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Sustainable management and entrepreneurship development in fisheries for nutritional and livelihood security

(9 - 20 January, 2020)

Training Manual

ICAR-Central Institute of Fisheries Technology

Willingdon Island, Matsyapuri P.O., Cochin-682 029, Kerala, India.

Training Manual

on

Sustainable management and entrepreneurship development in fisheries for nutritional and livelihood security

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Foreword

The ICAR-CIFT, Cochin has been partnering with the Ministry of External Affairs, Government of India in organising capacity building programmes for nationals belonging to partner countries under the ITEC (Indian Technical and Economic Cooperation) Programme. The latest in the edition is the programme on *Sustainable management and entrepreneurship development in fisheries for nutritional and livelihood security* (9-20 January, 2020) that was specially designed for officials from Sultanate of Oman.

India is a leading fish producer and has significant exports as well. The Institute has been in the forefront of developing technologies for capture of fish through designing of crafts and gear with stress on conservation and sustainability. All the aspects that follow capture like preservation, processing, by-products development, packaging, quality assurance etc. are also the areas in which the Institute has had significant contributions. The participants attending the training can take back the learning to their countries for further dissemination.

I hope that this e-manual based on the lectures that were organized for the participants will be useful to them for future reference and will lead to greater enquiry on their part to get more knowledge on these topics.

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Preface

Indian fisheries and aquaculture is an important sector of food production providing nutritional security, besides livelihood support and gainful employment to more than 14 million people, and contributing to agricultural exports. During 2017-18, total fish production in India was 12.59 million metric tonnes of which nearly 65% is from inland sector and about 50% of the total production is from culture fisheries, and constitutes about 6.3% of the global fish production. Fish is a source of valuable animal protein and is now considered a health food. The higher preference for fish and increased fish demand and consumption in India will create more demand and production, and this is an opportunity for the fisheries sector. Fisheries sector also has an important role in the socio-economic development of the country has become a powerful income and employment generator, and stimulates the growth of a number of subsidiary small, medium and large scale industries.

India has made notable technological advances in both marine and inland fishery sectors. It is important to explore novel ways towards responsible fisheries and ecosystem-based sustainable management of fish resources, increase the value of harvested fish through processing and working towards total utilization of the resources with zero waste.

The ITEC Programme on *Sustainable management and entrepreneurship development in fisheries for nutritional and livelihood security* has been sepcifically designed for professionals from the Sultanate of Oman to expose them on the recent advances in culture & capture fisheries, and post harvest sectors. This compendium is a collection of the lectures that were presented during the Programme and can be used as future reference material.

Course Coordinators

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CIFT: Its contribution to Indian fishery

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Introduction

Fish as a cheap source of protein, bioavailable minerals, vitamins and essential fatty acids, ensures global nutritional security. India witnessed around 14-fold increment in fish production from 0.7 million tonnes in 1950's to 10.43 million tonnes in 2014-15. With a contribution of 5.05% to world's capture production and 6.6% of total aquaculture fish production, India emerged as one among the most progressive fish producing countries in the world. Fisheries as a major agricultural sector, constitutes 0.92% of total GDP and 5.58% of total agricultural GDP of India. With the global fish export value of 148,147 million USD, India ranked seventh position among the top fish exporters of the world. The sector is crucial in securing food supply, job opportunities, nutritional needs and earning foreign exchange for the country, cataloguing it as a sunrise sector of Indian economy.

Technological developments in harvest sector

Introduction of new materials for fishing gears, mechanization of fishing crafts and modern electronic technologies for navigation and fish location, paved way for the significant increase in fish production in India over the years. ICAR-CIFT has been involved in the design and optimization of a range of crafts and gears since its inception, which gave a major fillip to the harvest sector of Indian fisheries. Considering the plateauing /decline in catches perceptible since last two decades, ICAR-CIFT has shifted its focus from increasing production to responsible harvest of resources. As a result a large number of technologies for sustainable harvest and green technologies with reduced emissions were developed.

Environmental protection and eco-friendly technologies for harvest sector

The Institute has successfully constructed few rubber wood canoes treated with a dual preservatives and combination treatment technology developed at the Institute for marine and backwater fishing. The cost of the canoe is 35-40% less than a canoe of same size built of 'Anjili' (*Artocarpus hirsuta*), the usually used wood. This saves the depleting forest wealth, helps the rubber farmer to get a better prize for the under-utilized wood and gives a durable, maintenance-free boat at affordable cost to the poor (Fig.1).

Six new designs of eco-friendly and resource specific demersal trawls were developed. Trials carried out have shown that with proper rigging, none of the designs dragged bottom debris and benthos, preserving the bottom ecology of the trawling grounds. V-form otter boards designed and popularized by the Institute have also helped in eco-friendly trawling which has become popular along Gujarat, Andhra Pradesh and Kerala coasts.

Harvest technologies for responsible fishing

Square mesh codends and V form otter boards were popularized as eco-friendly and conservational fishing methods. Square mesh cod ends were seen to function better than diamond mesh in conservation by ensuring escapement juveniles. Use of optimum mesh size for target species and size class is imperative in order to prevent capture of non-target species, sub-adults and juveniles. With this in mind, a simple device for easy measurement of mesh size was developed. Selection of right size of mesh will help in popularizing responsible fishing.

Turtle Excluder device (TED) developed at the Institute was tested at Cochin, Visakhapatnam and Paradeep and found to be working satisfactorily. Turtle escape was 100% with minimum loss of valuable catch. The device is being popularized in maritime states where fishing induced turtle mortality is reported to be high. The purseine fishery of Kerala was facing hard times and as the number of vessels was reduced to 17 from 100 when ICAR-CIFT came up with suggestions for change in the mesh size. The purse seine nets and ring seines of Kerala are criticized for its very small mesh size (10-18 mm) destroying the fish wealth, as very small fish and juveniles cannot escape the net. The newly introduced purse-seine net has 45 mm mesh which has improved the catches. With increased mesh size, the target species were large sized mackerels, skipjack tunas, pomfrets, large sized carangid species etc. This net has found wide acceptance among fisherman. The new version of purse seine is a step towards conservation of fishery resources and at the same time assures good income to the fishermen, as the catches are of good marketable size.

CIFT SPTS-1 was developed as an alternative to shrimp trawling in the small-scale mechanized trawler sector, after extensive field –testing .It is capable of attaining catch rates beyond 200 $kg.h^{-1}$ in moderately productive grounds and selectively harvest fast swimming demersal and semi–pelagic finfishes and cephalopods, which are generally beyond the reach of conventional bottom trawls, currently used in commercial trawl fisheries in India.

Harvest technologies for the traditional sector

An improved design of FRP boat for backwater fishing was developed and canoes constructed for use in place of wooden canoes, which are very costly. Light weight, strength and durability are the main advantage of this material. They also have longer life when compared to traditional wooden canoes, which is a boon to the poor fisherman. The boat can be used for coastal fishing also. Fiberglass reinforced plastic (FRP) sheathed, untreated rubber wood canoes were constructed and given for experimental fishing to artisanal fishermen. Both, the preservative treated rubber wood canoe and FRP sheathed untreated rubber wood canoe, were found to be in sound condition even after 26 and 16 month field operation respectively. Fishermen have shown interest in the new technologies.

High tenacity nylon monofilament of mesh size 30 mm bar were found to be superior to nets with other mesh sizes and was found best for fabrication of gillnets for obtaining good catches. Design of twin hulled 3.6 m solar-powered boat for use in aquaculture farms, gillnetting, line fishing, transportation and aqua tourism (Fig.2). The boat with length of 3.6 m is twin hulled and is solely propelled by solar power. It can be put to use in aqua farms for aquacultural purposes and for gillnetting, line fishing, transportation and aqua tourism. Its main advantages are that it does not burn fuel, there is no atmospheric or sound pollution, has more deck space with clean FRP surface for fish handling and is suitable for shallow waters.

Harvest technologies for the mechanized sector

A prototype of a 5.22m L_{OA} aluminum alloy boat was designed and constructed for fishing and related activates in reservoirs and rivers. This is the latest in a series of materials being evaluated by the Institute for construction of fishing vessels for the artisanal as well as mechanized sectors. Light weight, corrosion resistance, toughness and resilience make aluminum alloy a good material for construction of marine craft. This new material avoids expenditure on paints etc. and gives good re-sale value.

A sail system for use on-board medium class fishing vessels was developed for reducing fuel consumption during free running mode. Experimental fishing carried out with nylon gillnets and hand lines at Agatti islands, Lakshadweep have revealed the scope for use of these gears on the island. The islanders are now taking to such fishing methods in addition to the traditional pole and line fishing for tuna. Standardized the parameters to exploit semi-pelagic fishery resources.

Separator trawl studies confirmed the differential behavior and sorting of catch to the lower and upper cod ends. The Internationally recognized Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) was the resulting invention.

Design and construction of an energy efficient, green combination fishing vessel named, 'Sagar Haritha'. The 19.75 m multi-purpose fishing vessel, FV Sagar Harita, built under the project "Green Fishing Systems for the Tropical Seas" funded by National Agricultural Science Fund is a fuel efficient combination fishing vessel combines deep sea fishing methods like long-lining, gill netting and trawling (Fig.3). This development has turned out to be a land mark in the deep sea fishing industry of the country as no standard design of combination fishing vessel incorporating fuel efficiency features, to reduce carbon foot print is available for mechanized fishing sector of Kerala. Modifications in the hull design and changes in the operation parameters of this fishing vessel significantly reduce fuel consumption and emission of green house gases. The hull of the vessel is made of marine grade steel and the cabin and wheel house is made of FRP to reduce weight and to improve the carrying capacity and speed. The main engine power is 400 hp which is 20% lower than comparable size vessel. The fishing gear handling equipment such as split trawl winch, long line hauler, setter and gillnet hauler designed at ICAR-CIFT with hydraulic power are installed onboard. A 600 watt solar power panel is designed and installed for emergency lighting and navigational aids to promote the utilization of renewable energy resource in the sector. Acoustic trawl telemetry system with under water sensors is also installed onboard.

Harvest technologies for the inland fisheries sector

- Monoline fishing (long lining) was introduced for the first time in the reservoirs (Hirakud reservoir).
- Trammel nets of 70mm bar mesh size were found superior to other mesh sizes tried in the reservoir, contributing to 76% of the total catches
- Potential fishing zones of Thangu reservoir on Hariharjore, a tributary of Mahanadi, were demarcated based on optimum water quality parameters and depth. Survey was undertaken of some of the rivers of North Kerala with particular reference to use of bamboo in fishing. Bamboo is currently used in fabrication of traps, barriers and as gear and aquaculture accessories.
- ICAR-CIFT has designed and fabricated new collapsible fish trap and crab trap for the helping the poor fishermen operating fish traps. Crab traps were operated in Cochin backwater with fish and chicken waste as bait. The design of the collapsible trap is simple and cost-effective and any fisherman can adopt the technology. Since it is made of synthetic netting, it is light in weight. A fisherman can transport and easily operate 10-15 traps using a canoe unlike the traditional traps.

Technological developments in post harvest sector

Preservation and processing aids

Chilling is the most common and traditional method of keeping fish in fresh condition. The simplest way for chilling is icing, by which fish can be kept for 12-15 days without spoilage. However, fatty fishes like oil sardine and mackerel show visible signs of spoilage even before 10 days of storage in ice. Freezing is the major processing technique applied for long term storage of fishes for human consumption. About 12% of the fish catch is frozen for further marketing or utilization against 26% in world scenario. Fisherfolk with no/little access to modern facilities rely on the traditional methods for the preservation of fish. This includes drying, salting, pickling and smoking. All these techniques are still in practice and are preferred over a wide range of population, even though chilling and freezing gets a preference. Drying and curing also remains as of considerable importance for the utilization of seasonal bulk landings. The conventional method of curing follows sun drying the whole/gutted fish with or without prior salting. Cured fish products have good economic potential and fetch attractive prices in global market.

ICAR-CIFT has introduced a hybrid solar dryer with an alternate electrical back up heating system. Effective harnessing of solar energy using specially designed solar air heating panels and proper circulation of this hot air across the SS trays loaded with fish with the help of blowers makes the drying process faster (Fig.4). The chance of contamination and spoilage due to sand, dust, flies, insects, birds, animals and rain is completely eliminated as drying takes place inside closed chamber. The spreading of fish in S.S. perforated trays and stacking of the trays inside the drying chamber helps in reducing the space requirement of the drying process. The alternate electrical back-up heating system under controlled temperature conditions enables drying to continue even under unfavourable weather conditions like rain, cloud, non-sunny days and even in night hours, so that the bacterial spoilage due to partial drying will not occur. The eco-friendly solar drying system reduces fuel consumption and ensures significant impact in energy conservation. In India, on an average, 5% of the total fish catch is converted to cured products against 12% of the cured product proportion in world fish production.

