7) times more eggs as compared to snow-trouts giving a competitive advantage to exotic carp

up of these streams in autumn season when the fry are ready to migrate into the lakes. In this process, the fry perish and natural recruitment of this indigenous species is significantly hampered.

A fisherman from Dal lake in Kashmir showing a small catch of *Schizothorax* spp. (snow-trout)

8.2.2 Stream Ecology

General creel census of important trout streams in Kashmir valley was undertaken to determine fishing pressure and productive potential. The study was important in order to fix the bag limit for angling on a sustainable basis. This work assumes importance in view of promoting angling tourism of brown trout, *Salmo trutta fario*. Similarly in the Jammu region of J&K state, potential mahseer seed collection sites were identified and quantified in local streams *viz*., Jhajjarkotli, Anji, Behani, Duddar and Ujh. Based on various ecological parameters involving water quality and status of benthic population in different streams, a classification of streams was developed which reflect an estimate about the productive potential of each type of stream. This investigation assumes importance in any ecological action plan for streams with a focus on fisheries development and conservation.

8.2.3 Fish Biology & Ecology

The centre generated important database on the general and breeding biology of snow-trouts from different aquatic biotopes such as river systems, lakes and streams in Kashmir valley. For the first time breeding ground of *Schizothoraichthys niger* was located in the Dal lake implying that this species of Schizothoracid group does not require breeding migration. The destruction of natural snow-trout seed in local streams was also estimated and quantified. The investigations carried out to assess the natural recruitment potential of Schizothoracids in Kashmir waters revealed that majority of species migrate to the tributaries of the river Jhelum and other snow-fed streams and lay eggs in shallow pools under sand and stones. However, the investigations revealed that in case of *Schizothoraichthys niger* there is significant deviation. Apart from migrating upstream of the Dal lake for breeding, it also lays eggs in shallower regions of the lake. Spawn is usually available during June to August. The average densities of mixed spawn of *Schizothoraichthys esocinus. S. planifrons, S. plagiostomus, S. micropogon, S. curvifrons* from the Isthal, the Vishaw, the Mirhama, the Erin and the Arah streams ranged between 50-245 fry m^{-2}. Since the spawn is usually under boulders, it is difficult to collect it from streams. However, under favourable conditions, approximately 2000-3000 fry can be collected per day (assuming 6 hour working) by employing 2 persons. This makes the artificial propagation of this group all the more important.

improvement if management norms are applied. The lakes fixes on an average 2463 g C m^{-2} y^{-1} at primary level out of which only 6% is contributed by phytoplankton and 94% by macrophytes. On the other hand, zooplankton fix about 16.7 g C m^{-2} y^{-1} and fish harvest is estimated at only at 0.250 g C m^{-2} y^{-1} on an average indicating low conversion efficiency at each succeeding trophic levels. The conversion efficiency between primary producers and zooplankton was 0.055% and between former and fish it was only 0.002%. In such wetlands, most of the energy fixed by macrophytes remains un-utilised as no vegetation feeder fish species is available in the system. Similarly the energy fixed by the phyto-and zooplankton in the system was not efficiently being utilized in the system towards fish production. Combination of different fish species will help in optimal utilization of energy fixed from different sources and promote fish yield. Four species combination could be trial tested in these ecosystems with Schizothoracids, *Cyprinus carpio* (coldwater strain), Grass carp and Silver carp, as possible candidate species. However, stocking density of grass carp can be kept low in order to have sustainable growth of aquatic weeds in the systems, which the local inhabitants put to other uses also.

Eutrophication problem and energy transfer in natural flood-plain lakes/ wetlands of Kashmir were investigated. Based on the data generated, judicious fishery exploitation strategy was developed for these ecosystems. Similarly biological indicator species for eutrophication were identified in the local lake systems which will help in pollution and general health monitoring of lakes in the valley. These indicator species were very stable and reliable. Based on the energy transfer investigations, a fish stocking action plan for

temperate systems was developed. For the first time in the country high altitude (>3000 masl) glacial lakes were investigated in detail in order to develop a strategy for fishery development at those inhospitable areas of Kashmir Himalayas. Some of the scientific data useful for developing management norms is indicated in table 12, 13.

Spear fishing locally called "Narsoo" being operated by a fisherman in a Kashmir Lake

Table 12. Photosynthetic Energy fixation and its Conversion in a typical valley Lake

Parameters	Values for different ecological indices
Location	34 °06' N
Total average radiant	
(a) energy received Cal m^{-2} y^{-1} x 10^8	14.0
(b) average visible radiation Cal m^{-2} y^{-1} x 10^8	10.0
Phytoplankton photosynthetic prouction	
(a) g C m^{-2} y^{-1}	115-327
(b) Cal m^{-2} y^{-1} x 10^6	1.1-3.2
Photosynthetic efficiency (percent)	0.067-0.32
Fish production	

