HISTORY AND DEVELOPMENT OF FISHERIES RESEARCH IN INDIA

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Fishing in the earlier half of the last century mainly comprised artisanal inshore capture fishery using sailboats and catamarans, and culture of Bengal carps (catla, rohu and mrigal). The Indian Fisheries Act of 1857 defined the powers and responsibilities of the erstwhile presidencies and princely states. Immediately after India's independence, for a few decades, the erstwhile Madras and Bombay States led the country in fisheries surveys and research activities. With I.A.S. officers at the helm of state fisheries departments, these aspects have been relegated to the background and replaced by central governmental agencies.

Precursors of today's multitude of research organisations were the CMFRI and CIFRI (for the full names of these acronyms, please see the body of the article), established just a few months prior to the country's independence. With the proliferation of fishery activities and research, these parent institutions were split, in 1987, into CICFRI, CIFA, CIFE, CIBA, CIFT, NRCCWF and NBFGR. CMFRI studies the fishery biology of commercially important fish and shellfish (both molluscan and crustacean), while the Fishery Survey of India (FSI) is concerned with offshore fishery surveys. The original culture of Bengal carps has now diversified to aquaculture of other carps, high altitude coldwater fishes, edible and pearl oysters and mussels, prawns, crabs and lobsters, and their associated diseases and parasites.

INTRODUCTION

"With timely action, fisheries can continue to provide food, jobs and enjoyment for millions of people worldwide. But ultimately this means changing our focus from what is done to a fish to what can be done for the fish. And the time for that change is now."

(Anne Platt McGinn, 1998)

The world's oceans were for long considered to have limitless fishery resources freely open to all for exploitation. The conflicts of fishers over open access and exclusive rights have intensified in the past fifty years. Worldwide, many of the major fish stocks have declined, reaching critical levels or have collapsed as was the case with the once thriving whaling industry prior to World War II. Now we know that the living aquatic resources, while renewable, are not infinite, and need good management for maintaining sustainable yields. Today, with depletion of many stocks, rising tensions prevail among fishers who are loaded with excess capacity in fishing crafts and gears. All this, despite the United Nations Law of the Sea Convention (UNCLOS) of 1982, which was ratified in 1984, granting rights to Coastal States to have an extended jurisdiction over their Exclusive Economic Zone (EEZ) of 200 nautical miles from the coast for developing their fisheries. From the traditional 12 nautical miles of territorial waters along the coast by Bay Islands, India today has 2.02×10^6 sq. km sea area, comprising 0.86×10^6 sq. km on the west coast (including the Lakshadweep Sea), 0.56×10^6 sq. km on the east coast and 0.60×10^6 sq. km around the Andaman and Nicobar Islands.

For those interested in the wealth of our knowledge about the fish and fisheries dating from the pre-Vedic, Vedic and post-Vedic periods, the period of the Sangam literature of south India, the works of Kautilya (ARTHASHASTRA) and King Someswara (MANASOLLOASA) and the Mughal period, reference is invited to Hora (1952), Raj (1955), Rao (1957) and Chitranshi (2000).

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FOUNDATION OF FISHERIES RESEARCH IN INDIA

Carolus Linnaeus to Francis Day

The foundation for fisheries research in India was laid by some of the early naturalists, zoologists and botanists who either worked in the Museums of Natural History in England and in European countries, where dried or preserved material from the east, including India, was received, identified, catalogued and reported on. From the times of Carolus Linnaeus, founder of the modern classification for plants and animals, there have been a number of taxonomists who have studied fishes, crustaceans and other aquatic organisms from India which earlier included Pakistan, Bangladesh, Burma and Sri Lanka (Ceylon), and from the coastal waters. Notable ichthyologists among them were Cuvier, Valenciennes, Lacepede, Bloch, Schneider, Forsskäl, Bleeker and Albert Gunther. Among early carcinologists were Fabricius, H. Milne Edwards and de Man. They have described several fishes and crustaceans new to science, many of which are of commercial importance today.

There were also naturalists with different avocations in India, who collected and described fishes, other aquatic animals and plants and made observations on bionomics. Notable among those who had contributed to our knowledge are Patrick Russell, Hamilton-Buchanan, Edward Blyth, Stolizka, Sykes, J. McClelland and T.C. Jerdon. The most outstanding contribution was that of Dr. Sir Francis Day, a veterinary surgeon and naturalist who travelled extensively in India in the mid-nineteenth century and wrote several scientific papers and monographs such as the FISHES OF MALABAR (1865). Day's *magnum opus* THE FISHES OF INDIA in two volumes (1875-78) followed by FISHES in the 'Fauna of British India' Series in two volumes (1889) describing 1,418 species are the two most indispensable works on Indian fish taxonomy to date. Day's interests were catholic and, besides his works on ichthyology, his most important contribution was a book entitled THE LAND OF THE PERUMALS. Day was knighted and he was appointed the Inspector General of Fisheries of India and Burma. Recently an excellent book on the life and works of Francis Day by Dennis Tucker and K.C. Jayaram, was published by the British Museum of Natural History.

Indian Fisheries Act - 1897

A milestone in the history of Indian fisheries is the enactment of the Indian Fisheries Act of 1897. The Act delegated to the erstwhile Provinces (States) the responsibility of development and conservation of fisheries in the inland and the territorial waters of the respective States. It also empowers the States to formulate their own rules and regulations for the protection and safeguard of their fisheries. Further, the Act provided adoption of conservation measures to prevent the destruction of resources. As a consequence, the development, management and conservation of fish and fisheries became a State subject.

The last 106 years have witnessed a sea change in fisheries research, education, extension and development, and there is an imperative need for promulgating a new Fisheries Act.

Early marine surveys

The *H.M.S. Challenger* Expedition in the late sixties and seventies of the 19th century triggered interest in marine resource surveys in the Indian seas. This was followed by the *R.I.M.S.S. Investigator* which carried out coastal and deep-water surveys in the Bay of Bengal and the Andaman Sea. These resource surveys brought to light many new and interesting fauna. James Wood-Mason published a series of papers on deep-sea crustaceans, especially from the Andaman Sea. The Navy also had Surgeon Naturalists working on board the *Investigator*, and among these the works of Alfred Alcock, Lloyd and Lt. Col. R.B. Seymour Sewell are most invaluable. Alcock's book A NATURALIST IN INDIAN

SEAS (1902) is a very interesting narrative of the many discoveries made during his voyages. Sewell was an authority on marine Copepoda. Later, when the Zoological Survey of India was founded in 1908, Sewell joined the Survey and his work on the hydrology and plankton of the Rhamba Bay, published in the *Memoirs of the Indian Museum* as part of the Survey of the Chilka lake, is an outstanding piece of work.

Role of the Zoological Survey of India in fisheries research

The Zoological Survey of India from its inception functioned as the Centre for research on fish, fisheries and marine biology. It was the national repository for terrestrial and aquatic organisms collected from the Indian region. This was made possible by its eminent Directors, namely Nelson Annandale who initiated studies on the hydrology of upland lakes, and coastal lagoons and lakes; Stanley Kemp who, in 1924, led the British Antarctic Expedition; R.B. Seymour Sewell whose forte was marine biology and oceanography; Baini Prashad, an authority on Indian molluscs and fisheries, and Sunder Lal Hora, an ichthyologist *par excellence*, ecologist and fish taxonomist. It is their leadership and research output that kept the Zoological Survey of India in a pre-eminent position among research institutions in India until the mid-1950s. Each one of them in their own right contributed to the early development of fish and fisheries research in India.