Smoking or smoke curing is an ancient method of preservation of fish. Smoking also imparts a unique taste and flavour to the fish. It is an age old practice of preserving certain varieties of fish like tuna and little tunnies. The practice of smoke curing of fish by heating fish in an earthen pot with firewood is popular in NEH states of India, Lakshadweep islands, and remote deltas like Godavari and Krishna deltas in Andhra Pradesh. Masmin, Ngari and Colombo cured fatty fishes are some traditional cured fish products commonly prepared in these regions. However, the practice is being discouraged by many on health grounds, as wood smoke quite often contains a carcinogen, benzopyrene. Also, long term and frequent exposure to wood smoke creates respiratory and eye ailments. ICAR-CIFT has developed an eco-friendly model of a community smoking kiln (Green kiln) popularly known as COFISKI, which ensures more shelf life of over six months to the smoked fish. The smoke cured fish products of COFISKI were free from human pathogenic bacteria such as *Salmonella*, *Shigella* and *E. coli* and harbored very few number of hygiene indicator bacteria viz., fecal Coliforms, fecal *Streptococci*, Coagulase positive *Staphylococci* making it safe and fit human consumption. In traditional fish smoking kilns curing of fish are confined to individual family, whereas, COFISKI inculcated community feeling among the fisherwomen in all the villages under adoption. Thus removing socio-economic barriers and tackling the problem as one group instead of solving alone.

Smart processing and packaging technologies - A leap towards energy efficiency

Seafoods are highly perishable and usually spoil faster than other muscle foods. They are more vulnerable to post-mortem texture deterioration than other meats. Freshly caught fish undergoes quality changes as a result of autolysis and bacterial activity. Extent of these changes with time determines shelf life of the product. The novel non thermal technologies like high pressure processing, pulsed light, ultrasound, irradiation etc. find application in preservation of food and are in the line of commercialization. Microwave processing is a thermal processing aid, which has gained wide popularity owing to the rapidity of the process and applicability to a large category of products. Recent trend is to employ these techniques in newer combinations that can deliver effective preservation, without the extreme use of any single technique. These techniques aim at inactivation of microorganism rather than inhibiting them. Another interesting application in the development of ingredients and finished products is the functional modification of the food macromolecules that help the processor to have outstanding quality, with reduced cost, time and energy. The new technologies now introduce more possibilities in non-thermal or mild heat alternatives to the conventional heat processing.

High pressure processing:

High pressure processing (HPP) is a non-thermal processing technique, which uses very high pressures of more than 100Mpa to preserve food by inactivating microorganisms, spoilage enzymes and alter the food attributes, in order to achieve consumer-desired qualities. HPP was initially adopted for processing beverages and semi-liquid food items, but now this has been one of the most explored technologies and today it is a commercial reality (Fig.5). Usually the product is packed in flexible packages before processing and preferably kept in refrigeration after processing. The major attraction is that the nutritional or sensory qualities of the product are retained and thermal ill effects are avoided. This technology is used in the area of seafood safety that led seafood processors to explore high pressure technology in product development and extension of shelf life. Oysters, clams, mussels, lobsters, crabs, shrimp, cod, hake, ready to eat (RTE) seafood meals, are some examples of products that are currently being processed with HPP. A potential application of HPP is for shucking bivalves (complete separation of meat from the shell) providing high yield of product without any mechanical damage. This technology could open up the new areas of product development and product improvements in all segments of meat and fish industry. Another approach in food industry is pressure assisted freezing and thawing, which finds its unique application in product development and product quality improvement. Since HPP has minimal detrimental impact on thermally labile bioactive compounds the technology is becoming a topic of major interest for cosmetic, nutraceutical and pharmaceutical industry. Salient findings of HPP in work done at ICAR-CIFT are as follows: Indian white prawns were subjected to pressure levels of 150, 200, 250 and 300MPa with holding time at 5 min at 25 °C and subsequent stored in iced condition for shelf life evaluation. 250 MPa had a shelf life of 30 days with respect to physical and biochemical parameters. Yellow fin tuna chunks were subjected to 150, 200 and 250MPa with holding time at 5 min at 25°C and subsequent stored in iced condition for shelf life evaluation. 200 MPa had a shelf life of 30 days. Evaluation of gel strength of fish mince (unwashed) and surimi (single washed) by high pressure treatment were carried out and HPP treated had positive effect on the gelling property of sausage.

Pulse light technology:

This non thermal preservation technique uses very high-power and very short-duration pulses of light emitted by inert gas flash lamps to decontaminate and sterilize foods (Fig.6). A spectrum of white light from UV wavelength of 200nm to infrared wavelength of 1100nm is used. Exposure to PL is in the form of high intensity UV light pulses resulted in microbial inactivation through a photochemical, photothermal, and photophysical route. Hence an effective microbial inactivation is achieved, without any adverse effect on the product properties. The application of pulse light has been conducted in various foods but only few studies have been reported in fish and fishery products. The use of pulse light for the sterilization of packaging material is a growing area of food research.

Pulse electric field technology:

PEF uses high voltage short pulses to preserve the food, so as to inactivate microbes with minimal effect on quality attributes of the product. It is one of the most appealing technology due to short treatment time (typically below 1 second); hence, foods treated this way retain their fresh aroma, taste, and appearance. It is suitable for preserving liquid and semi-liquid foods. Application of PEF technology has been successfully demonstrated for the pasteurization of foods fish soups, tomato juice and liquid eggs. Application of PEF processing is restricted to food products with no air bubbles and with low electrical conductivity. PEF is a continuous processing method, which is not suitable for solid food products that cannot be pumped.

Irradiation:

Irradiation (gamma rays, X rays, and electron beams) process exposes the food to controlled levels of ionizing radiations which is detrimental to harmful bacteria, pests or parasites. The food packed is passed through the radiation chamber on a conveyor belt and exposed to radiations, without direct contact with radioactive material. Effect of irradiation on nutritional quality depends on the type of food and the dosage of radiation used. It can be used to prolong the shelf life of fruits and vegetables by inhibiting sprouting and delays ripening. Irradiation produces some chemical changes, which, although lethal to food-borne bacteria, do not affect the nutritional and sensory quality of the food but lead to the production of small amounts of radiolytic products.

Ultrasound Processing:

The application of ultrasound in food processing is another area in non thermal approaches, which exploits the preservative effect of the high intensity sound waves. The treatment enhances shelf life of product with greater homogeneity and energy savings. The preservative effect is by the inactivation of microbes and spoilage enzyme by mechanical actions. Ultrasonication (application of ultrasound at low temperatures), thermosonication (application of ultrasound at high temperatures), manosonication (application of ultrasound and pressure together) and manothermosonication (combined application of ultrasound, pressure and heat) are the various categories of ultrasound processing techniques. The technology finds its application in the field of extraction of proteins, lipids and their functional modifications, emulsification, viscosity improvement, homogenization and improvement of dispersion stability in liquid foods. Ultrasonics has been successfully used to inactivate *Salmonella* spp., *Escherichia coli*, *Listeria monocytogenes*, *Staphylcoccus aureus* and other pathogens. Ultrasound technology can be effectively used for freeze thawing of foods without generation of excessive heat.

Microwave processing:

Unlike non-thermal processing techniques, microwave processing involves generation of heat. Still it is attractive due to its instantaneous and rapid increase in temperature, controllable heat transmission, and easy clean-up opportunities. It is currently being used to replace or complement conventional processing technology for pasteurising or sterilising food products as well as to meet the demands of on-the-go consumers who want quick food preparation and superior taste and texture. The largest use of industrial microwave processing of food has been for tempering of meat for further processing. Conventional tempering techniques take a lot of time with considerable drip loss resulting in loss of protein and quality and economic loss. The microwave tempering can be performed in few minutes for a large amount of frozen products (5–10 min for 20–40 kg). Currently, most food industries use microwave at 915 MHz for tempering purposes.

Applications of microwave drying include microwave assisted hot air drying, microwave vacuum drying and microwave freeze drying. Microwave heating is found to be an ideal system for cooking bacon and sausages, a sit greatly reduces loss of moisture through drip, fat, nutrients, and flavour. Microwaveable foods in suitable packaging materials are being developed by food processers to meet the growing demand. These convenience foods are microwaveable for use at home and away. High-density polypropylene (HDPP) is a suitable for microwave process over other materials since it can withstand the high temperature.

Modified atmosphere packaging:

Modified atmosphere packaging is a technologically viable method to extend the storage life of fresh seafood products. In modified atmosphere packaging air is replaced with different gas mixtures to regulate microbial activity and /or retard discolouration of the products. The composition of the gas mixture changes from its initial composition as a result of chemical, enzymatic and microbial activity of the product during storage. It is primarily the enrichment of carbon dioxide in the storage atmosphere as a means of controlling microbial growth, which results in the extension of shelf life of products. Packaging materials generally employed for this purpose are flexible films of nylon/surylyn laminates, PVC moulded trays laminated with polythene, polyester/low density polythene film etc. The use of high barrier film along with MAP that contains CO_2 effectively inhibits bacterial growth during refrigerated storage of packaged fresh fishery products. On the other hand, oxygen can inhibit the growth of strictly anaerobic bacteria like *Clostridium botulinum* although there is a very wide variation in the sensitivity of anaerobes to Oxygen. It is also seen that inclusion of only some Oxygen with Nitrogen or Carbon dioxide will not prevent botulism with absolute certainty.

Active packaging system:

The concept of active packaging started with a shift in the protection function of packaging from passive to active. It is an innovative concept that can be defined as ‘a type of packaging that changes the condition of the packaging and maintains these conditions throughout the storage period to extend shelf-life or to improve safety or sensory properties while maintaining the quality of packaged food’. They can be divided into three categories of absorber (e.g., O_2, CO_2, odour, ethylene), releasing system (e.g., N_2, CO_2, ethanol, antimicrobials, antioxidants), and other system. Other active packaging system may include the tasks of self-heating, self-cooling, microwave susceptor, anti-fogging and selective permeable film. The most important active packaging concepts for fishery products include O_2 scavenging, CO_2emitters, moisture regulators, antimicrobial packaging, antioxidant release, release or absorption of flavours and odours. Active packaging systems with dual functionality (combination of oxygen scavengers with carbon dioxide and/or antimicrobial /antioxidant substances) is also available nowadays.

Intelligent packaging systems:

Intelligent packaging systems provide the user with information on the conditions of the food or its environment. It is a packaging system that is capable of carrying out intelligent functions (such as detecting, sensing, recording, tracing, communicating, and applying scientific logic) to facilitate decision making in order to extend shelf life, enhance safety, improve quality, provide information, and warn about possible problems. The intelligent devices such as sensors, small inexpensive labels or tags that are attached onto primary packaging (e.g., pouches, trays, and bottles), or more often onto secondary packaging (e.g., shipping containers) etc. are the integral part of intelligent packaging system, which facilitate communication throughout the supply chain so that appropriate actions may be taken to achieve desired benefits in food quality and safety enhancement. In contrary to active components, intelligent components do not have the intention to release their constituents into the food.

Smart packaging system:

Smart packaging is a broad terminology encompassing both active packing and intelligent packing concepts. Smart packaging offers a number of additional functionalities depending on the type of product, in addition to performing the four basic functions of packaging such as protection, communication, convenience and containment. They help extend shelf life, monitor freshness, display information on quality, improve safety, and improve convenience. The term smart packaging is substituted at times as diagnostic packaging, communicative packaging, functional packaging, enhancement packaging, etc.

Value addition – processor's opportunity:

Value added products are the need of the hour, since the consumers find little time for spending in preparing such products. The present day consumers, particularly urban consumers are showing more and more interest in food products which are available as ready to eat or ready to cook. The high level of expendable income and the usage of microwave ovens in households made the value added products an inevitable commodity in the super markets of the urban and even rural area. Obviously, the processors are at a side of great opportunity, as the global demand for convenient products such as marinated fillets, steaks, mince based products, extruded products etc is increasing rapidly. The major opportunities in value addition lie in the following areas:

Fish mince and mince-based products: Fish mince separated from skin, bone and fins are used for preparation of a variety of ready to eat/fry products. Battered and breaded products commonly known as 'coated products' like fish fingers, fish balls, cutlet, patties etc. are the most popular among them. Battering and breading techniques have contributed significantly to value addition of fish and fishery products. These products fetch good demand in domestic as well as export markets as they require minimum financial requirement and are affordable to low time traders.