Table 13. Main Characteristics of different lake types in Himalayan region

Characteristics	Zone-I (32-36 °N)			Zone-II (28-32 ° N)	
Altitude (masl)	1587	2200	>3000	600-850	1300-2200
A. Waterspread (ha)	10-6000	15-30	2-160	25-75	40-100
Max. depth (m)	3-12	6-8	6-85	5-50	20-30
Mean depth (m)	1.5-2.5	2-3.5	8-20	20	10
B. Surface temp. (°C)	28-29	23-25	7-15	31-33	23-27
Maximum	(J/A)	(J/A)	(A/S)	(J/J)	(M/J)
Minimum	5-6	sub-zero	sub-zero	12-15	9-12
Bottom temp. (°C)					
Maximum	13-28	15-16	6-8	26.0	20.0
Minimum	5.5-6.5	4-5	3-4	13.0	10.0
C. Difference between Surface & bottom (°C)					
Maximum	6-17	8-9	7-8	7.0	17.0
Minimum	0.5	0.5	nil	1.0	0.5
D. Thermocline depth (m)	3-6 (weak&stable)	1-3 (stable)	3-6 (stable)	3-9 (stable)	3-5 (shortlived/ stable)
E. Thermal type	wm & pm	dm	dm & cm	wm	wm
F. Dissolved oxygen (ppm)	7-11	5-10	8-9.6	4-12	7-14
G. pH	7.2-9.2	7.8-8.4	6.8-7.1	7.2-8.9	6.8-9.5
H. Macrophytes	P	P	nil	P	P
I. Fish	*Cyprinus*	*Cyprinus*	*Salmo*	*Cyprinus*	*Cyprinus*

B. Kumaon Himalaya

After being created as the independent National Research Centre on Coldwater Fisheries under ICAR set-up in the year 1987, the Centre was located in U.P. hills with temporary headquarters at Haldwani. The centre started operating from 1988 in Kumaon hills. Subsequently the institute addressed many problems related to openwater fisheries and hill aquaculture in particular with focus on Kumaon Himalaya. The region has large number of streams, lakes and rivers where fish catches have declined considerably owing to environmental degradation of resources through increased human activities. The achievements in brief from the region are summarized hereunder.

8.3 Aquaculture

8.3.1 Indigenous species

8.3.1.1 Artificial propagation of golden mahseer (*Tor putitora*)

For seed production of this fish species, a hatchery unit was designed and established at Bhimtal (Dist. Nainital) close to the lake. The unit comprises series of tanks placed at a specific height, with water supply and distribution systems creating a flow-through impact on the hatching trays and troughs. This design was developed to fit in the rural hatchery concept and was cost effective.

During the breeding season, the right maturity spawners are collected by gill nets from the local Kumaon lakes namely, Bhmital, Naukuchiatal, Garurtal. The female brooders are normally in the size range of 350-620 mm/500-2200 g in these lakes. The ripe eggs are stripped and fertilized with oozing milt from the male spawners in the size range of 290-460 mm/300-800 g by dry method. The rate of fertilization varied from 88.5-97.0%. The incubation period ranged between 92-100 hours at a water temperature of 22-24 °C. The hatching rate ranged between 93-97% while the yolk absorption was completed in 10-12 days. The cumulative survival from fertilized eggs to swim-up fry was estimated at 95%.

After size grading, the mahseer fry were stocked in flow-through water troughs ($2m^2$ area) having flow rate of 3-4 litres/minute @ 2500-4000 m^2 .The fry were fed with laboratory compounded dry diet, having crude protein level of 45.5%. The main ingredients of the artifical diet were casien, soybean, silk-worm pupae, fish oil supplemented with vitamin and mineral pre-mix. The feeding was carried out at 10-15% of body weight initially (20-25^{0}C) and reduced to 5-10% latter (10-20^{0}C). After the fingerling rearing was over, the ranching programme was initiated in different lakes and streams in the locality. During the rearing period the water quality parameters ranged between 10.5-26.5 °C temperature, 7.1-7.9 pH, 8.2-11.5 mg/l dissolved oxygen, 60-140 mg/l total alkalinity, 1,4-4.5 mg/l silicates, nil-0.02 mg/l phosphates, and 12-15 mg/l nitrates. In the process, a survival in the range of 70-90% has been achieved at different developmental stages.

8.3.1.2 Flow-through hatchery for mahseer

A flow-through hatchery, designed and fabricated by National Research Centre on Coldwater Fisheries at Bhimtal in Kumaon hills, has the capacity of incubating 0.25 million eggs, rearing 0.2 million swim-up fry and production of 0.1-0.15 million advanced fry of golden mahseer. The capacity of a flow-through hatchery can further be increased with installtion of more troughs/trays and nursery facilities with substantial increase in the water quantity through overhead tanks. In comparison to conventional methods in flow-through hatchery, it was possible to achieve 30% higher survival from fertilized egg to advanced fry stage. This hatchery is very useful in producing stocking material of golden mahser on large scale for ranching in natural waters and for raising under aquaculture programme.

given to a site where gravity water supply can be assured in the hatchery and farm. The water source to hatchery should be of good quality and adequate in quantity.