Annandale felt that the focus of research at ZSI should not be confined to only pickled specimens, but extend to observations in the field on the ecology and life habits of species as well. This dictum was carried out to the maximum by Sunder Lal Hora whose work on hill stream fishes published in the *Transactions of the Royal Society of Edinburgh* is a classic piece of work which has given us an in-depth understanding of an ecosystem that is gaining in importance today. Hora propounded the "Satpura Hypothesis" which led to a considerable amount of work on animal and plant species diversity. His contribution to ichthyology, ecology and biology of freshwater fishes has enriched our knowledge. Hora's interest in fisheries research led him to head the Department of Fisheries of West Bengal for some time and also play an important role in the founding of the Central Inland Fisheries Research Station at Barrackpore, Calcutta (=Kolkata). His researches on fish, especially the "wandering of the Bombay duck", on *Hilsa* and several others, helped in understanding more of the ecology and species diversity of the Gangetic estuarine system. He was a source of great encouragement to many. Those who worked with him, such as T.V.R. Pillay, E.G. Silas, A.G.K. Menon and K.C. Jayaram, subsequently headed research management positions in both national and international organisations, thereby influencing the development of fisheries research in its different facets.

Role of State Fisheries Departments in promoting fisheries research

It was Sir Frederick Nicholson who established the Department of Fisheries, in the erstwhile Madras Presidency, and a fish preserving unit for improving the keeping quality of fish. He also recommended the establishment of fisheries research centres. Madras Presidency had also a very distinguished scientist in James Hornell who initiated research in the coastal waters of the Presidency, especially in the Gulf of Mannar and along the southwest coast, as the Presidency extended along the west coast up to Goa. His works on the chank and pearl oyster fisheries and the monograph on Kathiawar are outstanding contributions. Marine surveys were conducted in the coastal waters along Malabar coast and the Lakshadweep Islands. James Hornell, in 1917, reported on the widespread mortality of fishes along the Malabar coast caused by a "Euglenid or Flagellate B, or an Infusorian Protozoa +". It was through the research of R. Subrahmanyan,

one of India's leading phytoplanktologists, that in 1954 the causative organism for such recurring fish mortalities was identified to belong to Chloromonadineae, and the flagellate was named in honour of Hornell as *Hornellia marina* gen. *et* sp. nov. Hornell laid a sound foundation for fisheries research in the Department.

The Madras Presidency played an important role in Human Resource Development (HRD) for fisheries research and management in the early years, as many of its scientists went on to head State Fisheries Departments, National Fisheries Research and Development Institutions or hold responsible positions in the Department itself. The *Madras Fisheries Bulletin* of yesteryear documented the research conducted in the Presidency's rivers, lakes and reservoirs and the coastal waters, especially in the Gulf of Mannar where a lot of effort was expended in the chank and pearl oyster fisheries.

Other states too had Departments of Fisheries carrying out both research and development activities. Dr. S.B. Setna, rightly known as the "Father of mechanisation" of fishing boats in India, pioneered research and development programmes in the erstwhile Bombay State/Presidency comprising present-day Gujarat (excluding the erstwhile Saurashtra State), Maharashtra and North Kanara districts, which were ably carried on by C.V. Kulkarni, and A.G. Kalawar. Kulkarni's contributions include his studies on the breeding of *Hilsa ilisha* in the Narmada estuary, and the description of a unique new Cyprinodont fish *Horaichthys setnai* gen. *et* sp. nov. The establishment of the Taraporevala Aquarium and Taraporevala Marine Biological Station, closely linked to the Fisheries Department, facilitated research activities on ornamental fishes and live feeds by scientists such as H.G. Kewalramani, B.F. Chhapgar, K.N. Sankolli and others.

Gujarat, including erstwhile Saurashtra, with S.T. Moses, C.B. Srivatsa and K. Chidambaram heading the Fisheries Department, witnessed a rapid development in its marine sector. Today, Veraval fishing port in Gujarat accounts for the maximum number of fish landings in India. T.V.R. Pillai, who published his account "The Fishes of Kodinar" in the *Journal of the Bombay Natural History Society*, left Gujarat and went on to Calcutta where he spent a few years with the Central Inland Fisheries Research Institute before joining the FAO. Pillai carried out outstanding research on racial studies of *Hilsa ilisha* and *Puntius sarana*, which are yet to be emulated.

Karnataka, in the early years, grouped fisheries under the Animal Husbandry Department, but it had dedicated scientists such as B.S. Bhimachar, A. David and H.D.S. Iyengar, who contributed much to the understanding of reservoir and riverine fisheries, identifying natural spawning grounds, and research on the advantages of integrated aquaculture of paddy-cum-fish.

The Department of Fisheries of Bengal, Bihar and Orissa was a linked unit. T. Southwell, who headed Bengal Fisheries, established the fisheries laboratory in the Indian Museum, Calcutta. A series of scientific publications came from this laboratory, some jointly by Southwell and Baini Prashad. The latter became the first Fisheries Development Adviser to the Government of India, Ministry of Food and Agriculture.

When Orissa got its own Department of Fisheries, it was G.N. Mitra's catholic interests that moulded it, and carried it on with researches on marine capture fisheries, Chilka lake fisheries, population dynamics and aquaculture engineering, the last being his obsession. Eventually, he became the Fisheries Development Adviser to the Government of India, and stimulated innovative research programmes in the Fisheries Research Institutes under the Ministry of Agriculture.

In Madhya Pradesh, bund breeding of carps and research on reservoir fisheries were initiated by G.B. Dubey. Some of the other states,

in spite of having Fisheries Departments, did not have any viable research component, devoting all energy to developmental and welfare programmes. Some states had Fish Wardens who also helped in the conservation of stream ecology and game fishes such as the mahseer. Although individual initiative in fisheries research was there in some of the states, with the passage of time this was no longer a priority, especially as technocrats lost ground to bureaucrats from the Indian Administrative Service. Added to this, with the establishment of the State Agricultural Universities (SAUs) after the 1960s, the research activities and responsibilities from the State Departments of Fisheries were transferred to the SAUs.

Action for the Establishment of Fisheries Research Institutions

Dr. Baini Prashad, the Director of the Zoological Survey of India in 1943, stressed the need for the establishment of fisheries institutions in India in a Memorandum entitled "Post-War Development of Indian Fisheries". He became Fisheries Development Adviser to the Government of India in 1944. His recommendation as Member Secretary, in the "Report of the Fish Sub-Committee of Policy No. 5 on Agriculture, Forestry and Fisheries" dated January 18, 1945, for the creation of research institutes in fisheries was referred by the Government to Lt. Col. R.B. Seymour Sewell, under whose advice the Central Marine Fisheries Research Station (presently known as the Central Marine Fisheries Research Institute or CMFRI) was established on February 3, 1947 in the Zoology Department of Madras University, and subsequently shifted in 1949 to Mandapam Camp, Tamil Nadu, and in 1972 to Cochin, Kerala. On March 17, 1947, the Central Inland Fisheries Research Station, renamed Central Inland Fisheries Research Institute (CIFRI) was established at Barrackpore, West Bengal. The Central Fisheries Technology Research Station was started at Cochin in December, 1957 and in the following year a processing wing was added to it for dealing with research on handling, preservation, processing, product development and quality control. In 1961, the Centre was elevated to the status of an Institute as the Central Institute of Fisheries Technology (CIFT). The Central Institute of Fisheries Education (CIFE) was established in 1961 at Versova, Mumbai and was elevated to the status of a Deemed University on March 29, 1989. CMFRI, CIFRI and CIFT were transferred in August 1967, and CIFE on April 1, 1979, from the Ministry of Agriculture to the Indian Council of Agricultural Research.