Surimi and surimi-based products: Surimi, washed mince added with cryoprotectants, also act as an intermediary in development of various products. World-wide, there is a continuous search of raw material which is suitable for surimi production. Low cost white fleshed fishes such as pink perch, croaker and perches can be conveniently used for the preparation of surimi. Even though, surimi and surimi-based products such as sausages are less popular in India, it is a much sought-after item in western markets. Moreover, shell fish analogue products from surimi fetches good demand in domestic and export markets. The

Indian company 'Gadre Marine' is a leading manufacturer of surimi, exporting to 24 countries over the world.

Thermal processing and ready to serve products: Long storage life at ambient temperature without any compromise for the nutritional quality made the ready to serve thermally processed products to emerge as a highly demanded commodity. Thermal processing, which is commonly referred as heat processing or canning is a means of achieving long-term microbiological stability for non-dried foods without the use of refrigeration, by prolonged heating in hermetically sealed containers, such as cans or retortable pouches, to render the contents of the container sterile. ICAR-CIFT has standardized the processing conditions for more than 25 product styles, including the ethnic varieties such as Hyderabadi prawn biriyani, Goan mackerel curry, Malabar seer fish curry (Fig.7), Tapioka and fish curry, Seerfish Moli, mussel/oyster masala etc. This technology has a long term impact as evidenced by the adoption of fish products in retort pouch by more than a dozen companies in India. Different types of packaging materials like cans, retort pouches with different layer configurations, semi rigid containers are used for the development of these products.

Extruded snack products: Extrusion helps to improve the versatility for the development of high-nutritive, low cost and convenient food products. It is a thermodynamically efficient process and ensures the destruction of bacteria and anti-nutritional factors during extrusion process. Flavour, texture and taste are the major characteristics affecting the acceptability of these products. Usually, extruded products are prepared using cereal flour, which have less protein content and are limited in some essential amino acids. By incorporating protein-rich fish mince instead of cereal, the product is protein enriched snack food. 'Fish cure' is such a product developed by ICAR-CIFT with fish mince as base material. The flavour and taste of these products may be altered by coating with suitable spice/flavour mix. The production process involves mixing of fish mince with cereal flours, spices and salt and extrusion using a twin screw extruder (Fig.8). The dried and coated products are then packed in metalized polyester polyethylene pouches using nitrogen gas filling. The product is acceptable up to 3 months at ambient temperature.

Seaweed incorporated products: A more recent addition to the food industry from marine sector is 'processed seaweeds and seaweed extracts'. The South-East and North -West coasts of India and the Andaman- Nicobar and Laccadive archipelagoes harbour a variety of seaweeds with rich biomass and species diversity. The seaweed industry is certainly on its way marching towards socio economic development of our nation. Apart from bringing umami taste to foods, seaweeds serve as a major storehouse of polyunsaturated fatty acids, dietary fibres, minerals, vitamins and sulphated polysaccharides in good amounts, which could be used to fortify beverages and health drinks. Dietary fibre extract from seaweeds, 'Nutridrink' (grape juice fortified with seaweed extract), fish soup fortified with seaweed bioactive compound, seaweed incorporated semi-seaweed biscuits (Fig.9) and noodles are a few novel products developed in this line by ICAR-CIFT.

Fish nutritional bars: The new life styles of consumers add to the requirement of new health foods and nutritional energy supplements, in pleasing and portable way. Modern market, have gained a more attraction towards the convenient type nutritional bars/

energy bars/ protein bars in various forms and wide varieties can be made on the basis of different consumer requirement of health food, diet replacer, work out food, energy supplement, geriatric food, sugar free product and nutrient requirement for children. Globally, this trend is being driven by growing consumer awareness about better nutrition in physical performance and personal appearance. ICAR-CIFT has standardized some formulations for nutritional bars added with the best quality supplements from fish source. The protein from fish has been regarded as the high quality with well-balanced amino acid profile, that is easily digestible than any mammalian counter parts. ICAR-CIFT has developed a nutrient formulation with cereal mixes, dried fruits fortified with different biomolecules like high profile fish protein/ collagen peptide/ omega-3 oil in crunchy type granola bars with good shelf stability. Fortification of 10-15% fish protein alone and provide an average energy of 400 Kcal/100g was achieved (Fig.10).

Processed fish roe and caviar substitutes: Fish roes, which form a major component of process discards, are nutritionally valuable sources of omega-3 fatty acids and essential amino acids. Generally, the roe obtained during dressing of fish is either discarded or sold at very low price as it forms a jelly mass during cooking. However, the roe mass may be spray dried using a suitable stabiliser like gum Arabic and the powder can be added to a wide range of foods without affecting the sensory characteristics of the products. Besides the commercially available roe from sturgeon, salmon and cod, fish caviar substitute from fresh water carp roe reconstituted with suitable gelling agents such as sodium alginate will have a greater potential as fish caviar substitutes.

Miscellaneous products: A variety of products like fish sauce, fish salad, fish pickles, frozen whelk, squid fillet, shrimp skewer, stuffed squid with shrimp etc. have fairly good movement in domestic and foreign market. Canned crab, chilled pasteurised crab, crab cut, frozen 'snap and eat' legs are some of the crab based products available in the market. Identifying live crab exports as a money spinner, the Indian seafood industry is all set to rear mangrove crabs, so as to scale up the export of the crustacean that commands high price in the global market.

High value byproducts - Wealth from waste: Nearly 70-80% of the total weight of fish catch is generally discarded as bycatch or processing waste. Global fish waste generation is estimated to be in excess of 75 MMT and in the Indian scenario it is >4 MMT. It is estimated that fish processing waste after filleting accounts for approximately 75% of the total fish weight. About 30% of the total fish weight remains as waste in the form of skins and bones during preparation of fish fillets. Bio-conversion of these wastes is an environmental friendly and profitable option for the utilization of fish waste. Some viable options for generating wealth from waste are detailed below.

Fish meal: Fish meal is highly concentrated nutritious feed supplement consisting of high quality protein, minerals, vitamins of B group and other vitamins and other unknown growth factors. Fish meal is rich in essential amino acids. It is produced by cooking, pressing, drying and grinding the fish, bycatch fish, and miscellaneous fish, filleting waste, waste from canneries and waste from various other processing operations. The composition of fish meal differs considerably due to the variations in the raw material used and the processing methods and conditions. Better quality fish meal has been a prominent item of export from the very beginning of this industry. BIS has brought out the specification for fish meal as livestock feed for facilitating proper quality control. The proximate composition of fish meal, in general, is protein, 50-60%; fat,5-10%; ash, 12-35% and moisture, 6-10% employed. Around 15% of the global fish meal demand is met from fisheries resources alone. The projected (2030) annual growth rate in fishmeal use in aquaculture is 1.7%, where the current usage is at a tune of 3.9%. The recent development in captive breeding and rearing high value species such as cobia, grouper, pompano, Nile tilapia, lobster, Asian seabass etc. implies that there is a good scope for flourishing finfish and shellfish production through aquaculture in near future. This in turn highlights the bright future of fish meal industry in coming years, as most of these species demand high protein feeds for their optimum growth.

Fish protein hydrolysate: Hydrolysates find application as milk replace and food flavouring. Enzymes like papain, ficin, trypsin, bromelein and pancreatin are used for hydrolysis. The process consists of chopping, mincing, cooking and cooling to the desired temperature, hydrolysis, sieving, pasteurizing the liquid, concentrating and drying (by vacuum or spray drying). The fish protein hydrolysate have desirable functional properties with potential applications as emulsifiers and binder agents; and can used in place of diary based and plant based protein hydrolysates as well as protein powders currently available in market place. The peptides formed by the hydrolysis of fish proteins are proven to have bioactive properties like antihypertensive, antithrombotic, immune modulatory and antioxidative properties. Also, they are good source of nutritional and functional properties. A variety of nutraceuticals from FPH are commercially produced and are available in international markets. Oyster peptide extract developed by ICAR-CIFT possessed antioxidant and anti-inflammatory activities. Similarly, hydrolysate made from squilla meat effectively reduced oil absorption in breaded and battered products, when incorporated in the batter mix.

Fish collagen/gelatin/collagen peptides: Collagen is the major structural protein in the connective tissue. Collagen extracted from fishes can be used in cosmetics, foods, biomedical applications etc. ICAR-CIFT has developed the method for the preparation of absorbable surgical sutures from fish gut. Gelatin is the hydrolysed form of collagen with applications in development of bio degradable packaging, food and pharmaceuticals. Both collagen and gelatin are high molecular weight proteins of approximately 300 kDa, hence a considerable proportion is unavailable to human body for biological functions. Consequently, in recent years, much attention has been paid to the development of small molecular weight peptides from the native collagen with improved biological activities. This can be achieved by the process of hydrolysis in which the native collagen/gelatin molecules are cleaved to small fragments of less than 5 kDa. Currently, collagen peptides are being incorporated in a wide array of food products including protein bars, cereal bars, protein drinks, smoothies, yogurts, cold desserts, soups, cured meats etc. Nowadays, collagen/gelatin peptides have gained increasing attention as these peptides exhibit various biological activities such as antioxidant, anti-hypertensive, anti-human immunodeficiency virus, anti-proliferative, anticoagulant, calcium-binding, anti-obesity, anti-diabetic activities and postponement of age-related diseases. ICAR-CIFT has standardised a protocol for the extraction of collagen peptide from fish scale and bone (Fig.11). Further a nutritional mix based on collagen peptides was developed with a protein content of 78%. The product is mainly intended for middle aged and old people, ladies and sports-persons who needs a regular supply of collagen for healthy joints and bones. It may also be beneficial for patients suffering from osteoporosis and long-term- nursing home residents where there is a possibility of development of pressure ulcers.

Chitin: The shrimp processing industry in India churns out more than 2 lakh tones of head and shell waste per annum, which can be economically converted to chitin and its derivatives. Chitin is the most abundant polymer next to cellulose. It is a linear polymer of N acetyl-D-glucosamine. Glucosamine hydrochloride can be produced from chitin by hydrolysis. Glucosamine hydrochloride and sulphate are at present marketed as food supplement for the treatment of osteoarthritis. It also possesses other beneficial actions in wound healing and skin moisturization. The deacetylated chitin is known as chitosan. Chitin and chitosan have various applications in agriculture such as in germination of seeds and enhanced protection against pathogenic organisms in plants and suppress them in soil to induce chitinase activity and protenase inhibition, antivirus activity, in micro encapsulation fertilizers and insecticides. The delivery of drugs and the interactions with living tissues seem to be the major topics of current research on chitosan. Other areas of interest are the antimicrobial action, nerve regeneration, cartilage and bone regeneration, skin and bone substitutes, oral delivery for wound healing etc. Carboxy methylation of chitosan imparts water-solubility to chitosan. ICAR-CIFT has recently standardized the methodology for production of chitin, glucosamine hydrochloride, chitosan and carboxymethyl chitosan. Similarly, collagen-chitosan film from fish waste, developed by the Institute has wide applications in wound dressing and dental surgery. The antioxidant chitosan derivative developed was found to be useful in micro-encapsulating vitamins and ß carotene, so as to give a novel delivery system. Similarly, a biocompatible and biodegradable wound healing formulation, composed of microencapsulated curcumin and hydrogel composite (Succinyl chitosan-fish collagen-poly ethylene glycol) developed at ICAR-CIFT, showed significantly enhanced rate of collagen deposition and hydroxyproline content in wound tissue on 14th day of post wounding as compared to control and standard. Apart from that, free radical mediated grafting of gallic acid, ferulic acid, vanillic acid and coumaric acid onto chitosan were optimized. All the derivatives showed good antioxidant and antimicrobial activities.

Fish ensilage and foliar spray: When the animal farms are very near to fish landing centres it is worthwhile to go for silage production. Fish silage is made from whole fish or parts of the fish to which no other material has been added other than an acid and in which liquefaction of the fish is brought about by enzymes already present in the fish. The product is a stable liquid with a malty odour which has very good storage characteristics and contains all the water present in the original material. It is a simple process and it requires little capital equipment particularly if non-oily fish are used. The use of oily fish usually requires oil separation. This involves expensive equipment and is suited to a fairly large-scale operation. The silage may be suitable converted to foliar spray, as foliar feeding is an effective method for correcting soil deficiencies and overcoming the soils inability to transfer nutrients to the plant. The experiments conducted at ICAR-CIFT have shown that foliar feeding can be 8 to 10 times more effective than soil feeding and up to 90 percent of foliar fed nutrients. The application of foliar spray has been advocated in spices like cardamom, black pepper, tea etc and encouraging results have been reported. The quick absorption of the nutrients and precise dosage of foliar sprays has resulted in the success of precision farming of costly vegetables and flowering plants. The controlled nutritional supply through praying is an effective method which gives predicted resulted in most of the cases. The optimized supply of required micro and macro nutrients results in the maximum productivity of the available space and minimizes the wastage of costly inputs.