Water source

The source of water may be either reheocrene or limnocrene type of spring or from a brook/stream having low silt content and organic nutrients. The water supply to the hatchery must not contain pollutants or toxic substances detrimental to fish life. Water from a spring source is the most ideal for mahseer cultivation as temperature regime does not fluctuate much. The oxygen content of water is of paramount significance and should be in the range of 7.0-9.0 mg/l at all times in all seasons. The water temperature between 20-25°C during breeding and marginally higher during rearing phase is desirable. It is always better that the water is passed through desilting device or a deep storage chamber before it is fed to the hatchery.

The distribution of water in the hatchery should be so regulated that each unit, comprising hatching troughs, nursery tanks, etc., have separate inlets to receive the required quantity of fresh oxygenated water in various components of the hatchery, overhead tanks with pumping facility can be a suitable alternative. The quantity of water required during various phases of golden mahseer rearing under controlled conditions are tabulated below:

Table 14. Water requirements in a hatchery system

Incubation of fertilized eggs & hatchlings	1.5-2.0 liter/minute for 5000-10000 stock at water temperature of 20-25°C
Swim-up fry and early fry	2.0-3.0 litres/minute for 3000-5000 stock at water temperature of 25-27°C
Fry and advanced fry	3.0-5.0 litres/minute for 1000-3000 stock at water temperature of 25-30°C

Brood stock

Unlike salmonids which are a domesticated species, the availability of brood stock either from farm or from the wild waters is a pre-requisite for mass scale seed production of golden mahseer. The species is said to have multiple spawning periodicity. The

Hatchery unit

A hatchery, for incubation for eggs and rearing of swim-up fry is generally sheltered with a roof having number of hatching troughs and tanks especially designed for this purpose. The floor should be cemented with a gradient to facilitate cleaning and removal of water. The hatchery should be protected from direct sunlight and should have adequate neat and clean working space.

Troughs

The hatchery troughs may be of different shapes and sizes but each should have the capacity to hold sufficient water for rearing the eggs, larvae and early fry. The rectangular troughs (220 x 50 x 40 cm or 220 x 60 x 50 cm) which are generally used in the trout hatcheries can be used for rearing mahseer eggs and raising its larvae and fry. The depth of troughs may be increased by 10-25 cm to facilitate rearing of spawn and fry of mahseer. These troughs can be made from cement, aluminium but preferably of fiber-glass. The arrangement of hatching troughs may be in a series so that water source flows into the first or head trough to subsequent troughs. Additional water supply to augment the dissolved oxygen content can be provided for each trough. Each trough should have separate inlet and outlet mechanism for water, A trough with at least five hatching trays can hold 20,000-25,000 fertlised eggs.

Trays

The hatching trays made of fiberglass/wood may be rectangular or square shape with the size so adjusted that 4-5 trays can be placed in each trough. The bottom of each hatching tray is fitted with synthetic netting cloth (mesh: $2mm^2$) to ensure regular water movement and the height of each try ranges from 3-4 inches. The outside dimensions of each tray are such that they can be accomodated in series along the length of each trough. Each tray (50x30x10 cm) has a capacity to hold, 4,000-5,000 fertilized eggs.

Nursery tanks

The nursery tanks are the other important components of a hatchery which are used for rearing the early fry of mahseer during their initial feeding stage. These tanks may vary in shape and size but should not be very deep. Efficient nourishing of tiny mahseer fry can be possible in shallow tanks. The suggested size of the rectangular nursery tanks can be 2.0 x 0.5 x 0.6 m or 2.0 x 0.75 x 0.6 m and

or made of fiberglass with continuous water renewal facilities (flow rate 2-3 litres/ minute). In these ponds fry @ 1000 m^{-2} can be stocked.

8.3.1.3 Artificial propagation of snow-trout, (*Schizothorax richardsonii*)

The recent threat posed to the stocks of snow-trout, the principle indigenous fish of Kumaon Himalayas and also available in other upland regions, either due to environmental degradation or man-induced changes has made its rehabilitation in depleted waters a priotity activity. Though the institute had earlier achieved the artificial fecundation of different species of Schizothoracids but the success in local variety of *Schizothorax richardsonii* could not be achieved. The institute at its Chirapani farm has now achieved the success in artificially breeding this species from the wild spawners. The survival at the hatchling stage was around 60-85%. The size of the hatchlings ranged between 9-10 mm, having a large yolk-sac, which is absorbed during 5-10 days of hatching. The early fry are fed with starter feed comprising skimmed milk powder and egg-yolk supplemented with casein and vitamin premix. The starter diet has been found to be very helpful in reducing the mortality rate at this critical stage. The methodology developed has opened the possibility of raising *Schizothorax richardsonii* seed on large scale to ranch depleted waters for enhancement of fish stocks in Himalayan region.

period with 41% survival of fry stocked @ 5 fishes m^{-2} whereas their respective values were 4.41 g and 65.5% in case of fry stocked @ 2.5 fishes m^{-2}, each having an initial average weight of 0.150 g. In case of fingerlings which were stocked in the month of July/September the observed growth increment was 85.7g, 38.5g, and 15.7 g, from the initial range of 12.5 to 45.6 g. The respective survival rate for these test fishes was 27.5% 89.3% and 20%. The experimental fishes were reared in cemented tanks and were fed with artificial diets comprising rice polish, wheat bran, soybean meal, mustard oil cake fortified with vitamin and mineral mix.