Fisheries research organisational linkages

A number of Ministries and Departments in the Government of India support fisheries research. The Department of Animal Husbandry, Dairying and Fisheries under the Ministry of Agriculture (MOA) has the following research-cum-development, training and extension institutes: the Fishery Survey of India (FSI, earlier known as Deep Sea Fishing Station) which has seagoing facilities and helps in fish stock assessment research, the Central Institute of Fisheries Nautical and Engineering Training (CIFNET), and the Integrated Fisheries Project (IFP) (the erstwhile Indo-Norwegian Project). The seagoing facilities of these Institutions have also been utilised by the ICAR Fisheries Research Institutions for conducting research programmes.

The Ministry of Commerce has under it a statutory body, the Marine Products Export Development Authority, which also funds research programmes in aquaculture and post-harvest technologies. The Authority has its own research wing.

The Central Salt and Marine Chemicals Research Institute (CSMCRI), jointly with the CMFRI, has conducted seaweed surveys and analysed their biochemical constituents, studied the industrial uses of seaweeds, and conducted trials in seaweed farming using different

techniques. The NIO, CMFRI, and the National Drug Research Institute (NDRI), Lucknow, have been working on isolating bioactive compounds from marine organisms in the programme "Drugs from the Sea." The Central Food Technology Research Institute (CFTRI), Mysore is the nodal institute for food technology and has, on its own and in conjunction with CIFT, Cochin, developed food products and quality standards.

FAO/UNDP Pelagic Fisheries Project (PFP)

This internationally aided programme was aimed at estimating mainly the pelagic fishery resources along the neritic and oceanic waters using pelagic fishing gear and acoustics from the FAO Research Vessel *Rastrelliger*, an all-weather boat. The Project also had a smaller vessel *R.V. Sardinella* for work in shallower coastal waters, but well equipped with acoustic instruments. A considerable amount of research went into standardising acoustic procedures. This was the first time in the tropical seas that such an innovative acoustic survey programme to estimate fish stocks and fishery resources was attempted.

FAO/UNDP Bay of Bengal Programme

Prior to the 1970s, the concept of social scientists, anthropologists and economists being associated with fisheries research was alien in the Indian set-up. The Bay of Bengal Programme helped reorient our thinking. The project has thrown wide open, subject areas where sociologists and economists could investigate problems, develop models, indicate options for development programmes and conduct malady-remedy analysis.

Reorganisation of the Fisheries Research Institutes under the Indian Council Of Agricultural Research

In the name of strengthening and streamlining research, education, extension and training activities of the fisheries institutes under ICAR, a major reorganisation was undertaken in 1987. In this process, the erstwhile institutes were realigned and the following institutes were set up:

1. Central Marine Fisheries Research Institute (CMFRI); Headquarters (HQ) at Cochin with 12 Regional and Research Centres and 28 Survey Centres.
2. Central Institute of Fisheries Technology (CIFT); HQ at Cochin with five Research Stations.
3. Central Inland Capture Fisheries Research Institute (CICFRI); HQ at Barrackpore (a part of the original CIFRI) with 11 Research Centres and 6 Survey Centres.
4. Central Institute of Freshwater Aquaculture (CIFA); HQ at Bhubaneswar (a part of the original CIFRI) established on April 1, 1987, with 6 Research Centres and 11 Field Centres.
5. Central Institute of Brackishwater Aquaculture (CIBA); HQ at Chennai (a part of the original CIFRI) established in November, 1985, with 3 Research Centres and 1 Field Centre.
6. National Research Centre for Cold Water Fisheries (NRCCWF); HQ at Bhimtal (part of the original CIFRI) established in 1988, with 2 Field Centres.
7. National Bureau of Fish Genetic Resources (NBFGR); HQ at Lucknow established in December, 1983.
8. Central Institute of Fisheries Education (CIFE); HQ at Mumbai, given the Deemed University status on March 29, 1989, with 5 Research Centres.

Role of ICAR Fisheries Institutes in the Growth of Fisheries Research

A. Freshwater Fisheries and Aquaculture

For the past half a century, the ICAR fisheries institutes have been playing a dominant role in fundamental and applied research in fisheries in the freshwater, coastal brackishwater

and marine sectors, both in capture fisheries and in aquaculture/mariculture. We shall look at these developments in a sequential order.

I. RIVERINE FISHERIES

Riverine fishery has been, and still is, mainly an artisanal level activity. In the early years, research was directed towards surveys to understand resource distribution, physical and ecological features, hydrology of rivers, plankton, benthic biomass and nutrient load, and pre-impoundment surveys. Natural spawning grounds, estimation of spawn availability and breeding migrations were studied, so also resource availability in relation to zonation. An important achievement was the breeding and rearing of *Hilsa ilisha* at Allahabad. Research today is oriented towards anthropogenic pressures, pollution and engineering works that adversely affect the ecosystems and endanger indigenous fish and other aquatic organisms. The protection of wild stock to prevent genetic drift in farm-reared fish, the conservation of river habitats and biodiversity, the protection of endangered riverine fauna such as the river dolphin *Platanista gangetica*, the gharial *Gavialis gangeticus* and fishes such as the mahseer (*Tor* spp.) and *Neolissacheilus hexagonolepis*, and the development of management measures through scientific inputs are ongoing. The technology and scientific know-how to restore natural populations through ranching, habitat improvements and adoption of management strategies are available with the Institutes (CICFRI, NRCCWF), but need to be implemented at the State level.

II. RESERVOIR FISHERIES

In 1995, VV. Sugunan classified and gave the State-wise distribution of large irrigation tanks, small, medium, and large reservoirs in India, altogether 19,370 in number and covering a waterspread area of 3,153,366 ha. All are man-made and combine the fluviatile and lacustrine systems.

III. UPLAND COLD WATER FISHERIES

The works of Sunder Lal Hora, E.G. Silas, A.G.K. Menon and K.S. Misra added much to our knowledge of the ichthyofauna of the upland cold water rivers and lakes. The ecology and hydrological conditions of a number of natural lakes in the Kumaon Himalayas were studied. Under the UNESCO sponsored "Man and Biosphere Programme," the limnology of the Loktak Lake, Manipur was studied. Research has been done in induced breeding of different species of snow trout (species of *Schizothoraichthys* and *Schizothorax*) from wild stock for ranching in the streams. Besides successfully breeding the golden mahseer *Tor putitora* and pond-rearing it in Bhimtal, the new Centre (NRCCWF) has also developed composite fish culture suitable for the hill regions with the following combination, namely *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Ctenopharyangodon idella*.

The breeding and propagation of the mahseer was a successful programme at the Tata Electric Company's Wulvhan Lake facility at Lonavala, Maharashtra.

IV. FRESHWATER AQUACULTURE

The progress from spawn collection from natural spawning grounds by stripping, to induced breeding of Indian major carps (IMC), other carps, catfishes and other fish species, was a giant step forward. In 1955, H. Chaudhuri successfully spawned the minnow *Esomus danricus* by pituitary injection. By 1957, carps such as *Labeo rohita*, *L. bata*, *Cirrhinus mrigala*, *C. reba* and *Puntius sarana* could be induce-bred. This was a major breakthrough which gave a fillip to freshwater aquaculture. Subsequently, research has kept pace with developmental needs, and great strides have been made in the hormonal physiology of fish and shellfish so that a wide range of species could be induced to breed, some even months before the normal breeding season.