Fish calcium: In marine ecosystem, there is a large amount of calcium, mainly in the form of calcium carbonate and calcium phosphate, distributed as skeletal elements of teleosts, exoskeletal elements of molluscs or as coral deposits. Every year a considerable amount of total fish catch is discarded as processing left overs and these include trimmings, fins, frames, heads, skin and viscera The bone fraction, which comprises approximately 15-20% of the total body weight of fish has high calcium content. Calcium and phosphorus comprise about 2% (20 g/kg dry weight) of the whole fish. Generally, fatty fish have lower ash levels compared to lean species. The filleting wastes of tuna and other bigger fishes are very good sources for calcium when the quantity of calcium is concerned. Also, the bone structure differs between species since a large number of teleosts have acellular bone (bone without enclosed osteocytes). Cellular bones are confined to only a few fish groups, e.g. Salmonidae. The higher surface to volume ratio in acellular fish bone is likely to increase the calcium availability compared to cellular bone. The ash content is highest in lean fish species with acellular bones. Apart from that exoskeleton of mollusks and coral deposits are excellent source of calcium. However, the calcium form these deposits are mainly in the form of calcium carbonate. Central Institute of Fisheries Technology, Cochin has optimised the process to extract from fish bone which is mainly treated as processing discards during filleting operation of larger fishes, *viz* tuna, carps etc. The calcium powder was supplemented with vitamin D which is known to enhance absorption and bioavailability of calcium in the body. *In vivo* studies conducted at ICAR-CIFT in albino rats have shown that fish calcium powder supplemented with vitamin D has improved the absorption and bioavailability.

Chondroitin Sulphate: Chondroitin sulphate obtained from shark cartilage is used for the treatment of arthritis. It is part of a large protein molecule (proteoglycan) that gives cartilage elasticity.

Squalene: Squalene is a highly unsaturated hydrocarbon present in the liver oil of certain species of deep sea sharks mainly *Centrophorus* and *Squalidae* spp. The liver oil of these species contain high percentage of squalene (90%) which can be isolated and purified and can be used as a dietary supplement. It belongs to a class of antioxidant molecules called isoprenoids. Squalene is found to be a proficient chemo preventive agent against lung metastasis in mice bearing lung carcinoma. Squalene revives damaged body cells and aids to revitalize cell generation. Its chief attribute is the protection of cells from oxidation reactions. Squalene assists to clean, purify, and detoxify the blood from toxins, facilitating systemic circulation. It purifies the gastrointestinal tract and kidneys, causes better bowel movement and urination. Squlalene helps in regulating the female menstrual cycle and also improves irregular and abnormal cycles. ICAR-CIFT has standardized the protocol for extracting squalene from shark liver oil.

Hydroxyapatite (HAp): Hydroxyapatite is the major mineral component of bone tissue and teeth, with the chemical formula of $Ca_{10}(PO4)_6(OH)_2$. The composition Hap derives from biological sources differs from that of synthetic hydroxyapatite, due to the presence of several ionic substitutions in the lattice, such as CO_3, F, Mg^{2+} and Na^+. It is a member of the calcium phosphate group with 1.67 stoichiometric of Ca/P ratio. It is one of the few materials, classified as a bioactive biomaterial that supports bone in growth and osseointegration when used in orthopedic, dental and maxillofacial applications. Fish bone and scale is a rich source of hydroxyapatite. The hydroxyapatite content of fish skeleton may vary between 40-60%. Generally, very high heat treatment is used for extraction of HAp from bone and this temperature gives a higher strength to HAp structure. The high temperature also burns away any organic molecules such as collagen protein. Hydroxyapatite, found in fish is chemically similar to mineral components of bone and hard tissues in mammals. Approximately, 65-70% of the fish bone is composed of inorganic substances. Almost all these inorganic substances are hydroxyapatite composed of calcium, phosphorous, oxygen and hydrogen.

Pigments: Astaxanthin, fucaxanthin, melanin etc. from different fish resources are found to have a variety of bioactive properties. The filleting discards of salmonids and the shell wastes of crustaceans contain significant amounts of carotenoid pigments such as astaxanthin and canthaxanthin. The protective role of carotenoids against the oxidative modification of LDL cholesterol could be explored by incorporating in health drinks. Carotenoids are also highly sought after as natural food colours. Cephalopod ink is another less tapped reservoir of a range of bioactives having therapeutic and curative values. It is an intermixture of black pigment melanin, glycosaminoglycans, proteins, lipids, and various minerals. Cephalopod ink has been reported to have anti-radiation activity, antitumor activity, immune-modulatory activity, procoagulant function and so on. The pigment melanin can be used both as a natural colorant as well as antioxidant, in addition to a number of other therapeutic and prophylactic properties including anticancer, antihypertensive, anti IDA etc.

ICAR-CIFT in quality assurance of post harvest fisheries sector of India

As fish is a food commodity that has been traded across the world, there is lot of research and development activities carried out by ICAR-CIFT on the quality and safety of fish and fishery products. For ensuring quality and safety of seafood, the Indian Council of Agricultural Research set up an independent division in 1996 for taking up research, consultancy, training and analytical services in seafood quality assurance. ICAR-CIFT has proved its expertise in areas such as seafood quality assurance, food safety, sanitation and hygiene in fish processing establishments, production and evaluation of process water and ice, modern quality management programmes such as HACCP, ISO 22000 and regulatory requirements *viz*., EU regulations, Codex/IS/ISO standards etc. ICAR-CIFT is involved in the Assessment Panel of Experts (APE) and Supervisory Audit Team (SAT) for establishing quality regime in fish and fish based products. Also ICAR-CIFT humbly takes the credit of implementing HACCP in India for the first time in the early 1990s. Some of the salient research activates include microbiological interventions, development of methods for chemical contaminants, different package of practices based on HACCP, withdrawal period of antibiotics, challenge studies of different food borne pathogens, quality index schemes, different chemical hazards, antimicrobial property of phytochemicals etc. ICAR-CIFT is actively involved in developing and implementing an energy efficient effluent treatment plant for the fish processing units within the state and outside. The institute is also providing consultancy in the design, development and getting accreditation as per ISO/IEC

17025:2005. ICAR-CIFT has proudly contributed to the development of standards and the recent one is development of four standards for International Standards Organizations (ISO) for the traceability of both wild and cultured Molluscs and Crustaceans. CIFT has taken accreditation as per ISO/IEC 17025:2005 in 2005 and has been doing service to the industry and the needy. The institute has accredited for more than 120 parameters in chemical, microbiological and mechanical areas. The institute is also identified as the quarantine centre for fish and fishery products, for DADF, Ministry of Agriculture.

Conclusion

Fisheries is considered as a sunrise sector in India due to its recent renaissance and growth potential. The technological advancements in the harvest and post-harvest sector catalysed by the mechanization of fishing crafts and modern electronic technologies for navigation and fish location, along with energy efficient processing aids, offer good scope for the development of sector. Product diversification, promoting more public-private partnerships, creating more awareness on quality assurance throughout the value chain, taking initiatives for increased infrastructure facilities for market development, awareness creation on responsible and sustainable fishing practices etc. are crucial steps towards achieving 'blue revolution'.

Fig.1. Rubber wood canoe Fig.2. Solar-powered boat useful for aquaculture etc

Fig.3.Sagar Haritha': Energy efficient green fishing vessel

Fig.4. Solar dyer

Fig.5. High pressure processing unit Fig.6. Pulse light processing unit

Fig.7. Fish curry in retortable pouches Fig.8. Extruded fish snack

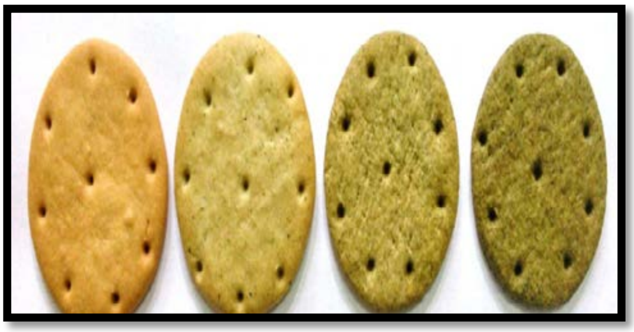

Fig. 9 Seaweed enriched biscuits developed at ICAR-CIFT

Fig. 10 Nutritional bar developed at ICAR-CIFT

Fig.11.Collagen peptide from fish scale and Nutritional mix formulated by CIFT

Introduction to aquaculture practices

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Introduction

The term ‘aquaculture’ literally means cultivation in water (‘aqua’ means water; ‘culture’ means cultivation). Aquaculture not only includes cultivation of finfishes and shellfishes but also sea weeds and other aquatic creatures. On a global basis, the major share of fish comes through fishing from our water bodies such as sea, rivers, lakes, estuaries etc. As per Food and Agricultural Organization (FAO), the global fish production peaked at 172.6 million tonnes in 2017, with capture fisheries and aquaculture contributing 92.5 million tonnes 80.1 million tonnes respectively representing 53% and 47%. The total estimated sale value from the fisheries sector was USD 383 billion while the aquaculture sector contributed USD 238 billion. This shows the significance of the sector in the global economic scenario. Increased fishing effort by rapid advancements in fishing methods (fishing gears like various types of nets) and fishing vessels (boats) have resulted in the decline of fishery resources in our oceans. At the same time, the ever growing human population needs more and more fish to meet their everyday nutritional requirements. As it is well known, fish is one of the cheapest sources of quality dietary protein and aquaculture is regarded as the only feasible way to produce more fish, and is the fastest growing food production sector in the world.

In simple terms, aquaculture may be defined as the growing and maintenance of aquatic organisms (like carp culture, shrimp culture, seaweed culture etc.) under human control and the person practicing it is known as an aquaculturist. The level of control refers to the environment in which an organism is grown and how much it is different from the natural habitats like sea or lake under natural conditions. Aquaculture can be as simple as introducing carp seeds into an unmanaged pond to complex activities like shrimp or prawn seed production in the controlled environment of a hatchery where the water may even be recycled and reused. It also covers the multibillion dollar cage culture industry operated off shores fully managed with artificial intelligence and advanced gadgets. Aquaculture includes all the activities from parent fish maintenance to seed production (production of young ones), farming, feeding, water quality maintenance, health management and harvesting.

The medium for fish culture, i.e. water- can be divided into three categories based on its salt content.

- Freshwater: with no/negligible salt content (below 0.5 ppt)
- Brackish water : with a salinity range of 0.5 to 25 ppt
- Seawater: with a salinity more than 30 ppt (aquaculture in seawater is also called as Mariculture)

Salt content of water is also referred as salinity and expressed as parts per thousand (ppt), which means the salt content in grams in a litre of water. Sodium chloride (common salt) is the major contributor to the salt content of water; but the seawater contains several other minerals and salts as well.

History of aquaculture

Aquaculture has a history of more than 4000 years and is believed to have originated in China. The oldest written records on aquaculture are also from China (Classic of Fish culture by Fan Lui). However, different techniques were followed in many parts of ancient world to raise fishes. The Chinese cultured different species of fishes (carps) in ponds while the Japanese and Romans farmed oysters in the sea. Egyptians farmed Tilapia. Extensive farming techniques were followed for culture until 19th century. Industrialization and advances in biology made the way for rapid intensification of aquaculture.

Cultivable species

The fishes/other aquatic organisms and plants are selected for aquaculture by looking into certain characteristics of these species.

- Fast growth rate
- Good market demand
- Capacity to withstand diseases and other culture conditions
- Capacity to accept prepared feeds
- Easy reproduction

The major species used for freshwater aquaculture include Grass carp, Silver carp, Common carp, Nile Tilapia, Big head carp, *Carassius* sp., Catla, Rohu, Pangasius etc. Freshwater prawns, most important of them being the giant freshwater prawn *Macrobrachium rosenbergii* are also farmed in freshwater. Marine shrimps like *Penaeus monodon* (black tiger shrimp) and Indian White shrimp (*Penaeus indicus*) are used for culture in brackish water. *Litopenaeus vannamei* (Pacific white shrimp), an introduced species, is also cultured widely in brackish water. Freshwater catfishes (Magur, Singhi, etc.), many brackish water fishes (milkfish, seabass, mullets, pearlspot, etc.), mud crabs, lobsters, several marine fishes (cobia, grouper, etc.), molluscs and seaweeds are some of the indigenous groups emerging for aquaculture in the world. In 2016, a total of 598 species were farmed in the world which include 369 fin fish species, 109 molluscs, 64 crustaceans, 7 amphibians and reptiles, 9 aquatic invertebrates and 40 aquatic plants. 20 species are the major ones accounting for almost 84.2% of the total production.