8.3.1.4 Nutrition and artificial feeds for coldwater fishes

The institute in its efforts to develop a balanced formulated feed for coldwater fishes especially for mahseer, has conducted large number of experiments, in which six (6) diets were formulated and compounded. The feeding experiments were carried out on the hatchery reared hatchlings, advanced fry, fingerlings and the juveniles collected from nature. Artificial diets in the protein range of 21.4 to 50.2 percent were trial tested but better growth and survival was recorded in 45.4% protein diet. A positive correlation was observed between the dietary protein content and overall growth performance and conversion ratio. The percentage composition of test diets tried at the institute is presented in the table hereunder:

Table 15. Proximate composition (%) of different formulated diets

Parameters	Formulated diets					
	1	2	3	4	5	6
Crude protein	21.45	27.62	31.94	36.66	45.38	50.21
Ether extract	24.14	16.44	12.47	17.13	14.12	13.69
Nitrogen-free extract	39.90	37.11	38.59	24.78	22.34	20.36

The formulated diet no.5 gave the overall best survival, feed efficiency, conversion ratio, growth etc. amongst all the six feeds compounded for young stages of golden mahseer. Any balanced formula for fish diet must include required indispensable aminoacids plus the energy source in the form of lipids and carbohydrates besides essential vitamins and minerals to support life and promote growth. The golden mahseer inherently shows poor growth behaviour, therefore, making available artificial feed which is nutritionally balanced is very important in developing a culture system for the species. The results of different trials conducted at the institute are presented in the table below. Further, improvements in the feeds is continuing. It is expected that already tested feed showing good performance will be released to the industry very soon.

Table 16. Comparison of growth behaviour with different trial diets

Parameters	Stages	Tests diets					
		1	2	3	4	5	6
Survival (%)	SUF	40.7	46.8	52.5	54.9	65.1	64.2
	F	48.3	52.1	57.9	63.4	74.8	69.1
	AF/Fin	52.6	60.5	64.4	75.2	82.6	73.3
Feed efficiency (%)	SUF	31.4	31.5	36.9	37.9	41.7	34.9
	F	35.7	37.6	40.9	39.2	43.5	40.9
	AF/Fin	34.8	36.2	41.2	42.1	44.6	39.7
Growth rate	SUF	7.3	8.4	8.2	8.8	7.3	8.8
	F	2.5	2.7	3.0	2.9	3.0	2.9
	AF/Fin	4.7	4.9	5.1	6.3	6.6	5.1
Body wt. increase/ day (g)	SUF	0.23	0.24	0.26	0.27	0.29	0.25
	F	0.08	0.09	0.10	0.10	0.10	0.10
	AF/Fin	0.08	0.09	0.09	0.10	0.11	0.08
Feed conversion ratio	SUF	3.4	3.2	2.7	2.7	2.4	2.8
	F	2.8	2.7	2.4	2.5	2.3	2.5
	AF/Fin	2.8	2.4	2.4	2.4	2.4	2.5

SUF = Swim-up fry ; F = Fry ; AF = Advanced fry ; Fin = Fingerling

8.3.1.5 Biochemical physiology of mahseer and snow-trout

Tor putitora which can be correlated with their habitat ecology. The seasonal analysis of enzymatic activities in male and female fishes of *Schizothorax richardsonii* revealed that there was no remarkable variation in the activities of LDH, GOT, GPT, ACP, and ALP during pre-spawning (June-July) and spawning season (August to October) in both the sexes. Similarly insignificant drop ($P>0.05$) was also recorded in the values of RBC, Hb, and PCV in both male and female snow-trout fishes during spawning season, probably fishes undergo naturally caused starvation due to paucity of space in abdominal cavity caused by matured gonads during breeding season.

The comparative electrophoretic pattern of blood plasma proteins and soluble heart tissue proteins of *Tor putitora, Schizothorax richardsonii, Garra gotyla* and *Barilius bendelisis* collected from natural habitats revealed that the overall number of bands vary with genera. The variations in band pattern of an animal species mostly occurs as a result of their genetic constitution and influence of environmental and physiological factors. The maximum number of protein bands appeared in both the tissues of *G. gotyla* and minimum in *T. putitora*. The interesting aspect was that some of the protein bands exhibited almost similar values of relative moblities (Rf) irrespective of the genera of fish due to their same ratio of charge and molecular weights upon which they moved under the electric field during PAGE. This indicated that the tissues of these fish species have proteins of identical nature and function probably due to the same ecological and environmental conditions in which they live.