It must be added that during the 1970s and '80s, with scarcity of carp pituitary extracts,

research was directed towards the use of human chorionic gonadotropin (HCG) for fish breeding; isolation, characterisation and purification of fish gonadotropin (GtH) and its use in fish breeding; use of mammalian gonadotropin releasing hormone for fish breeding and use of fish gonadotropin releasing hormone (GnRH). Today, Ovaprim® prepared from salmon gonadotropin releasing hormone and domperidone are widely in use, with dosages standardised for induced breeding of carps and catfishes. The importance of Ovaprim® which has given a boost to aquaculture will be evident from the logarithmic proportions in which fish seed production has increased from only 490 million fish fry in 1973-74 to over 20,000 million fry today.

Research has been underway in the use of pheromones in fish reproductive physiology. It has been shown that waterborne steroids and steroid glucuronids originating from the reproductive organs act as pheromones in many species of fishes. Exposure of spawners to the ovarian fluids induces ovulation and gonadotropin release, increasing plasma gonadotropin (GtH) in the catfish *Clarias batrachus*.

In an All-India Coordinated Research Project on air-breathing fish culture, techniques were developed for the maturation and breeding of air-breathing catfish, and their nutritional requirements were studied in order to successfully culture them. Research on sewage-fed water bodies holding fish demonstrated the recycling of organic waste as well as their treatment and further utilisation for agricultural purposes. Research was also carried out on a variety of diseases that afflicted Indian carps and on the prevention and control of fish parasites.

Another important area of research in freshwater aquaculture was composite fish culture, i.e. the culture of compatible combinations of Indian and Chinese carps. Research on composite fish culture has yielded excellent results; from the traditional culture methods producing about 600 kg/ha/year, it has been possible to exceed 10 t/ha/year. Some fish farmers in Eluru, Andhra Pradesh have achieved production of 13 to 15 tons and more, per hectare per year. The research and development at the Balabhadrapuram experimental fish farm of CIFE was so supportive as to result in an explosive growth of freshwater fish culture, from nothing to over 100,000 t, in the Kolleru wetlands in the late 1980s.

For increasing productivity and better economic returns, research was initiated on integrated fish-farming involving crop-livestock-fish-prawns in various combinations. The operations, though highly location-specific, yielded good economic returns. Polyculture of combinations of carps and non-carp species also showed high yields and good economic returns.

One of the recent developments has been the production of pearls from the freshwater mussels *Lamellidens marginalis, L. corrianus* and *Parreysia corrugata*, using gonadal implantation of nucleus for spherical pearls. Research on culturing of pearl nacre-secreting mantle epithelial cells under *in vitro* conditions has been successful, enabling production of uniform quality of pearls. Research aimed at post-harvest value addition as well as mussel spat production for the grow-out system is also being done. In view of the importance of this research, and the need for further refinement to meet international standards, ICAR has established the Centre of Excellence in Pearl Culture at CIFA.

Research on Fish Genetics

India is one of the few countries that have taken a lead in research on fish and shellfish genetics. Until the early 1970s, fish culture remained largely empirical and artisanal. Then onwards, research in fish genetics started receiving greater attention for the purposes of upgrading the quality of cultivated species like

Indian major carps for enhanced productivity, and the conservation and management of genetic diversity in natural stocks. The National Bureau of Fish Genetic Resources (NBFGR), Lucknow, was established to focus on fish genetic resources of the country, their collection, classification, evaluation and cataloguing; conservation and protection of endangered aquatic species and to monitor introduction of exotic species.

I. Research on Stock Identification

NBFGR has been actively involved in the cytogenetic analysis of Indian major carps, exotic carps, mahseers, freshwater catfishes, snakeheads (*Channa* spp.) and the endemic species of the Western Ghats, developing species-specific banding profiles and characterising the genetic stocks. In 1998, NBFGR brought out a chromosome atlas of karyotypes of 128 species of teleosts from Indian waters. Three schools of research, one at CIFE, Mumbai, the second at the Department of Zoology, Kurukshetra University, Kurukshetra, and the third at the University of Kalyani, West Bengal, have been actively carrying on research on chromosome banding techniques in many freshwater teleosts which has been helpful in detecting polymorphism in Indian species at inter-specific and inter-generic levels.

II. Biochemical and Molecular Genetics

At NBFGR, different stocks of *Catla catla* and *Labeo rohita* from different rivers of the Gangetic plains and northeast India have been identified using molecular and allozyme markers. H.K. Lal found the anadromous hilsa (*Tenualosa ilisha*) population in the River Ganga, above and below Farakka Barrage, and the Brahmaputra not exhibiting significant genetic heterogeneity. Use of allozymes and DNA markers has helped to find that the butterfish *Lactarius lactarius* from the east and west coasts of India were distinct stocks, as also the highly endemic yellow catfish *Horabagrus brachysoma* from Chalakkudy and Meenachil rivers, Kerala. Genetic markers for the marine catfish *Tachysurus* in which taxonomic ambiguity exists have been identified. Studies using allozymes and RAPD markers have shown that the stocks of shrimps *Penaeus indicus* and *P. monodon* along the east and west coasts of India were distinct. Nuclear fingerprinting in Indian major carps and tilapia has been done with a view to develop species-specific patterns and to differentiate between individuals within a population.

III. Techniques for Enhancing Aquaculture Productivity

a. Sex control

Monosex culture of fish has the advantage of growing one sex with faster growth rate and good meat quality. So also, production of sterile populations is economic in fish farming as there is no energy loss in gonadal maturation, which otherwise may utilise about 20% of the food energy. Research is on for the application of either androgen or oestrogen to juveniles to override the intrinsic sex-determining mechanism and direct it to either male or female sex or induce sterility without altering the genotype. At the Madurai Kamaraj University (MKU), Madurai, 100% masculinisation and feminisation were achieved in tilapia (*Oreochromis mossambica*). *Betta splendens*, *Poecila reticulata* and *Brachydanio rerio* by administration of steroids.

b. Chromosomal manipulation

Chromosome sets can be manipulated in externally fertilising fishes to produce gynogenetic, androgenetic and polyploid individuals.

1. Gynogenesis: The various applications of gynogenesis are chromosomal mapping, inbreeding with homozygosity, and generation of monosex populations. Gynogenesis has been induced in Indian major carps *Labeo rohita*, *Cirrhinus mrigala* and *Catla catla* by using cold shocks (12° C for 10 minutes) or heat shocks (39° C for 1 minute). Gynogenetic specimens of silver carp have also been produced. Production

of gynogenetic zebra fish (*Betta splendens*) and tilapia, and of YY supermale tilapia by gynogenesis and sex reversal have been carried out at MKU, Madurai.

2. Androgenesis: Androgenesis can be induced by the destruction of female nuclear genome before fertilisation using UV rays and fertilising it with normal sperm, whereby only the paternal genome is contributed to the offspring. This is useful in producing inbred lines. In conjunction with sperm cryopreservation, androgenesis may prove useful in conservation programmes where females of a species are not available. Survival of androgenic individuals is much lower compared to gynogens, as the cellular organelle of the egg is affected during irradiation. Putative androgenic common carp has been produced in NBFGR but further improvement and upgrading of teleost androgenic production is yet to be done.