Culture Systems

Farming of fish can be classified in many ways:

Based on the number of species stocked in the pond, the culture system may be classified as monoculture (example: culture of a single species like in a shrimp farm or a magur farm); and polyculture (example: carp culture). In carp polyculture, compatible species sharing different feeding regimens are cultured together in the same pond.

Based on the number of fishes stocked in unit area (stocking density) and management practices, aquaculture may be categorized as:

(i) Extensive Farming

Very low investment-farming operation with low stocking density in a larger area and yielding low production. Prawn filtration fields of Kerala and Bhasabadha fisheries of West Bengal are examples. In this system, natural seed availability and productivity of the water body are utilized for growing fish. Such systems are eco-friendly that do not alter the properties of the wetland and ensures sustainable income to the fishermen against very low capital investment. Hence, they are considered to be sustainable aquaculture systems.

(ii) Semi-intensive farming

Medium-investment farming operation with higher stocking densities yielding high production. In addition to the natural food materials available for the fish, supplementary feeds like rice bran, oil cakes etc. or formulated feeds may also be given. Brackishwater shrimp farming is an example, where the investment includes preparation of farm, procurement of seeds, supplementary feeds, water quality maintenance and health management. It is a commercial activity ensuring reasonable profit for the farmers.

(iii) Intensive farming

High-investment farming operation with very high stocking densities yielding very high production. Fishes are exclusively fed with nutritionally complete formulated feeds. Raceway culture, silo culture and cage culture are some of the examples. It is a capital intensive activity that utilizes resources like space and water to the maximum. It is an ideal method for aquaculture in places with water shortage. In addition to these farming methods, integration of different crops (paddy, vegetables, duck, poultry, pig, cattle, sheep, etc.) with fish ponds can be done in such a way that the wastes from one farming operation become the input for the other. Depending on the temperature preference of the cultured species, aquaculture can be divided into cold water aquaculture in the upland areas (example: salmon and trout culture) and warm water aquaculture in the plains.

Facilities for aquaculture

Aquaculture can be practiced in different facilities. They are

(i) **Ponds**: are of two types
   a) Excavated ponds: constructed by digging the ground so as to form pond.
   b) Levee ponds: prepared by building dikes around areas excavated/level ground to impound water. They are named after the purpose it is used for. Eg: nursery pond, grow-out pond, broodstock pond etc.

(ii) **Tanks**: Usually made of concrete, fibre reinforced plastic (FRP), glass or water proof liners. They may be in different shapes according to the requirement. Example: round, oval, square, rectangle etc.

(iii) **Raceways**: A continuous flow-through system in which water makes single pass through the unit before being discharged. Usually concrete tanks are arranged in series or parallel, so that water moves from one unit to the other mostly by gravity and gets discharged. The residence time of water the units is very short to ensure good water quality.

(iv) **Silo culture**: Deep tanks where water is pumped from the bottom of the tank and exit at the top.

(v) **Pens**: Enclosures on all four sides in open water bodies like sea, lakes, etc. Bamboo poles/fences and nets are used to make the pens. Pens may also include enclosures which are natural, semi-enclosed water bodies where shorelines forms one side of the enclosure and other three sides are manmade by solid barriers or netting. Sizes of these enclosures often vary from 0.1 to 1000 ha.

(vi) **Cages**: Entirely manmade net enclosures suspended in water. Cages may be permanently fixed (fixed cages), floating along with the fluctuations in water level (floating cages), lowered under the water at the time of bad weather like storm, cyclone, etc. (submersible cages) and fully submerged under water (submerged cages).

Water quality parameters in aquaculture

Since fish lives in water throughout of its life, the quality of water in every sense is very important for the successful aquaculture. In general, water has to be pollution free having congenial quality parameters. The most important water quality parameters are listed below:

Dissolved oxygen

Oxygen (O_2) is the most important gas dissolved in water. It is essential for respiration of fish and plants, and decomposition of organic matter. The two main sources of dissolved oxygen (DO) are: atmospheric oxygen dissolved into water and oxygen generated by photosynthesis. DO in fish pond by photosynthesis depends on the amount of light available. During cloudy days, O_2 production decreases and it completely stops at night. The amount of DO decreases with increasing temperature and salinity. Dissolved O_2 is minimum at daybreak and maximum at evening. When dissolved oxygen in water becomes too low fishes show signs of suffocation and will start surfacing. The ideal level of dissolved oxygen is >5 ppm (parts per million or mg/L) for warm water species. DO levels should not go below 3 ppm in fish culture ponds. Excessive amount of dissolved oxygen in water is also not good, and may cause gas bubble disease in fish.

pH

The pH is defined as the negative logarithm (base 10) of the hydrogen ion concentration in moles per litre. As $[H^+]$ concentration increases, acidity increases or pH decreases and vice versa. pH scale ranges from 0 - 14, 7 is ***neutral*** (hydrogen ions and hydroxyl ions equal). As pH value decreases from 7, hydrogen ion predominates and it is ***acidic***. As pH increases from 7 hydroxyl ions predominate and it is ***basic*** or ***alkaline***. In general, fish likes a slightly alkaline pH. The desirable values are in between 7.5 to 8.5.

Alkalinity

Alkalinity is a measure of the amount of acid (hydrogen ion) water can absorb (buffer) before achieving a designated pH, and in effect total alkalinity is the measure of alkaline (acid neutralizing) minerals in water. Alkalinity in most natural waters is due to the presence of carbonate ($CO_3^{=}$), bicarbonate (HCO_3^-), and hydroxyl (OH^-) anions. total amount of carbonates and bicarbonates of Calcium (Ca) and Magnesium (Mg) present in water. It indicates how much the water pH can vary and the availability of CO_2 for photosynthesis. Water with high alkalinity has good buffering capacity. Water should have a total alkalinity greater than 25mg/L $CaCO_3$. Best fish production may occur in water where total alkalinity ranges from 50 - 100 mg/L $CaCO_3$. Total alkalinity is an important factor to be considered in fish farming. It depends on characteristic of soil and water and also how the farm is operated. It is also affected by liming which adds calcium material to the water and pond soil. Soft water with little Ca and Mg has low alkalinity and hard water have high alkalinity.

Salinity

Salinity is a measure of the concentration of dissolved ions in water and is expressed in grams of solute in kilogram of solution (parts per thousand ppt, %o). *Seawater* salinity varies from 33 to 37 ppt with an average of 35 ppt and *freshwater* salinity is < 0.5 ppt. *Brackishwater* has salinity ranging in between seawater and freshwater. Salinity is influenced by rainwater, runoff, evaporation, river discharge, etc. Estuaries are characterized by fluctuating salinities.

Temperature

Water temperature has direct effect on fish growth. Temperature affects oxygen solubility (the capacity of water to hold oxygen decreases with increase in temperature), interacts with other parameters, influences respiration rates, feeding, assimilation, growth, behaviour and reproduction. A temperature increase of 10^oC causes rates of biological and chemical reactions to double and is called Q_{10}. Fishes can be grouped according to their temperature requirements. The fishes which live in warm and colder regions are called warm water and cold water fishes respectively.

Turbidity

Turbidity is a measure of transparency or light penetration in water or degree of opaqueness. It is produced by suspended substances such as clay particles, silt, plankton or dissolved compounds, humic substances, etc. Generally, turbidity caused by phytoplankton is desirable as it enhances fish production while by suspended clay and other colloidal particles restricts visibility and inhibits development of good phytoplankton population. *Safe level is < 80 ppm* (suspended solids). Excessive runoff may cause turbidity to > 20,000ppm. High loads can restrict phytoplankton growth by inhibiting light penetration, clog gills, settle onto eggs, shield food organisms, settle in tanks, clog filtration equipments and sediment on pond bottom and decrease depth. Water turbidity is measured with ***Secchi disc***. It is a round disc (30 cm diameter divided into quadrants, alternate quadrants painted white and black). The disc is attached to ropes and has weight to lower the device into water. The disc is lowered and the depth at disappearance is ***Secchi disc visibility*** (cm).

Hardness

Total hardness is the content of divalent ions, Ca^{++} and Mg^{++} and is expressed as mg/l of $CaCO_3$. It is the sum total of carbonate (CO_3) and bicarbonate (HCO_3). Hence hardness can be increased by calcareous materials. Fish can survive in hardness ranging from 10mg/l to over 400 mg/l depending on the region it comes from. Waters with a hardness of up to 60 mg/l are referred to as "soft", while those containing 120-180 mg/l as "hard".

Conclusion

In 2017, fish accounted for about 17% of animal protein to the human kind. It provided almost 20% of the per capita intake of animal protein to at least 3.2 billion people. It is estimated that between 1961 and 2017 there is an increase of 3.2% in global fish consumption., while the meat consumption from other terrestrial animals shows only 2.8% increase. In 1961, the per capita fish consumption was 9.0 kg while in 2015 it was recorded as 20.2 kg. The value shows and increasing trend year after year (2016: 20.3 kg; 2017: 20.6kg). The Increased consumption has been driven not only by the increased production but also by other factors including reduced wastage. The global aquaculture relies increasingly on inland aquaculture. In 2017, inland aquaculture contributed about 52 million tonnes of food fish. Generally, fin fish production had been dominating in inland aquaculture. But from 2016 onwards, farming of other species showed increasing trend such as crustaceans including shrimps, crayfish and crabs. From the above account, it is clear that aquaculture can be a very avenue for enhancing the income of the farmers, strengthening the economy of nations, improving the protein security of the population and creating more employment.

Cage farming technology in India

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Introduction

Fisheries sector in India has emerged as an important industry during the last six decades. Fish is an important source of cheap protein to the people of India, and also a potential employment and income generating sector, besides earning substantial foreign exchange through seafood exports. Fisheries contributed about 5% of India's agricultural GDP and about one per cent of the total GDP during 2016-17. The sector supports livelihood options for about 40 million people in India. The marine fishery resources of the country include a coastline of 8129 km with numerous creeks and saline water areas, an Exclusive Economic Zone (EEZ) of 2.02 million km^2, which are suitable for capture as well as culture fisheries.

The marine fish production in India during 2018 was estimated at about 3.4 million tonnes, which is below the estimated harvestable potential, but the capture of high valued fishes is reducing considerably in capture fisheries. With the marine capture fisheries reaching almost a stagnation phase with limited scope for further expansion, the alternative is to look for augmenting the fishery resources of the sea. Since the existing capture methods have exploited the resources indiscriminately mainly due to socio-economic pressure, there has been a necessity to exploit the resources in a sustainable way. Under such circumstances, mariculture or cage farming has been identified as one of the methods for augmenting the fish catch from the sea.

Cage culture has been originated in Southeast Asian countries and now it is a major culture activity all over the world. Mariculture in cages began in Japan in the 1950s but developed largely as a result of the salmon farming industry in northern Europe and North America during the past two decades. Raising fish in floating cages, set up in sea, a lake or other body of water can be a simple and inexpensive alternative to raising fish in ponds (Beveridge, 1987). The cages are generally constructed of a rigid material than simple fish netting. Cage culture allows holding of fish, with free exchange of water between the water body and the fish. Thus, raising fish in cages allows an aquafarmer to utilize existing water resources that may have other uses also. For example, fish cages may be constructed in lakes and estuaries where there are active natural fisheries or used as a waterway for boat transportation.

The advantages of farming fish in cages

- Ownership of the entire water body may not be necessary, thereby reducing land costs. However, permits from governmental agency overseeing the use of common water bodies may be necessary.
- There are relatively little investment costs in fabrication of cages, nets and harvest.

- Harvesting is simple.
- Observing fish behaviour and monitoring fish health is simplified.
- It is possible to use the water body in other ways also.

Disadvantages of cage farming

Disadvantages of the production of fish in cages are mostly related to greater management effort due to large numbers of fish confined in a relatively small space. The following are some specific disadvantages of cage farming:

- The fish must be fed with nutritious diet, since the fish cannot rely on the natural productivity of the water body for their diet and density is also high in cages.
- Due to the higher stocking of fish and heavy inputs of feeds into the cages, there is the possibility of localized hypoxia or low oxygen stress, if the water movement is restricted. Enclosed fish cannot freely swim to areas of better water quality as they do in ponds. Similarly sudden occurrence of harmful algal blooms and sudden discharges can cause mortality of the stocked fish
- The incidence of diseased fish may be high, if conditions are not favourable and diseases that appear can spread rapidly.
- Vandalism and poaching are often problems, particularly if the cages are placed in common-use water bodies.