The changes in proximate composition and energy content of muscle tissues have also been observed with different size groups of male and female in *Schizothorax richardsonii*. Among both the sexes protein, total lipids, ash, glycogen, phospholipids and energy contents increased significantly with increase in size of fish from 100 mm to 200 mm. However, moisture and cholestrol decreased significantly with increase in size of fishes. Comparatively, in either sexes of different size groups, only glycogen and phospholipids were significantly higher in females (<0.01) and moisture in males ($p<0.01$), though other muscle constituents did not exhibit any significant variations.

8.3.2 Exotic species

8.3.2.1 Farming prospects of exotic carps in Kumaon Himalaya

Among the cultivat

Himalayan states as well in the uplands of Deccan plateau. To assess the feasibility of mixed culture in temperate and sub-temperate climates of Himalayas, trials have been under taken by NRCCWF to rear these fishes in running water ponds at Chirapani, Champawat, so as to evolve package of practices.

8.3.2.2 Monoculture of common carp (*Cyprinus carpio*)

Common carp reared at different stocking density of 1.5, 3,4 and 5 fishes m^{-2} in small cemented ponds of $30m^2$ size registered growth of 0.239, 0.173, 0.118, 0.178 and 0.085 gd^{-1} with the net weight of 62.5, 30.5, 46.7 and 22.2 g, respectively during 200 days of rearing. It indicates an inverse relationship between fish growth and stocking density. It has also been observed that the water temperature has the profound role in determining the growth of the fish in this climatic condition, where the higher growth rate (0.14-0.34 g d^{-1}) was recorded at the water temperature range of 20.0-25.9 °C. On the other hand, the daily growth rate of 0.02-0.11 g d^{-1} was registered at the temperature range of 9.2-18.1 °C. The survival range of 77.3-100% was observed to be independent of stocking density.

A balanced supplementary feed for the exotic carps developed by the centre

8.3.2.3 Mixed culture of exotic carps

In the upland waters, the Indian major carps do not grow well due to the low thermal regime. Therefore, Chinese carps were taken as the candidate species for mixed culture trials. The experiments conducted at chirapani farm on mixed culture were based mainly on common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*). The stocking densities tried were 1.5, 2.0, 3.0, and 5.0 fishes m^{-2} in the combination of 50: 25: 25 ; 50:20:30 ; 25:25:50; and 20:20:60, respectively. The experimental fishes were fed twice daily @ 2% of their body weight with supplementary feed constituted from mustard oil cake (30%), soya flour (25%) rice polish (15%) wheat bran (20%) and fish meal (10%) in addition 0.001 g of cobalt chloride was mixed as growth promoter. The analysis of data on growth and survival of various carps with different stocking densities revealed that in a rearing period of approximately 200 days, the highest production (412 g m^{-2}) was achieved at the stocking density of 3 fish m^{-2} with the species combination of 25,25 and 50 percent of common carp, grass carp and silver carp. In comparison the total fish production at the stocking

Table 17. Growth of exotic carps at varying temperatures at Chirapani experimental farm

Month	June/July	August	September	October	November	December
Temperature (°C)	22-28	27-29	25-27	18-22	16-18	5-10
Fish species	Growth per day (g)					
C. carpio	0.18	0.39	0.24	0.21	0.09	0.09
C. idella	0.20	0.37	0.30	0.18	0.13	0.00
H. molitrix	0.23	0.37	0.41	0.22	0.112	0.00

From the data generated, it is observed that eight month period between April to October is the most suitable for growing fish in the temperate climate prevalent in higher reaches of Kumaon. From large number of experimental trials conducted by the institute, a culture technology suitable for water temperature range of 5-29°C in hills, based on three species combination of *Cyprinus carpio, Hypophthalmichthys molitrix* and *Ctenopharyngodon idella* stocked in the density range of 3-4 fishes m^{-2} with recommended supplementary diet, has been developed. It has been possible to achieve a production range of 1300-1700 kg ha^{-1} yr^{-1} under these low temperature conditions. This technology opens up the possibility of promoting exotic carp culture in hills where existing production of indigenous fishery is very low.

8.4 Openwater fisheries & Aquatic Resource Management

8.4.1 Stream ecology

The investigations were carried out in the Gaula and chirapani streams, the two important fishery resources in the region. The productive potential of the systems was evaluated in terms of biodiversity. The density of plankton populations in these systems ranged between 175-1030 units l^{-1} while the benthic populations recorded a range of 4-57 units m^{-2}. The major benthic groups recorded in these systems were Ephemeroptera (nil- 64.5%), Odonata (nil-18.5%), Plecoptera (nil-12.75%), Trichoptera (nil-24.4%), Diptera (nil-37.5%) and miscellaneous forms (nil-80.5%). The pre-dominant benthic forms recorded were *Baetis, Rithrogena, Heptagenia, Iron*, and *Epeorus* from Ephemeroptera ; *Gomphus* and *Ophiogomphus* from Odonata; *Choloroperla* from Plecoptera; *Elmis, Gyrinus* and *Dityscus* from Coleoptera : *Hydropsyche, Rhyacophila*

frequently encountered. The sex ratio recorded in case of *Tor putitora* was 0.5 : 1. The males were in oozing stage in the month of June while the gravid females were encountered between July to August. The experimental fishing revealed the CPUE value to range between 107-500 g man^{-1} h^{-1}. The contribution of *Schizothorax richardsonii* to total catches was nil-67.3% and that of *Tor putitora* between nil - 59%. Other species also contributed significantly to total at specific stretches.