3. Polyploidy: By chromosomal stimulation it is possible to obtain haploid, triploid and tetraploid fishes. These fishes are likely to be sterile, and since the process of gametogenesis is avoided, they can grow faster. Direct induction of triploidy has been done in the common carp and grass carp. Triploids can be produced by suppression of meiotic metaphase II by subjecting the egg to a pressure or temperature shock shortly after fertilisation. Triploid rohu has been produced at CIFA, and *Heteropneustes fossilis* at Benaras Hindu University, Varanasi. MKU, Madurai has produced triploid tilapia and introduced tetraploidy in *Betta splendens*, *Brachydanio rerio* and *Poecilia reticulata*.

c. Hybridisation

Selective breeding, multiple breeding and hybridisation are spin-offs from the induced breeding technology developed at CIFRI, Cuttack in the mid-1950s. So far about 44 intergeneric and interspecific hybrids have been produced in India, many of which are fertile, but most hybrids have not performed well with regard to desired economic traits. Only one combination, namely rohu female x catla male, which combines the small head and the meat quality of rohu with the fast growth of catla has found favour among fish farmers and consumers. Locally called 'naadan', it is produced in hatcheries in West Bengal, and Andhra Pradesh. Reciprocal hybrids of *Heteropneustes fossilis* and *Clarias batrachus*, and *H. fossilis* and *H. microps* have also been produced.

Hormonal advancement of maturation and multiple breeding of Indian major carps has become possible through the application of non-steroid hormones such as HCG, LHRH-a and PGE.

d. Selection

The success of selection depends on the additive genetic variation in the selected population. Heritability estimates of the traits selected are essential for fish breeders to assess the response to the selection programme and the time and cost required to reach the desired goal. A 5% predicted response was obtained in one generation selection of *Etroplus suratensis*. Selective breeding of rohu for improving the growth rate, carried out at CIFA, Bhubaneswar, has given rise to a faster growing strain 'Jayanthi rohu' which is now distributed to farmers. The Mangalore Fisheries College has been carrying out selection experiments for *Labeo fimbriatus* and, under a NORAD assisted programme, CIFE has initiated selection experiments on *Penaeus monodon* and *Macrobrachium rosenbergii*.

e. Transgenic fish

Research on transgenic fish is being conducted at MKU, Madurai, in collaboration with CCMB, Hyderabad, and CIFA, Bhubaneswar. At MKU, transgenic zebra fish, rohu and *Heteropneustes fossilis* have been produced. For the zebra fish *Brachydanio rerio*, the gene constructs used were synthesised abroad from species such as the rainbow trout, while in rohu

and *H. fossilis* the growth hormone genes of these species were identified, isolated, sequenced and incorporated into vectors prior to gene transfer. The potential hazards in consumption of transgenic fish — a genetically modified organism (GMO) — on human health need careful assessment, as in the case of GMO vegetables and fruits. The ecological impact of releasing transgenic fishes in open waters is not yet tested. Biological containment of transgenic fish by inducing sterility is a priority. The ethical and biosafety issues need to be addressed before introducing transgenic technology to aquaculture.

III. Inbreeding

Inbreeding leads to genetic homozygocity. This, in turn, leads to reduction in growth and food conversion efficiency, increased abnormalities in the progeny, and poor survival rates — in short, inbreeding depression. This has been happening in the carp hatcheries in West Bengal and elsewhere. The rate of inbreeding was estimated in south Indian carp hatcheries to vary between 2 and 17 per cent. Stunted growth and irregular body shape combined with skeletal deformities have been observed in hatchery-bred silver carp, mrigal and *Tor putitora*.

IV. Cryopreservation

Storage of fish milt, eggs and embryos without loss of viability is of considerable importance in aquaculture, as this would make available gametes throughout the year and superior germplasm easy to transport over long distances. It greatly benefits selection and hybridisation programmes. A very important function is that it helps in the development of a gene bank for conservation by cryopreservation of our natural fish genetic resources.

NBFGR has taken a lead in the cryopreservation of fish gametes and has developed cryopreservation protocol for 14 species of teleost, which include some endangered and highly endemic species such as *Tor khudree*, *Labeo dussumieri* and *Horabagrus brachysoma*. Ultra-structure studies have been conducted for refining cryopreservation protocol. Cryoprotectant and dilutant solutions for fish sperm have been developed. Attempts have been made to cryopreserve nauplii of *Penaeus monodon* and gametes of *P. semisulcatus* and *P. indicus* with limited success. With proper cryoprotectant, it has been possible to successfully cryopreserve the freshwater cladoceran *Moina* — so important as live feed for shrimp larvae in hatcheries.

V. Genetic Introgression

Unintended intergeneric hybridisation and back crossing of F1 hybrids with their parents could result in genetic introgression among fishes, causing contamination of their gene pools. The rate of genetic introgression among Indian major carps produced during mixed spawning in Chinese model hatcheries has been recorded as 7.25-9.24%. Research has suggested modifying the hatcheries to have species-wise hatching pools to facilitate the breeding of the three Indian major carps separately, but within the same time span.

B. Marine Fisheries, Coastal Aquaculture and Mariculture

1. Marine Capture Fisheries

In the early years, the major research input was towards faunal studies and fish biology such as studies on phyto- and zooplankton, fish eggs and larvae, age, growth and reproduction, food and feeding habits, and related subjects. So also, with the meagre seagoing facilities available, coastal oceanographic studies were conducted in a limited number of areas. Fish biology studies were mainly focussed on some of the major constituents of fisheries such as the oil sardine, other clupeids, mackerel, Bombay duck, the larger croakers, and some of the regionally dominant species like the silver bellies and carangids.

In the years following World War II, the expansion of fishing in the temperate waters and the extension of industrial fishing necessitated management interventions and this saw a surge of research activity in fish population dynamics and fish stock assessment. Most of the models and methods were developed in the context of temperate water systems, where fisheries are characterised by the single species and single gear system, supported by species that have long lifespans and clearly defined spawning periods and breeding grounds. This also facilitated the determination of age structure of the exploited stocks, which formed the basis for most of the fishery assesment models. The pre-1970 fisheries work in India was thus, by and large, based on the idea that the fishes, especially sardine, mackerel and even penaeid shrimp had longevity over several years as in temperate waters. Until the mid-1970s, the fish stock assessment in the marine fisheries was primarily based on the catch-effort relationship, and in some cases population parameters were based on age structure estimated from fish scales and otoliths (ear bones). However, such assessments carried out over different years yielded divergent and highly variable parametric values. The Maximum Sustainable Yields (MSYs) in most cases were grossly underestimated and estimates of age for the same species varied considerably. Such internal inconsistencies were never validated, and perhaps, could not be validated because of the methodological and data constraints. The futility of such exercises became increasingly evident in the early 1970s, especially the non-applicability of models and methods developed for temperate waters for the multi-species tropical fisheries. Most of the exploited stocks in Indian waters have short lifespans and protracted spawning seasons, which precludes objective determination of the age-structure of the exploited stocks. We now know that some enter the fishery even before or during their 1st year, and by the 2nd or 3rd year they are no longer there. So also, species of penaeid shrimp mature and spawn 6-8 months after hatching! The multi-species and multi-gear fishery system further compounded the problem. All these have led to alternative approaches for tropical fish stock assessment.

a. Population dynamics and stock assessment

The mid-1980s witnessed intense activity round the world in tropical fish stock assessment, culminating in the development of length-based stock assessment methods and models. The advent of packages such as LFSA, ELEFAN, and LFDA incorporating a suite of length-based stock assessment methods accelerated fish stock assessment and created greater awareness among research workers, fishery administrators and stakeholders on the need for fishery management. Thus fish stock assessment and fishery management continues to be based on the new techniques, with improvements as and when required. High speed personal computers and matching software have facilitated simulation modelling for depicting the complex dynamics of a fishery in a very user-friendly manner, enabling development of various management scenarios. This is a comprehensive tool where socio-economic, biological, ecological and environmental implications of various management options can be visualised.