Cage farming in India

As an R & D activity, the first open sea cage culture was conceptualized in India during 2005 and the first sea cage was launched in Bay of Bengal off Visakhapatnam coast during May 2007. Further modifications in design have been resulted in the second version of marine cage involving marine engineering and naval diving experts. With a low stocking density, the trial was successfully completed in April 2008. Further, the third indigenous version of the sea cage was also experimented with more design modifications. The first to third versions were 15 m dia HDPE cages. For easy maneuvering and cost effectiveness in terms of reduced labour, the size of the HDPE cages were modified to 6 m in the fourth version. In a demonstration trial, these types of cages have been found to be successful in many maritime states along the Indian coast. Latest version of open sea cage is a cost-effective GI cage designed for low investment farming operations.

Site selection

Different criteria must be addressed before site selection for cage culture. The first is primarily concerned with the water quality parameters like salinity, pH, dissolved oxygen, pollution, algal blooms, water currents, tides etc. that determine whether the technology is feasible for the site and species to be farmed there. Other criteria that must be considered while selecting site for cage farming are the depth, substrate, access, proximity to hatcheries and fishing harbour, security, economic, social and market considerations. India has a coastline of 8129 km, of which at least 0.5 to 1.0 per cent can be made available for mariculture in the future and cage farming has been evaluated as the major technology for future mariculture in the country.

Cage components

Cage components usually consist of a frame, netting, floats, and mooring components. Cages for fish culture have been constructed from a variety of materials. The basic cage materials must be strong, durable, and non-toxic and the cage must retain the fish while maintaining maximum circulation of water to bring oxygen to the fish and to remove wastes. The most successful floating cages being used in India are indigenous ones, which are made of High density polyethylene (HDPE) and galvanized iron (GI). For farming fishes circular (6m to 10 m) or square (4 m x 4 m) cages are being used in Indian waters depending on the site. GI frames of cages should be coated with water-resistant epoxy paint to retard corrosion, especially when used in seawater or brackishwater.

Netting materials for cages are most often knotted or knotless fishing nets made of nylon or HDPE. Braided and twisted HDPE nets can be used for grow-out purpose, which would last for two or more crop seasons. Nylon net can be used economically, but since it is light weight, to hold the shape intact more weight has to be loaded in the ballast pipe. Sapphire is also good because of its high breaking strength compared to HDPE and nylon. The depth of net ranging from 2 to 4 m for fingerlings and 3 to 6 m for grow-out cages are ideal. The mesh sizes vary from 2 mm (for hapa nets) to 40 mm for grow-out nets depending on the size of the fishes. The mesh should allow good water flow, and as a general rule it is wise to use the largest mesh possible without allowing the fish to escape. Several nets of different mesh sizes have to be used as the fish grow. Also, as part of regular management, the nets should be periodically checked for fouling. This is especially critical if the cages are placed in highly productive estuaries or in marine waters and in places where molluscan attachment is possible. Most cages have protection nets to restrict predators from reaching the stocked fish. Cage flotation can be provided in a number of ways. Styrofoam barrels, PVC floats and painted metal drums have been used as flotation devices.

Mooring

Mooring lines are an important feature of any floating cage. Mooring line scope is an important consideration, especially in relatively deep water or in water bodies that are subject to wind and waves during storms. Mooring scope is the ratio of horizontal line run to the depth of the water. In single point mooring in the sea, the mooring scope should be three to four times of the depth of the water. The mooring lines are typically made of SS, SS alloys or MS of 10-12 mm diameter and usually adequate to hold the cage in place. For additional support for the cage in the sea 22 mm PP or SS ropes can be used. Anchors or dead weight for sea cages can consist of metal boat anchors, concrete blocks, rocks, or any other heavy material. If cages are put in small open backwaters or lakes, a mooring line of 2:1 (length: depth) may be all that is required to keep the cages in place. If in doubt, more mooring line scope is always better than less even though the cost for materials may be a little higher.

Properly locating cages or net pens is often critical for success. The two main factors influencing the location of cages are access for maintenance and harvest and water quality considerations. To maximize water flow, in a river or estuary, the cages might be placed in an area that is in a gentle current or is well flushed tidally. Cages are best placed in water depths in excess of 3 meters with a minimum of 0.5 m clearance between the bottom of the cage and the bottom of the water body and away from areas with frequent human activity. To minimize the likelihood of hypoxia or low oxygen around the cages, there should be a buffer zone between cages 4 meters or wider.

Species and Grow-out in cages

In general, most fish that are suitable for culture in ponds are suitable for culture in floating fish cages. The selection of species for cage culture should be based on a number of biological criteria like omnivore or carnivore, hardiness, fast growing, efficient food conversion ability, availability of eggs and juveniles, and disease resistance. Economic marketability and demand are also taken into consideration. Fish that have been successfully reared in floating cages include Asian sea bass, cobia, pompano, orange spotted grouper, snappers, giant trevally, grey mullet, pearl spot, milk fish and tilapia. Obtaining fry and fingerlings for some species is often by collection from the wild, but hatchery stock is available for others.

For fishes like grey mullet, pearl spot, milk fish and tilapia that feed low on the food chain and are tolerant of crowding, typical stocking rates in cages are between 50 and 70 fingerlings per cubic meter of water, depending on fish size and the amount of water flow through the site. For others the stocking rate is 30- 40 fish per cubic metre. For cobia, the preferred stocking is 7-10 fish per cubic metre, because of its fast growth in a year. The fishes can be thinned as they grow to larger sizes, if stocked at higher rates. Typical stocking densities for cobia, groupers, sea bass, and snappers range from 8 to 32 fingerlings/m^3, which is considerably lower than fish feeding lower on the food chain, indicating a greater sensitivity to crowding.

Most cage culture of fishes focuses on high valued species (Asian sea bass, pearl spot, giant trevally, grouper, snapper, cobia etc.) for which hatchery produced seeds are available; those are tolerant of crowding and can be fed on trash fish or inexpensive formulated diets. The culture of these fish, mostly carnivores, that have a very high market value requires considerable attention to feeding a very high-protein diet consisting of fresh “trash fish” or freshly prepared moist pelleted diets with a high percentage of fish or other animal protein.

Harvest

Fishes cultured in cages can attain marketable weight in six to eight months. Harvest in cages is easy compared to that in ponds. Cages can be towed to a convenient place and harvest can be carried out. Based on demand, partial or full harvest can be done in cage farms.

Cage management

Cage culture management must result in optimizing production at minimum cost. The management should be such that the cultured fish should grow at the expected rate with respect to feeding rate and stocking density, minimize losses due to disease and predators, monitor environmental parameters and maintain efficiency of the technical facilities (Chua, 1982). Physical maintenance of cage structures is also of vital importance. The frame and nettings must be regularly inspected. Necessary repairs and adjustments to anchor ropes and net-cages should be carried out without any delay. Exchange of net should be considered on fouling of the nets or fishes outgrowing the mesh size. Net change ensures good water exchange, removal of fecal matter and uneaten feed and result in improved growth of the stock. Herbivorous fishes such as rabbit fish, pearl spot and scat can be used to control biofoulers (Beveridge, 1987) in cages.

Success of cage farming in India

For future success of cage farming technology in India, measures to be taken by the concerned include many factors. Appropriate leasing policies conferring the rights to farmers, groups, SHGs or fishermen cooperatives to undertake sea cage farming has to be in place at the earliest. Once cage farming is popularized and spread across the country, adequate and regular supply of good quality seed of the farmed species from hatcheries, technical support, suitable financial assistance and insurance support for the crop have to be assured.

Conclusion

The challenge of filling the gap between growing demand and capture fisheries supply, mariculture production has to satisfy the optimistic expectations. Significant progress is being made by the Government of India through different institutions and organizations under its control. The economic analysis of the cage farming has been proved good with the net operating income and net income at an encouraging rate for a crop period of six to eight months. Cage farming is a viable alternative for fishing and economically and financially feasible mariculture operation for different levels of stake holders. It can impart empowerment of weaker sections of the society, youth, women, and can develop skill in different categories of people in different aspects of cage farming. Cage farming can lead to satisfy some objectives of the blue economy concept of Government of India. However, co-operation between government, investors and financial institutions is a prerequisite for achieving a new era of mariculture development in India. The State Fisheries Departments and the organizations like National Fisheries Development Board (NFDB)and National Bank for Agriculture and Rural development (NABARD) can play vital roles in promoting cage culture on a large scale with institutional and financial support.

Ornamental fish culture

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Introduction

Ornamental fishes form an important commercial component of fisheries, providing for aesthetic requirements and as a livelihood option. Little information exists that dates the origin of ornamental fish culture, but it can be assumed that it was developed in China, where the goldfish was cultured traditionally as ornamental fish around 2000 BC. Modern aquarium keeping of fish began in 1805 with the first public display aquarium opened at Regent's Park in England in 1853. The growing interest in aquarium fishes has resulted in steady increase in aquarium fish trade globally. The trade with a turnover of US $ 5 Billion and an annual growth rate of 8% offers a lot of scope for development.

Global market

About 80% of the world's ornamental fishes that are traded come from the freshwater resources, 20% being the marine species whose contribution is increasing with advances in breeding and rearing technology. Presently, only 5% of the marine fish are being bred and 95% collected from the wild. Since most of the freshwater species are bred and cultured, the overall contribution of the cultured species is 90%, only 10% of the fish traded being collected from the wild. An American estimate shows that for every dollar spent on fish, $5-$10 is spent on various accessories. A wide variety of pumps, air stones, filters, heaters, thermostats, assorted electrical gadgets, nets, tubes, buckets, are a prerequisite even for setting a home aquarium.

Types and species

The candidate ornamental fish species should have attractive colour pattern, swimming behaviour, resistance to captivity stress and should be compatible with other species (reef safe). The details regarding commercially important ornamental fish species can be obtained from the following website:

https://www.mpeda.gov.in/MPEDA/production_ornamental_fish_important_species.php#

Ornamental fish breeding

Pre-requisites- Units for farming, rearing, treatment tank; water quality; fish nutrition

Types of culture units:
1. Breeding & Rearing Unit
2. Rearing Units
3. Natural collection & rearing unit
4. Treatment/ isolation tanks- to isolate and treat infected fishes

Water quality parameters

The water quality is by far the single most important factor in the health of your fish, and the more you know, the better job you will do. This article provides a brief overview that is just the bare minimum that aquarium owners should know and understand. Fish obtain their basic necessities from the water in which they live. The most characteristic feature of any aquarium system is therefore the quality of the water it contains. This water must be obtained from some source, pre-treated to make it suitable for the fish, delivered to the fish in sufficient quantities and maintained in good condition. Finally, it must be disposed of. The water supplied to an aquarium is not pure, but contains dissolved and particulate materials, some are necessary for the well-being of the fish and others are harmful. Contamination may occur not only at source or form the animals, but often takes place within the aquarium form the materials used in its construction. The volume of water supplied to an aquarium may at first sight, seem to restrict the number of fish that can be maintained within it. However, it is rarely the quantity of water per unit which limits the carrying capacity. The capacity is usually set by the consumption of dissolved oxygen and the accumulation of toxic metabolic products.