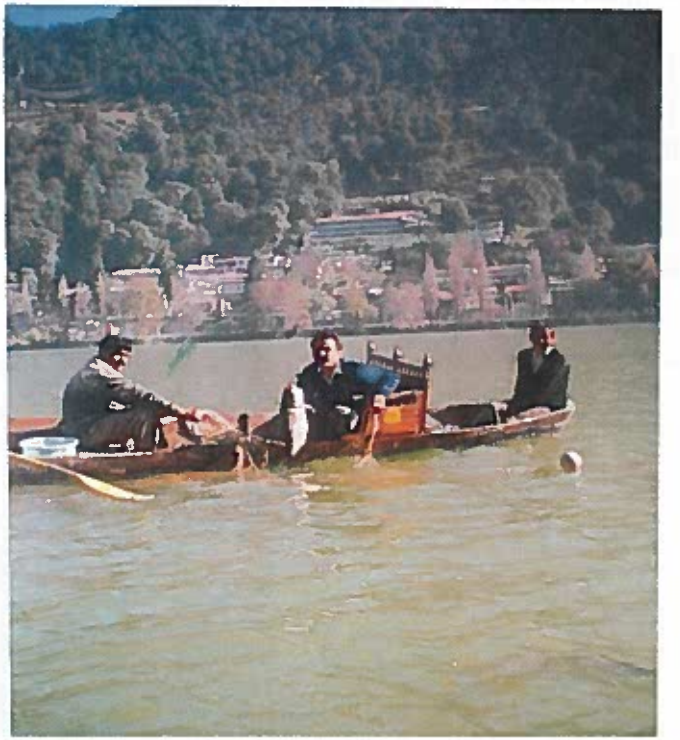
Table 18. Some water quality features of typical Kumaon rivers/streams

Name of river/stream	Source	Hydrographic regime	Length (km)	Temperature (°C)	D.Oxygen (mg/l)	pH	T.Alkalinity (mg/l)
Kali	Lipulekh	Fluvio-glacial	220	13.3	11.2	8.2	118.0
Gori	Milam	Glacial	100	13.2	11.2	8.2	108.0
Saryu	Sahastra Dhara	Fluvio-glacial	120	19.2	10.6	7.9	111.1
Ramganga (E)	Namik	Fluvio-glacial	85	21.5	9.9	8.0	121.4
Gomti	Angari	Fluvial	40	18.5	9.8	7.6	54.0
Ramganga (W)	Dudhatoli	Fluvial	85	20.2	9.4	7.4	120.0
Kosi	Bhatkot Kausani	Fluvial	150	16.8	8.8	7.3	120.0
Gaula	Motia patthar	Fluvial	78	22.3	9.8	7.4	78.0

Fishes once abundant in the Kumaon rivers and streams have now become rare. One of the principle reasons for decline in fish fauna is their mass killing by poisoning, dynamiting and using small sized mesh nets for catching. The rapid deforestation along the catchment of the streams and rivers facilitates soil erosion, which ultimately deteriorates the natural feeding and breeding grounds of the fish. Apart from these activities, the habitat loss due to water abstraction for agriculture, domestic and other uses, leads to an appreciable reduction in minimum water volume required for fish growth. These physical and chemical modifications of the river, result in an ecological imbalance for the fish communities which cause loss in their diversity.

8.4.2 Lake Ecology

Apart from other lakes in the region, as a case study investigation was conducted on Khrupatal located at 1600 masl. It is a typial warm-monomictic and closed type lake



with underground and catchment as the source of water. The lake supports massive growth of phytoplankton population which ranged between 1.27 to 15.84×10^4 units l^{-1}. The populations are mainly dominated by Dinophyceae (55-100%) followed by Bacillariophycae (nil-35%) and Cholorophyceae (nil-10%). On yearly basis, the dominant forms in the lake were *Peridinium palatinum, Glenodinium quadridens* and *Ceratium hirudinella*. The diversity of zooplankton population in the lake was low. The density in the littoral zone varied from 18-313 units l^{-1} with copepoda (41.2- 100%), rotifera (nil-48%) and cladocera (nil-37%) as the major groups. The macrobenthic populations in the system ranged from 267-1422 units m^{-2} recording a wet biomass of 4.43-86.56 g m^{-2}. Among the major groups, Odonata (nil-68%), Ephemeroptera (nil-88%), Diptera (nil-68%), Coleoptera (nil-49%), Mollusca (nil-77.7%) and Oligochaeta (nil-46%) were most dominant. The gross primary productivity at the littoral zone ranged between 67.5-112.72 mg C m^{-3} h^{-1} while at pelagic site, it ranged from 35.5-97.25 mg C m^{-3} h^{-1}.