More recently, multispecies stock assessment and an ecosystem approach to fishery management has been taken up, since a holistic approach, taking into consideration the trophic interactions, is so essential for understanding the dynamics of the exploited fish stocks. The 'Ecopath' model developed by Polovina in 1984 has been further expanded for application in complex fisheries issues. For the first time in India, a trophic model of the fisheries ecosystem of the southwest coast of India has been developed by CMFRI.

CMFRI has developed a Multistage Random Sampling Technique and refined it for estimating the exploited marine fishery resources

of the country as well as for obtaining data for fish stock assessment. This has enabled the Institute to develop the National Marine Living Resources Data Centre, which is supportive of fisheries research and management.

Short-term forecasts based on satellite imagery help in minimising the search time for shoaling fishes which congregate along current boundaries, slicks, areas of upwelling, submerged sea mounts and thermal fronts. Chlorophyll-a distribution patterns could also indicate spectral bands in which concentrations of herbivores such as sardines occur. A series of joint exercises were conducted along the west coast of India, in which the CMFRI, SAC, FSI, and NARSA participated, and this cooperative effort culminated in a national symposium on the utilisation of remote sensing as a tool in marine fisheries.

b. Fishery biology, marine biology and oceanography

The scientists of CMFRI during the past 55 years have considerably contributed through their research, to our knowledge of the life history and biology of most of the commercially important groups or species of fishes, crustaceans (penaeid and non-penaeid shrimps, crabs and lobsters), and molluscs (bivalves, gastropods and cephalopods).

N.K. Panikkar, P.R.S. Tampi and R. Viswanathan were deeply involved in the study of fish physiology, especially the milkfish *Chanos chanos* and its adaptation to fresh and brackish waters. P.R.S. Tampi was also a pioneer in marine fish farming, as he experimented successfully with milkfish culture at Mandapam Camp, but could not follow up this line of research since marine fish farming was not in fashion then. R. Raghu Prasad's work on the swarming of *Noctiluca* in Palk Bay and its effects on the local sardine fisheries, and studies on the plankton of the Gulf of Mannar were important contributions. His research with P.V. Ramachandran Nair in 1960, on primary production and its relation to fisheries in the Gulf of Mannar added considerably to our knowledge and showed that tropical waters are not "barren deserts" as was then believed by many scientists in the west. During the 1950s, work on seaweeds gained much importance. Thivy developed a method for producing *Gracilaria edulis* agar in which freezing is not obligatory. The research of V.K. Pillai added considerably to our knowledge on the biochemical aspects of seaweeds. Jayaraman and his colleagues, in 1959, reported on the trawl fishery of the Bombay and Saurashtra waters.

Late Dr. S. Jones was an authority on fish eggs and larvae of both freshwater and marine fishes. He contributed a number of papers on the subject and some were published in this *Journal*. As Director of CMFRI, he steered the research programmes on tuna and tuna-like fishes in the Indian seas and made a comprehensive study of the tuna live bait fishes of the Lakshadweep Islands. His *magnum opus,* "The Fishes of the Laccadive Archipelago" published jointly with M. Kumaran, describing, with illustrations, over 600 species, is the most exhaustive work on the marine ichthyofauna of this region to come out in recent years. It has also added much to our knowledge of the species diversity of the coral reef ecosystem of the Lakshadweep.

His founding of the Marine Biological Association of India in 1958 was a significant event, as the Association has a history of fostering marine biological, oceanographic and fishery research through its journal and special publications, as well as the national and international symposia on various aspects of marine resources, their utilisation, conservation and management that it has held from time to time. In 1961, the first International Symposium was held on Scombroid Fishes, followed later by Symposia on Crustacean Fisheries; Molluscan Fisheries; Coral Reefs; Endangered Marine Animals and Marine Parks; Indian Ocean, its Origin, History and Resources; Coastal Aquaculture; and so on, and the proceedings of all the symposia were published.

Dr. S.Z. Qasim, who succeeded Dr. Jones as Director of CMFRI, brought a lot of dynamism to marine fisheries research and the mariculture programmes. It was during his tenure that cultured pearls from the pearl oyster *Pinctada fucata* were produced. The protocol for cultured pearls using indigenous technology was standardised.

In the 1960s, the study of demersal fishery resources of the northwest coast based on catch and effort over a period of time, gave us for the first time, a detailed textual and illustrative account of the resources. For the first time, fishery oceanographic studies were conducted along the west coast of India on board the *R.V. Varuna* of the erstwhile Indo-Norwegian Project, Cochin. Deep-water surveys beyond the continental shelf along the upper continental slope enabled the discovery of many new resources and resource complexes such as the deep-sea lobster and shrimp resources, deepwater fin-fishes, sharks and crabs. Acoustic surveys were also conducted for the first time to locate "Kalava grounds". Silas reported on the Deep Scattering Layer (DSL) and its constituents in the Lakshadweep Sea. Scientists were able to find a correlation between humidity, barometric pressure and mackerel fishery. So also, it was found that there was a pivotal surface temperature at which mackerel spawn. It was also shown that upwelling along the shelf waters of the west coast commenced as early as February and was not monsoon induced. The decade of the 1960s showed the need for having an integrated approach while studying marine fishery resources, as fishery-independent physico-chemical parameters play an important role. The investigations conducted during the exploratory fishery surveys of the northwest coast and continental shelf waters by the Polish research vessel *Maurena* pointed to the limitations in demersal fishing ground resources, while finding untapped pelagic resources such as horse mackerel in sizeable population.

A tagging programme of pelagic fishes (mackerel and sardine) and shrimps (*Penaeus indicus*) gave valuable information on their growth and migratory behaviour from tag recoveries. Very significant was the recovery of *P. indicus* tagged off Cochin and recovered after 66 days from the Gulf of Mannar, off Manapad, about 400 km away.

The euphoria over the assumedly limitless capture fishery resources started crumbling with the collapse of the Peruvian anchovy fishery due to the *El Nino* phenomenon and of the North Sea mackerel and herring fisheries due to overfishing. These and many other instances brought about the need for alternate strategies to augment fish production through discovering new fishing grounds and resources, and utilising the normally discarded as well as underutilised and non-conventional resources. Besides this, the strategy was to also develop coastal aquaculture and mariculture.

c. Coastal aquaculture and mariculture

In the early 1970s, a major research effort was made to develop coastal aquaculture (in estuarine, coastal brackishwater lagoons and wetlands) and mariculture (sea farming), though there was considerable scepticism as to whether the programmes would succeed and be viable in the absence of any expertise. The assumption was that it would be too expensive, considering situations such as that which the Coca Cola got into after investing several million dollars in shrimp farming, or the long duration of the culture of 'Kurma' shrimp (*Penaeus japonicus*) in Japan (nearly 14-18 months), and the lack of information about captive hatchery breeding.