Table 1: Optimal water quality parameters for breeding of selected ornamental fish species

SL. No.	Name of the fish	Water Temperature (°C)	pH	Water hardness (mg/L CaCO3)
Egg layers				
1.	Gold fish	18 - 20	7-7.5	90-200
2.	Koi carp	20 - 22	7- 7.5	70 - 200
3.	Angel	22 – 32 (breeding), 28 – 30 (larval rearing)	6.3 – 8.5	70 - 200
4.	Gourami	24 - 30	6.0 – 7.0	60 - 100
Live bearers				
5.	Sword tail	28-30	6.5 – 7.5	80 - 250
6.	Platy	28-30	6.5 – 7.5	80 - 250
7.	Guppy	28-30	6.5 – 7.5	80 - 250
8.	Molly	28-30	6.5 – 7.5	80 - 250

Compatibility

The compatibility of the species should be ensured before keeping different varieties/ species of fish. Fish compatibility charts (Fig 1, 2) can be utilized for this purpose

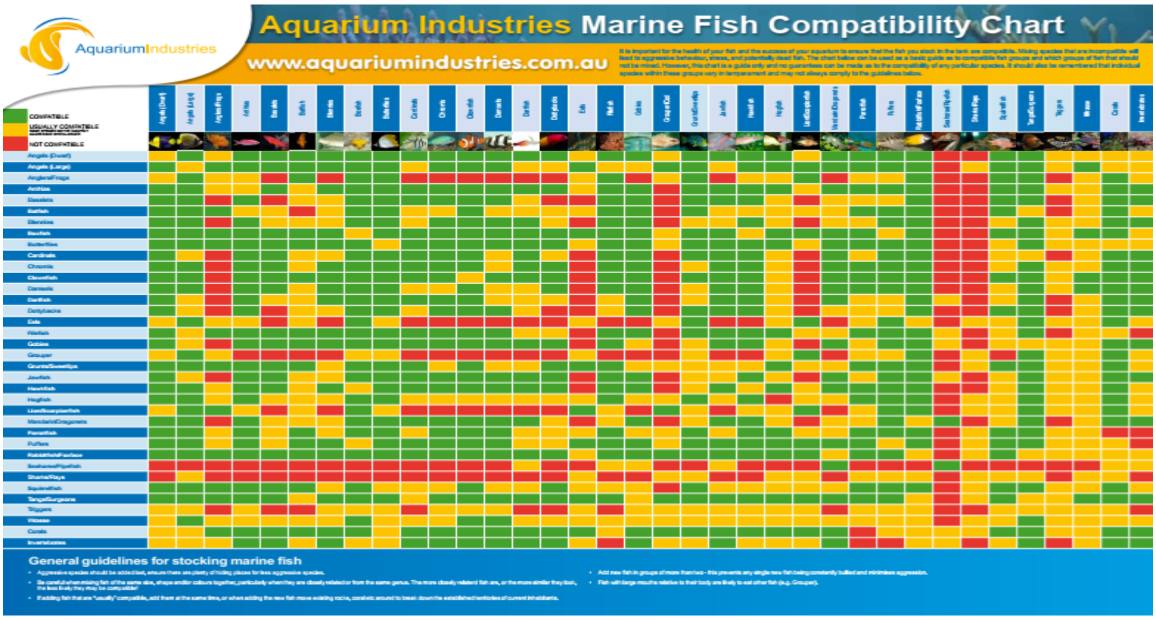

Fig.1 Compatibility chart for marine ornamental fish
(Source: https://www.aquariumindustries.com.au/wp-content/uploads/2015/03/Compatibility-Chart-MARINE.pdf)

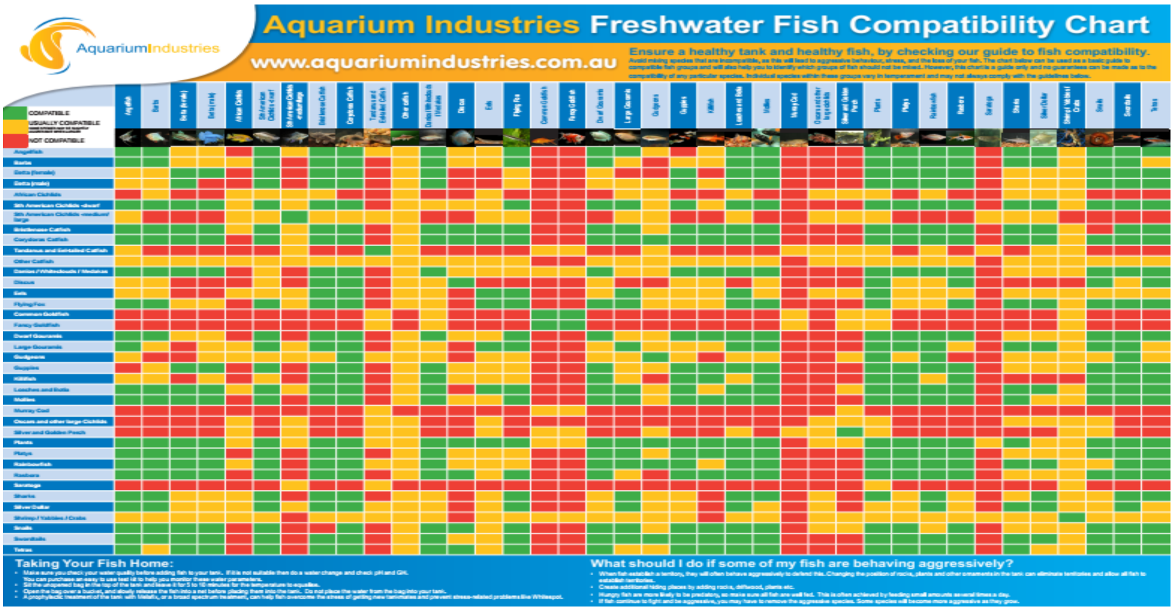

Fig.2 Compatibility chart for freshwater ornamental fish
(Source: https://www.aquariumindustries.com.au/wp- content/uploads/2015/03/Freshwater-Fish-Compatibility-Chart.pdf)

Ornamental Fish Nutrition

Many of the ornamentals lose their natural, bright colouration under captivity that irritates the hobbyists; perhaps the development of proper feeds with additives for pigment maintenance/restoration is necessary. The nutrient requirements of selected fish should be understood and appropriate balanced feeds should be provided, since their requirements vary widely with fish species.

Diseases and treatments

Ornamental fishes are very prone to diseases due to their captive habitat. Fish suffer ill health from a variety of reasons. The best way to prevent the disease is to maintain a healthy environment in the aquarium for all times to avoid the stress which is one of the most important factors for many fish diseases. Proper water quality is required to be maintained in the aquarium for good health of the fish Healthy fishes generally have clean body, erect fins, bright body colour, bright eyed, faster movement if frightened and skin and fins are in intact conditions. While unhealthy fishes show irregular swimming movement, jumping, rubbing of the body against any rough substrate, surfacing on water, gasping air, refusal of feed and excessive mucus secretion etc. Abdominal swelling or cyst formation also indicates some internal disorder of fish.

A. Bacterial diseases

(a) Dropsy
Agent: *A. hydrophila*
Symptom: Accumulation of water in the body cavity or in scale pockets; scale become loose; abdomen swollen.
Treatment: Long Bath: $KMnO_4$: 1g/100L for 1 hour.
Prevention: i) Aquarium treatment with $KMnO_4$ @ 1 mg/L, ii) Proper water quality management iii) Proper feeding to reduce the organic load iv) Quarantine measures before introducing the new fish in a tank.
Prevention is same for all diseases mentioned hereafter

(b) Fin and tail rot
Agent: *Pseudomonas sp.*
Symptom: Disintegration of fin and Tail by appearing a white lime on the outer margin of the fin, droppings of fin occur, tail become torn, rays become fragile.
Treatment: Long Bath: Oxytetracycline 3-5mg/L for 2-3 hours.
Long Bath: Sulfonamide: 100mg/lt. 3-4 h.

(c) Skin ulcer disease
Agent: *Psuedomonas aeroginosa*
Symptom: Presence of skin ulcers and hemorrhagic patchy lesions all over the body
Treatment: Long Bath: Oxytetracycline 3-5mg/lt. for 2-3 hours.
Long Bath: Sulfonamide: 100mg/lt. 3-4 h.

(d) Furunculosis
Agent: *Aeromonas salmonicida*
Symptom: Deep ulceration, Open red sores
Treatment: i) Bath treatment with providone iodine @ 25 mg/L single dose or ii) Bath treatment with acriflavin @ 1g/L
iii) Aquarium treatment with methylene blue @ 4 mg/L

(e) Columnaris disease
Agent: *Flexibacter columnaris* and *Cytophaga columnaris*

Symptom: Grayish white patches on head, lips, and fins, Lesions begin at the outer margin of fins and gradually spread towards the body surface, Haemorrhages & ulceration on body surface & muscle

Treatment: i) $KMnO_4$ bath 2 mg/L for 10-15 minutes or ii) $CuSO_4$ bath 33 mg/L for 20 min. iii) Incorporation of oxytetracycline (Terramycin) in the feed @ 100 mg/kg feed at 3% of body weight

B. Fungal diseases

(a) Cotton wool disease

Agent: Saprolegnia and Achyla

Symptom: Affected areas of the skin covered with cotton wool like deposits with grey-white patches, hyphae filamentous extended out into the water.

Treatment: Long Bath: Acriflavine: stock solution 0.001% solution - 10ml of stock soln. added to tank.

(b) Branchiomycosis (Gill rot)

Agent: *Branchiomyces demigrans*

Symptom: Hyphae and mycelium obstruct blood vessels in the gill, Gills lose their normal function and affected fishes surface, gasping for air and ultimately die due to non-availability of oxygen at tissue level.

Treatment: Long Bath: Acriflavine: stock solution 0.001% solution - 10ml of stock soln. added to tank.

C. Parasitic diseases

(a) White spot disease

Agent: *Ichthyophthirius multifiliis*

Symptom: Tiny white nodules or spot on the body, fins and gills covered; can be seen with naked eyes.

Treatment: i) Prolong Bath: Malachit green: 0.05- 0.10mg/l, 10day or

Flush: Mixture of Malachite green 5 mg/L and Formalin 100- 160 mg/L for 1-3hours alternate days

ii) Prolong Bath: Methylene blue: 1- 2drops of 5%solution

(b) Velvet disease

Agent: *Oodinium spp*

Symptom: Dusty appearance of yellow or rust colour on gills and skin.

Treatment: i) Short Bath: NaCl: 1.5-2.5% solution (15 – 25 gm/L)

ii) Long Bath: NaCl: 0.7-1.0% solution

iii) Dip: $CuSO_4$:500ppm for1min.

(c) Argulosis

Agent: Argulus sp.

Symptom: Restless and erratic swimming behaviour, Haemorrhagic areas on the body surface, fins and gills, Severe irritation in the skin, scale loosening

Treatment: i) Dip: DDT 10 mg/L for 30 seconds or ii) Short bath: NaCl 1.5 -2.5 % solution or iii) Short bath: Formalin: 5-10 ppm.

(d) Lernaeosis (Anchor Worm)
Agent: Lernaea sp.
Symptom: Fishes are restless, and swim erratically, heavily infested fishes become very weak, floats on surface, Scales slough off, loss of colour and ulceration
Treatment: i) Potassium permanganate in tank @ 4-5 mg/L or ii) Sodium chloride bath @ 3-5% for 15 minutes or iii) Formalin @ 250 mg/L for 30-60 minutes or iv) Antibiotic tetracycline bath @ 1cap (250 mg)/500 L water in tank.

(e) Whirling disease
Agent: *Myxosoma cerebralis*
Symptom: Rapid tail chasing behavior which develops while trying to feed, whirling movement of the fish; malformation of vertebral column, cranium etc.
Treatment: Difficult to control, remove the sick fish.

(f) Blue slime disease
Agent: *Costia necatrix*
Symptom: Slimy bluish-white appearance of the skin
Treatment: Prolong Bath: M. green :0.15mg/l
Bath: Formalin:160-250mg/lt. For 1h.
Short Bath: NaCl: 1.5-2.5%soln

(g) Trichodiniasis
Agent: *Trichodina spp*
Symptom: Greyish-blue veil like coating over the body surface; colour of the gills turns pale
Treatment: i) Formalin treatment @ 25 mg/L in tank or ii) Bath treatment in 2-5% sodium chloride solution for 7 days or more or iii) Potassium permanganate treatment @ 4-5 mg/L in aquarium or tank and iv) Aquarium or tank treatment with combination of 1 mg/L acriflavine with 2-3% salt and 1.5-2 mg/L potassium permanganate give good result.

Prevention and Therapy of Fish Diseases:

I. Prevention:

A. *Disinfection of tanks/ponds/aquaria*

- Disinfection is of a big importance in prevention and elimination of fish diseases.
- Sun drying fully used for disinfection due to economical convenience. Most of pathogens die after perfect drying when moisture dropped to 10 – 15 %.
- Chemical disinfection another effective way of prevention or suppressing of fish diseases.
- Burnt lime used for disinfection of ponds and reservoirs in the dose of 2.5 – 3 t./ha
- Immediately after fishing out the pond, the disinfection is performed on large ponds where whole-surface bottom disinfection is not possible.

B. *Disinfection of fish culture units and equipment*

- 5% water solution of formaldehyde used for treatment of concrete channels, troughs and other arrangements

- Potassium permanganate (5 g/l), can also employed.