Table 19. Some typical limnological characteristics of Khurpatal lake

Characteristics/Parameters	Values/Ranges
Altitude (m above sea level)	1670
Longitude (N)	29 ° 25' N
Latitude (E)	79 ° 27' E
Maximum depth (m)	20.0
Maximum surface Area (ha)	14.0
Water temperature (°C)	11.0-27.5
Secchi transparency (m)	1.5-3.5
pH range	7.8-8.4
Dissolved oxygen (mg/l)	10.1-15.9
Free carbondioxide (mg/l)	0.13-1.43
Total alkalinity (mg/l)	57.0-145.5
Chloride (mg/l)	12.0-17.85
Calcium (mg/l)	22.8-57.0
Magnesium (mg/l)	2.10-2.75
Total dissolved solids (mg/l)	155.1-182.1

The biological characteristics of mahseer population in the lake revealed the sex ratio to be 1:1 and fecundity to range between 8615-9120 eggs kg^{-1} of body weight. Aquatic insects and zooplankton were found to be the main food items for mahseer. The ripe specimens of either sex in case of mahseer to the tune of 83% were recorded from the lake between July to August. The experimental fishing carried out in the lake revealed *Tor putitora* to be dominant followed by *Cyprinus carpio*. The size frequencies of mahseer ranged between 305-425 mm in total length and 250-625 g in weight. The catch per unit effort was estimated at 3.5 kg per net per day. To enhance the mahseer fishery, advanced fry of mahseer produced in the hatchery are being stocked in the lake at regular intervals to adjust the balance between angling pressure and recruitment.

The basic ecological information generated by institute and from secondary sources about other lakes in the region are tabulated hereunder:

Table 20. Comparative water quality of important Kumaon lakes

Parameters	Naintial	Bhimtal	Sattal	Naukuchiatal
Altitude (masl)	1938	1347	1390	1220
Length (m)	1433	1901	920	951
Width (m)	463	451	270	692
Max. depth (m)	24.2	18.8	2.0	38.5
Mean depth (m)	14.2	11.5	8.0	22.5
Area (ha)	48.78	63.25	50.25	50.07
Secchi (m)	0.30-2.43	2.10-3.70	1.40-5.50	2.56-4.68
Water temp. (°C)	9-22	10.5-26.5	12.5-27.0	15-27
pH	7.2-8.4	7.2-8.3	7.2-8.3	7.3-8.2
D.O. (mg/l)	1.7-12.8	6.2-1.6	5.6-10.0	6.8-12.0
F. Co_2 (mg/l)	Nil-7.0	Nil-2.1	Nil-5.1	Nil-3.0
Co_3 (mg/l)	Nil-160	Nil-32	Nil-20.0	Nil-30.0
HCO_3 (mg/l)	136-250	80-182	46-110	60-142
T.alk. (mg/l)	140-470	80-182	46-124	60-142
Chlorides (mg/l)	24-32	13-22	8-18	8-18

9. EXTENSION SERVICES

The institute realizing the importance of transfer of the technologies developed in the labs to the user groups in the field has established a nucleus section. This nucleus is involved in promoting and popularizing the fish culture activity among the local farming communities and other persons involved in this activity. Concept of fish culture in the hills is to create awareness among the people about the economic benefits of multiple uses of water resources. Many strategies have been adopted to advise and extend the technologies to clients both in government and private sectors. In this direction a significant headway has been made by adopting 24 farmer's ponds located in the districts of Naintial and Champawat in which under the expert advise of NRCCWF, exotic carp based aquaculture is being successfully demonstrated. The seed of desired species is being provided to the farmers. This aquaculture awareness programme has now been extended to the district of Almora.

9.1 Exhibitions/Fairs/Farmer days

The institute has been extending necessary advice and support for R&D activities in coldwater fisheries through user-based extension programme. In this regard, the institute actively participated in following events:

- Aquaculture fairs during 1997 and 1999 at the Central Inland Capture Fisheries Research Institute, Barracakpore, West Bengal.

The Director briefing the activities of centre to Vice-chancellor, Kumaon University and Advisor Planning Commission, Govt. of India at an exhibition

- Diamond Jubilee celebration of National Jim Corbett Wildlife Sanctuary, Ramnagar, Distt. Nainital.
- Aqua-resources exhibition at the International conference on Tropical Ecosystem Health and Management, in year 1999 at Nainital.
- Aquafair at the Central Institute of Freshwater Aquaculture, Bhubaneshwar, Orissa. in the year 2000.
- An exhbition was organized by the institute on India's Golden Jubilee year of Independence.
- Participated and displayed exhibits at the Millennium International angling Festival held in the year 2000 at Panchashwer.
- Exhibition organized in 2001 at the First Indian Fisheries Congress held at Chandigarh.
- The institute has been participating in various exhibitions organized at the district and

The centre celebrating Fish farmer's day and present are Dr. M.Y. Kamal , the V .C, SUKAST, Kashmir & Shri S.K. Maheshwari, IAS, the D.M.,Champawat.