In view of the dwindling resources in capture fisheries and the great demand in the export trade for shrimp, culturing shrimp was given high priority. Within a year after the programme was taken up, it was possible to mature and breed, at the Narakkal (Cochin) farm of CMFRI, all the important penaeid species occurring along the

southwest coast, namely *Penaeus monodon*, *P. indicus* and *Metapenaeus dobsoni*, and in Chennai, namely *P. semisulcatus* and *P. japonicus*. Procedures were standardised and after stocking in the ponds, it was possible to harvest the shrimp in 3-4 months.

The situation was in no way different for other marine organisms. For instance, in the case of edible oyster *Saccostrea madrasensis*, after the mature oysters were induced to spawn and after successful spat settlement and transfer of the spat to submerged racks, harvesting was done in 10 months. In the pearl oyster *Pinctada fucata*, after implantation of nucleus, good lustrous pearls could be obtained in 6-8 months depending on the size of the nucleus. Likewise in the case of mussels, *Perna virdis* and *P. indica*, in open sea culture on ropes suspended from floating rafts, the harvest was done in 4 months by which time 3-4 kg of seed implanted on a 7-metre long rope could yield 80 to 100 kg shell mussel; a single raft of 6 m x 10 m could take 12 or more ropes. In the case of the spiny lobster *P. homarus*, through eye ablation technique and feed, it was possible to obtain from juveniles of 30 to 40 g, a marketable size of 100 g in 10 months, and in *P. ornatus*, from 200 g, 1.2 kg could be obtained in the same period. Fast growth was the case with all the fin fishes bred in the hatcheries and cultured in the farm, such as grouper *Epinephelus tauvina*, sea bass *Lates calcarifer*, mullets (*Mugil* spp.), pearl spot *Etroplus suratensis*, tilapia and other species. The eel *Anguilla bengalensis* took about a year from elver to marketable size with partial success of inducing maturation in the male. A good facility for grouper culture has been developed at Mandapam Camp. It is today possible to culture the sea cucumbers *Holothuria scabra* and breed them.

A special mention is needed about the ongoing mariculture and research facilities at the Central Agricultural Research Institute at Port Blair, Andamans. Blessed with good quality sea water, active work on the breeding of ornamental and other fishes, crustaceans and pearl oysters including the black lip pearl oyster *Pinctada margratifera* is going on.

In the culture of agar producing seaweed, *Gracilaria edulis*, excellent results have been obtained in floating coir network in which vegetative parts are implanted.

d. Centre of Advance Studies in Mariculture

The newly started mariculture research programmes of CMFRI in the 1970s was to some extent hampered by a lag in research, teaching and trained manpower. The techno-economic feasibility of the projects taken up as well as the transfer of technology and manning of hatchery and farm operations, to the existing staff needed considerable reorientation and at the same time nurturing a new generation of scientists. In 1979, a Centre of Advanced Studies in Mariculture was established at CMFRI, Cochin. It facilitated dozens of scientists from the Institute to go abroad for training in specialised subject areas such as fish and shrimp nutrition, reproductive physiology, fish genetics, endocrinology, fish and shellfish pathology, live feed cultures, hatchery technology, etc.

Research on Brackishwater Aquaculture

The recent research advances at CIBA are in the maturation, breeding and hatchery development of penaeid shrimp. Specially formulated economical feeds with good conversion efficiency have been developed for shrimp. Captive brood stock development of fin fishes such as *Etroplus suratensis*, *Lates calcarifer* and *Mugil cephalus* has been streamlined for technology transfer to fish farmers.

Research on Shrimp, Fish and Shellfish Pathology and Disease Management

Diseases were a bane of shrimp aquaculture in the 1990s and still continue to plague the industry. At least four diseases with proven viral

etiology have been reported from India, namely, the White Spot Syndrome Virus (WSSV), Monodon Baculovirus (MBV), Hepatopancreatic Parvo Virus (HPV) and Infectious Hepatopancreatic and Lymphoid Organ Necrosis (IHLN). Due to WSSV, there has been an annual fall of 10,000 to 15,000 t of shrimp valued at Rs. 300 to Rs. 500 crore, or a cumulative loss of over Rs. 2,000 crore during the last 6-7 years. This has also affected the livelihood of a number of shrimp farmers and has been a setback to the industry. This explains the reason for the number of national organisations and universities involved in the study of shrimp and fish pathology during the last ten years.

Research on Fish Diseases

During the 1980s and 1990s, fish culture in most parts of India and natural fish populations in rivers and lakes were seriously afflicted by Epizootic Ulcerative Syndrome (EUS), where the fish developed lesions on the body. CIFA, Bhubaneswar developed a medicine "Cifax®" to control the disease. The Institute was also able to suggest water quality standards to prevent the spread of the disease that badly affects carps, catfishes, murrel and other fish. Vaccines are being developed using RFLP (Restriction Fragment Length Polymorphism) and PCR techniques. Research on immune response of Indian major carps to *Aphanomyces invadens*, the fungal pathogen of EUS is ongoing.

Disease Management

A multi-pronged approach is being adopted to handle disease prevention and control involving Chemoprophylaxis and Chemotherapy, vaccines, immunostimulants, probiotics, specific pathogen-free (SPF) shrimp, specific pathogen resistant (SPR) shrimp, high health shrimp, and development of genetically resistant stock. With new rapid diagnostic techniques, it is possible to screen brood shrimp and shrimp seed before stocking them in ponds and to monitor the grow-out phase for viral and bacterial pathogens. A new concept, involving stimulation of the shrimps' immunity termed 'immunostimulation' has come up, as an alternative to vaccines against bacterial and viral diseases; the technology is being developed and transferred to the industry by the Microbiology Department, College of Fisheries, Mangalore. They also have a promising research programme on microorganisms antagonistic to pathogens or with anti-vibrio activity (*Pseudomonas* strains). Besides this, some groups of biological and synthetic compounds such as glucans are used to enhance the non-specific defence mechanisms in shrimp. To mitigate the disease problem and to enhance pond ecosystem, research on crop rotation as a health management tool is underway. A new research approach at the College of Fisheries, Mangalore has been the promotion of microbial film in ponds to enhance the quality of fish production.

A considerable amount of research for developing management strategies has been done and is ongoing at the Department of Microbiology, the UNESCO Centre for Marine Biotechnology, the Centre of Bioinformatics, and the Department of Aquaculture at this College, and at the Genetics and Biotechnology Division of CIBA.

Fish and Shellfish Toxicity

Marine toxins and harmful algal blooms seriously affect public health and fish and fishery products. There is a world watch on the occurrence of such harmful algal blooms that lead to shellfish toxicity and fatalities. For the first time in India, Paralytic Shellfish Poisoning (PSP) was reported from the west coast. The first record of diarrhetic shellfish-toxin producing dinoflagellates was made from India and the PSP toxins were analysed. The toxic alga (*Gymnodinium nagasakiensis*)-caused red tide and fish kills were reported from Someswar on the west coast of India.

A more recent outbreak of PSP has been recorded from Vizhinjam, south Kerala, where over 500 people were hospitalised and seven died. The Marine Science Department of the Cochin University of Science and Technology (CUSAT) was designated as the nodal centre for India in the global network of the "Mussel Watch" Programme. A PCR-based detection method for toxic dinoflagellates has been developed. In this background, a major national research programme on Toxic Algal Blooms in the Indian Exclusive Economic Zone (EEZ), under the auspices of the Department of Ocean Development, Government of India, is underway at CUSAT, Cochin.

Research on Harvest and Post-harvest Technologies

I. Fishing Technology

Research on appropriate design of fishing crafts and gear was initiated from the very inception of the CIFT and today 90% of the mechanised fishing vessels in the length range 7.6 to 15.2 m are built on one of the 12 designs developed by the Institute. A steel fishing trawler (15.5 m) has also been designed and is in commercial operation today. A fuel efficient nozzle propeller that reduces fuel consumption was also designed by the Institute. Various cost effective protective measures against biodeterioration of wooden fishing vessels have been developed and are in use. A number of non-timber building materials such as ferro-cement, fibreglass reinforced plastic (FRP) and toxic non-plastic composites have been tested as alternative boat building materials. Cathodic protection of fishing boats and metallic marine structures with a galvanic ternary aluminium, free from mercury, has been developed, and is eco-friendly, non-polluting, cost effective and durable.

II. Fishing Gear

The development of combination wire rope as an import substitute for deep-sea fishing is a recent innovation which has now been commercialised. CIFT has standardised specifications for the use of polypropylene multi-filament netting yarn with lower specific gravity and better tenacity than nylon. Research on fishing gear has led to innovative concepts and designs for multipurpose gear such as the high opening trawl, high-speed demersal trawl, hybrid trawl, bobbin trawl, large mesh trawl, rope trawl, semi-pelagic trawl with flexible headline and lifting devices, and mini-purse seine.

More research has gone into the development of by-catch reduction devices such as the radial escape device that facilitates escape of young and juvenile fish and by-catch from the trawl. The Turtle Excluder Device (TED) has also been successfully field tested and incorporated in the trawl nets. The device permits cent per cent escape of turtles (*Lepidochelys olivacea*), and escape of fish and shrimp in the catch is as low as 1.2% and 0.62% respectively. CIFT has also developed a new durable lobster trap which is widely used. Research on the right type of packaging for fish products has led to considerable improvements in the quality of the products. An emerging new area is the live transport of fish and crustaceans.

III. Fish Processing Technology and Product Development

A wide variety of value added individually quick frozen (IQF) products and specialised products such as dehydrated jellyfish, *bêche-de-mer*, high quality "maasmin" from tuna, fish wafers, soup powders, battered and breaded products have been developed and commercialised.

Research on utilisation of fish products has been high on the agenda as fishery by-products find application in several fields. A major thrust in this area was the development of many innovative programmes which furthered international contacts of the Institute in the area of product development and value addition. Chitin and chitosan from prawn shell waste are two such products that have a wide spectrum of uses. The uses of chitin in broiler chick

feed for weight gain, and for production of glucosamine hydrochloride that has application in antibiotics and baby food formulations, are well known. Chitosan has innumerable uses. Research on fish collagen, prepared from fish air-bladders, has led to a wide variety of uses. A new application has been the preparation of collagen-chitosan film which can be used as artificial skin for treatment of burns and also as a barrier device in dental surgery for Guided Tissue Regeneration (GTR) in cases of furcated gums. It is much superior to the presently used teflon which needs surgery for removal after tissue regeneration. Absorbable surgical suture, a bio-product, so important for healing of wounds after surgery has been developed from fish guts. The absorbable extra-fine sutures which are prepared from fish gut collagen by cross linking and polymer coating, have been found suitable even for eye and other microsurgery.

CIFT has also developed a procedure for processing shark cartilage rich in chondriotin sulphate into a clean, dry and attractive material that has application in medicine for treatment of arteriosclerosis, blood vessel thrombosis and prevention of infection.

The Institute has developed software for Hazard Analysis Critical Control Point (HACCP), a modern tool for implementation of quality assurance and safety in the seafood processing industry.

Role of the Department of Ocean Development in Fisheries Research and the Antarctic Programme

The Department of Ocean Development (DOD), Government of India from its inception in the early 1980s has played a major role in facilitating fisheries and oceanographic research in the Indian EEZ as well as the contiguous high seas. It acquired a new *Fishery Oceanographic Research Vessel* (*F.O.R.V.*) *Sagar Sampada*, built in Denmark with all-weather ocean-going capabilities and equipped with the most sophisticated acoustic, oceanographic and meteorological equipments. Besides, it has the capability of operating fishing trawls at depths up to 1,000 m. CMFRI was given the responsibility of running the research programmes of this vessel.

The DOD has also established a new Institute, the National Institute of Ocean Technology (NIOT) to address specialised ocean technology problems. Its facilities are also available for the marine fisheries research programmes.

Ever since 'Operation Gangotri,' the First Indian Expedition to Antarctica was undertaken in December, 1981 under the leadership of S.Z. Qasim, and its first research station 'Dakshin Gangotri' established, India has been sending an expedition consisting of multidisciplinary teams to Antarctica every year. The Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) manages the fishery and conservation of the Antarctic marine ecosystem and krill. India is one of the 23 Member Countries of the Commission.

The Antarctic Ocean supports biological communities of a few species with large populations, the most important of which, the shrimp-like krill, regulates the food chain. The Indian effort in studying the fishery resources of the region was the First Indian Antarctic Krill Expedition conducted by DOD in the area 58° 56' - 61° 17' S and 30° - 40° E.

Dissemination of Research Results

The research results are published both in Indian and foreign scientific journals. The ICAR-controlled fisheries research institutes have also a nodal journal, *The Indian Journal of Fisheries* published from CMFRI. Each institute has its own scientific association which also runs its own scientific journal. Some of the Associations are very active and organise national and international scientific meetings, symposia, seminars and workshops and publish proceedings of these. The Institutes bring out a lot of extension

literature, especially for transfer of proven technologies.

Conservation of Marine Living Resources and Marine Habitats

The international conferences and conventions held in various parts of the world during the last few years have drawn attention to the need for maintaining the marine biodiversity and protection of marine habitats and endangered species. A marine habitat such as the mangrove ecosystem is also a grow-out system for many species of marine fishes and crustaceans, and for some species, a spawning area as well. If these habitats are left unprotected, with human depredation, recruitment to the fisheries gets adversely affected.

A recent happening forcefully draws attention to the need for sound research data in order to provide scientific advice for making management decisions that will also stand the test of jurisprudence. The case in question is the ban imposed on fishing of elasmobranch fishes (sharks, skates and rays) which, for reasons unknown, were placed under Schedule I under the Indian Wildlife (Protection) Act by the Ministry of Environment and Forests, Government of India. The ensuing dialogues and debates resulted in back pedalling and short-listing the number of species to nine, though there is no justification for a ban on others on the list. A silver lining, though, is the major funding from the Ministry of Environment and Forests for research on elasmobranch fisheries, status of species and management issues, which is in the pipeline.

Fisheries research must help to tackle the conflicts that we see today in marine capture fisheries and the maladies in coastal aquaculture. Sharing common resources even within the territorial waters, the question of straddling stocks and highly migratory pelagic fishes, restoring habitats and fish stocks to original sustainable levels through sound management strategies involving a participatory approach of the stakeholders, and many other problems need to be addressed. A large infrastructure for fisheries research and trained manpower has been built up during the past three decades, and this has to be put to the best use in public interest. The focus, as mentioned by Anne Platt McGinn (quoted at the beginning of this chapter), should be shifted from what is done to the fish to what can be done for the fish.

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