9.2 Training Programmes/Group discussions

In order to develop desired manpower at the farmer and district level, the institute is organizing hands-on training programmes for different clients. The tailor-made programmes are also organized as per the demands of various clients. The institute has till date organized programmes pertaining to coldwater fisheries for following agencies.

- Fishery Scientists/Research workers/Officials from Food and Agricultural Organisation.
- Fishery Scientists from Nepal Agriculture Council, Govt. of Nepal.
- Officials of fisheries and other departments from the States of Jammu & Kashmir, Haryana, and Uttar Pradesh.
- Central Institute of Fisheries Education Research Centre, Lucknow.
- G.B. Pant University of Agriculture and Technology, Pantanagar.
- Christian college, Chenni, Tamil Nadu.
- Department of Zoology, Degree college Pithoragarh and Kumaon Uni...

The students and scholars from different universities attending a training programme

9.3 Advices Rendered

NRCCWF in accordance with its mandate has rendered advice to following organiztaions for developing Coldwater Fisheries.

- Design and layout for constructing State Trout fish farm at Barangana, district, Chamoli.

- Design and layout of trout fish farm at Molhoi, District Senapati, Manipur.
- Design and layout of mahseer hatchery at Tajewala, District Yamunnagar, Haryana.
- To develop coldwater fisheries in small impoundments / reservoirs under" Small hydro-schemes in lesser Himalayan belt in Kumaon and Garhwal".
- Extension of aquaculture activities in Himalayah region to an NGO, INHERE, Masi.
- Subject matter specialists and extension personnel attend to specific quries from farmers on various aspects of fish culture, breeding, water and soil quality.

10. CONSULTANCY SERVICES / CONTRACT JOBS

The NRCCWF, through the years has developed expertise in various fields of coldwater fisheries and hill aquatic resource management, accordingly it is in a position to offer following services to the specific clients :

- Developing layout design for trout fish farms.
- Designing and layout of ponds / tanks for carp farming in running water systems in hills.
- Designing and layout of hatchery system for golden mahseer.
- Water and soil quality management in temperate aquaculture.
- Supply of seed of cultivable exotic carps and Himalayan mahseer for fishery development in hills.
- Ecological management and fishery enhancment in Lakes/Wetlands/Reservoirs located in foot hills and high altitudes.
- Prepare feasibility/project reports.
- On campus and off campus training programmes for research scientists/ state officials/technicians/farmers.
- To organize tailor-made training programmes to suit the specific needs of NGO's/ state officials/university students and other organisations.

11. FUTURE APPROACH

Between VII to IX Plan the scientific information on hill fisheries and technology generation in hill aquaculture has been significant. But the impact of those technologies due to various constraints was marginal. In order to make these technologies economically and ecologically sustainable for contributing to overall fishery development in remote hilly regions, the future approach of the institute during X plan will focus on following issues.

(a) Up- scaling of existing technologies, (b) Improvement in indigenous germplasm, (c) Yield enhancement through better diet and health management, (d) Improvement of gears, (E) Import of better exotics for higher production and sport, (f) Resource assessment, population dynamics and fishery management. Some of the key areas to be addressed under these broad approaches are indicated hereunder:

11.1 Aquaculture

- Seed production and table size rearing of rainbow trout in the state of Uttaranchal and other promising states in the Northeast.
- Brood stock management and fingerling production of golden mahseer both for culture and conservation in natural waters.
- Seed production of snow-trout, brood stock development and establishment of hatcheries
- Development of composite fish culture technology for coldwaters with a suitable mix of exotic carps and indigenous coldwater species. Seed production of exotics at high altitudes.
- Artificial breeding of other vulnerable and threatened coldwater fish species which are critical to biodiversity.

11.2 Capture fisheries

- Total inventory of Himalayan fishery resources with food-chain biodiversity, using modern tools of remote sensing and Geographical Information System.
- Developing predictive fishery enhancement and eco-management models for Himalayan lakes/ Wetlands.
- Survey and production assessment of high mountain lakes both fresh and brackish waters in the regions of Ladakh (J&K), Uttaranchal, Himachal Pradesh and Arunchal Pradesh in the northeast.
- Gear inventory, its improvement for efficient harvest of fish in coldwater streams, rivers and lakes.

11.3 Sport Fishery

- Identification and survey of angling sites in major river/streams in Himalayan region.
- Evolve a scientific angling policy for specific streams based on their carrying capacity and other ecological parameters.
- Establishing linkage with State departments, Angling associations, Tourist organizations and local stake holders for conservation of sites and populations.
- Generate a database to estimate the revenue generation through angling tourism and its impact on the economy of local population.