C. *Providing water sources free of pathogens*

- Underground / rain waters are the most suitable water sources free of pathogens
- Never use water from the pond with fish stock (especially for hatcheries and units for early fish fry stages)

D. *Protection from transfer of pathogens*

- Fish with unknown health condition is to be avoided
- Fish should originate from healthy environment
- Stocking of fry not contacted with fish of higher age categories minimizes danger of infection
- Protection from piscivorous birds prevent expansion of fish diseases
- Protective nets to be used
- Where overpopulated numbers to be regulated
- Removal of dead fish prevent further transfer of fish pathogens
- Lower masses of dead fish are to be burnt or buried into deep pits (approx. 2 m) in distance of at least 20 m from pond with the bottom of pit and dead fish covered by burnt lime
- At least 60 – 80 cm of soil must cover content of a pit

E. *Optimization of environmental conditions*

- Keeping oxygen concentration on optimal level
- Protection against water pollution
- Supplementary feed mixtures amount and quality to monitored (the attention should be paid on the quality of individual feed components)
- High stocking density results in stress and makes the spread of diseases easier

Important chemicals and preparations used in the therapeutic baths of fish

a) *Sodium chloride (NaCl)*

- Used for parasite control (earliest stages of the fry to the market size)
- Zinc-coated containers should never be used for NaCl baths.
- Effective in control of species of Cryptobia, Ichthyobodo, Chilodonella, Trichodina and Trichodinella, and less effective in control of Dactylogyrus, Gyrodactylus, Piscicola, Argulus, and fungal diseases

b) Formaldehyde (36–38% aqueous solution)

- Used for parasite control in fish must be a clear solution free of paraformaldehyde sediment (white sediment on the bottom)

c) Malachite green

- Readily soluble in water. Exposure to a therapeutic malachite green bath without prior tolerance test may kill a whole stock
- Every new batch of the chemical must be tested for toxicity to fish and effectiveness of parasite control before it is used for the treatment
- Malachite green is used control of *Ichthyophthirius multifiliis, Cryptobia, Ichthyobodo, Trichodina, Trichodinella, Chilodonella* and for treatment of fish against the fungal diseases

d) Acriflavin (trypaflavin)

- Brown-red crystalline powder soluble in water. Recommended therapeutic concentrations are several times lower than the lethal concentrations to fish so comparatively safe

e) Lysol

- Aqueous solution of cresol with potassium soap. It is used at a concentration of 2 ml per litre in the form of immersion baths (5–15 seconds) to control Argulus and Piscicola

f) Potassium permanganate

- 1 g per litre, 30–45 seconds, short-term baths - 0.1g per litre, 5–10 min; 0.01 g per litre, 60–90 min as well as long-term baths for the control of fungal diseases, parasites (when protozooses occur) and bacterial diseases

g) Antibiotics

- Used to control bacterial diseases of the skin and gills of fish.

h) Metronidazol

- Absorbed via the gills and produces therapeutically effective concentration to kill the parasite Hexamita. Bath is particularly suitable for the treatment of aquarium fishes.

Value addition in ornamental fish

Value addition is a relatively novel arena in ornamental fish industry which improves the aesthetic value and fetches a higher price. The different methods employed for value addition include colour enhancement by specialized feeds, selective breeding, by transgenesis and by painting or dyeing or tattooing.

(i) Colour enhancement

The aesthetic value decides the demand of the fish and therefore the market value of them. Skin coloration is an important factor in this regard. Colour enhancement in fish helps to increase the quality, cost and thus the market value of ornamental fishes. This is possible by administration of pigment enriched eco-friendly feed. Since biosynthesis of carotenoids is absent in fish, adequate levels of dietary carotenoid pigments should be supplemented. Carotenoid pigments give red, orange and yellow coloration. Both synthetic and natural carotenoids can be used for this purpose. Plant-based sources of carotenoids include Alfa-alfa (*Medicago sativa*), Carrot (*Daucus carota*), Marigold flower (*Tagetes erecta*), China rose (*Hibiscus rosa sinensis*), etc. In animal-based sources, astaxanthin is the predominant carotenoid rich in crustacean discards and in dried shrimp meal, red crab meal, krill meal etc. Some of the microalgal sources include *Hematococcus pluvialis, Dunaliella salina, Arthospira maxima*, etc.

(ii) Value addition by transgenesis

The possibility of easier genetic manipulation in fish has led to the success of devolvement of genetically modified organism by transgenesis. It helps to bring out new color variants of ornamental fish to increase the aesthetic value and demand by the market. Value-added aquarium fishes have already been commercialized such as 'Glofish'.

This brand fish is patented and trademarked, available in the market in bright red, green, orange-yellow, blue, and purple fluorescent colors. Recently other variants also developed with six attractive fluorescent color combinations, including Starfire red, cosmic blue, electric green, galactic purple, sunburst orange, and moonrise pink.

(iii) Value addition by Painting or Dyeing or tattooing

Painted fishes are artificially coloured to increase the appeal. The artificial coloring or juicing is possible by injecting the fish with bright fluorescent color dye, dipping the fish into a dye solution, or by feeding the fish with food containing desired dye. This is done to develop exotic colors in fish which is not possible by line breeding. The coloring is not permanent; usually, last for six to nine months. Blueberry or strawberry Oscar which is available in the market is an example of dyed fish. Tattooed fishes with different patterns with different colors are also available in the market. Tattooing is done with a low-intensity laser with a dye. Administration of some of the hormone also showed to increase the coloration in fish.

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Ornamental fish nutrition and feed technology

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Introduction

Ornamental fish nutrition needs to be understood from two angles. One is from the basic or fundamental point of view and another is application of this fundamental knowledge as technologies. The fundamental understanding is in terms on the nutrients which are universally present and applicable. The macro nutrients classified as protein, lipid and carbohydrate determine the cost of the food because the quantity involved is more.

Proteins, the most expensive nutrient in nature is made up of amino acids, which are grouped as essential and non-essential based on their requirement in food and feed. Essential amino acids are those required in food or feed because they cannot be synthesised by animals to meet the total nutritional requirement. Non-essential amino acids are the ones that can be synthesised according to their requirement within the body. Functionally proteins are required for growth which means that its requirement is higher in the early stages of growth ad declines as growth progresses. Apart from this, there are a plethora of functions proteins impart. Immunity, structural integrity, biological catalysis (enzymes) and endocrine etc. are the functions to name a few. This list can be populated.

Lipids are energy rich nutrients and are made up of fatty acids. They are also classified similar to amino acids as essential and non-essential. Essential fatty acid requirements need to be met through feed. In aquatic nutrition, the essentiality unlike terrestrial animals is for highly unsaturated fatty acids (HUFA) or polyunsaturated fatty acids (PUA) which are characterized by carbon chains of more than 20 in number. The essential fatty acids essential in terrestrial animal nutrition, including humans are linoleic and linolenic acid. They have less than 20 carbon atoms. The essential fatty acids for aquatic animals are eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and arachidonic acid (ARA) whose number of carbon atoms and position of double bonds are denoted as 20:5 (n-3), 22:6 (n-3), 20:4 (n-6) respectively, indicating the presence of more than 20 carbon atoms or more in them.

Even though protein is also a source of energy in aquatic animals, they are not storable as lipids. Moreover, lipids approximately contain 2.25 times more energy than proteins or carbohydrates. Other than that, lipids have more biological functions as metabolic regulators, viz., structural component of membranes, storage and transport of metabolic fuel, protective coating on the surface of many organisms and cell surface components concerned in cell recognition.

Carbohydrates are the cheapest source of energy. There is no absolute requirement for this nutrient in aquatic organisms. This is because of synthesis of glucose from non-glucose precursors such as protein and lipid through gluconeogenesis is efficient in aquatic animals.

Now it is well known that their level of inclusion is limited in aquatic feeds compared to feeds for terrestrial livestock livestock like poultry. Fibre is not digested by ornamental fish and a level of inclusion exceeding four percent of the feed could be detriemental.

Vitamins are micronutrients. They are classified as fat soluble and water soluble depending upon their solubility. Fat being storable, fat soluble vitamins are also storable. Contrarily, water soluble vitamins are not storable. Day-to-day requirements are met through food and excess, if any, is excreted. In aquatic animals, occurrence of vitamin deficiencies are rare because, whenever the animals consumes fat, fat soluble vitamins A, D, E and K are also consumed and stored. Water soluble vitamins, mainly belonging to the B-complex group becomes available through microbial synthesis from the resident microbial population in water. The situation being so, the likelihood of a vitamin deficiency is only for vitamin C (Ascorbic acid). Primates, guinea pigs, birds and many fishes cannot synthesize vitamin C from glucose because of the absence of the enzyme L-gluconolactone oxidase.

Deficiencies due to vitamin C are (1) curvature of spinal column is prominent. (2) Scoliosis – lateral curvature, lordosis – vertical curvature of the spine. (3) External and internal hemorrhages. (4) Erosion of fins and depigmented vertical bands around mid-section. (5) Distorted gill filament cartilage. (6) Reduced rate of wound healing. (7) Deformed head and gill opercula.

Forms of vitamin Care. Ascorbyl monophosphate Ca (AAMP), Ascorbyl polyphosphate (AAPP) Stay C. Retention of 90% in stored feeds and 85% in semi moist feeds is achievable with these forms. Coated forms of Vitamin C were unstable (50% after extrusion). Vitamin C coated with cellulose derivatives, silicone coated ascorbic acid and proteins are also available. (Ref: Gadient and Fenster, 1994, Aquaculture 124, 207-211)

Mineral nutrition. Out of 90 naturally occurring inorganic elements, 29 are considered essential in all animals including fish. The dietary requirement of macro-minerals established in fish is for Ca, P, Mg, Chloride, Na and K and micro-mineral requirement of Cu, Co, Cr, Fe, I, Mn, Mo, Se and Zn for one or more fish species (NRC 2011). Age, sex, weight gain and body composition are the biological factors based on which the response criteria for determining mineral requirements should be assessed. In fish the aquatic environment complicates the matter further with water mineral concentration, salinity and temperature of the rearing medium interacting with the biological factors like, life stage (age), sex, trophic level, feeding status of the fish and dietary factors like, diet composition, bioavailability and nutrient interactions.

Additives and supplements. Apart from the above, material used to nutritionally fortify, complement and supplement the feeds are known as additives. There are several of them. The best and most common examples are vitamin and mineral supplements. Several other examples can be cited depending upon the functionality it can impart to the feeds.

Colour is the most important criteria dictating the economic value of ornamental fish. In order to maintain its colour the additives shown in the Table 1 below at recommended levels impart the colour functionality of the feed.

Table 1. Recommended levels to impart the colour functionality of the feed

Colour enhancing ingredient	Fish in which evaluated	Recommended level
Astaxanthin	Blood parrot (*Cichlasoma synspilum*♀×*Cichlasoma citrinellum*♂)	400 mg kg^{-1} Sodium taurocholate + 4 g kg^{-1} Astaxanthin
Astaxanthin	Red dwarf gourami, *Colisa lalia*	
Astaxanthin Canthaxanthin Paprika oleoresin	Gold fish (*Carassius auratus*)	astaxanthin 75 mg/kg, canthaxanthin 75 mg/kg and paparika oleoresin 180 mg/kg
Carophyll Red* Spirulina	Japanese ornamental carp (*Showa koi*) (*Cyprinus carpio* L.)	Carophyll Red1.5 g kg^{-1} Spirulina 75 g kg^{-1}
China rose (*Hibiscus rosasinensis*)	Gold fish (*Carassius auratus*)	petal 5 mg kg^{-1}
Marigold petal meal	Sword tail (*Xiphophorus helleri*)	Petal meal 15 g 100 g^{-1}
Lutein β -carotene	Koi (*Cyprinus scarpio*)	Lutein 50 mg kg^{-1} Lutein and β-carotene at 25 : 25 mg kg^{-1}

*Carophyll - CAROPHYLL® range of carotenoid additives from www.dsm.com

In general, nutrition and UV-light are primary factors of proximate morphological colour changes beyond the control of the organism. Background light conditions and social interactions are secondary proximate factors acting through the control of the organism. The ultimate morphological skin colour changes are due to alterations in skin structure and pigment deposition during metamorphosis in different species which are reviewed in detail by Leclercq et al. (2010).

Classification of feed stuffs. Feed stuffs can be classified basically in two. Feed stuffs of plant origin and feeds stuffs of animal/ aquatic /marine origin. Feeds stuff of plant origin are cereals, pulses and several agro-industrial by products generated in their processing. There are several non-conventional feed resources (NCFR) also. It will not be out of place to mention here that soybean meal is the most popular proteinaceous feed ingredient used in aquafeeds.

The most popular feed stuff of animal origin in aquatic animal nutrition is fishmeal. Fish oil follows. Others are, shrimp meal, squid meal, other molluscan meals. Rendered animal protein is another group of feed material immensely popular in replacing fish meal because there is a global effort to reduce the use of fish meal and fish oil in aquatic feeds.
The details of feed stuffs is now available through www.feedipedia.org which a website maintained by several countries. Feedipedia is a joint project of INRA (Institut National de la RechercheAgronomique, French National Institute for Agricultural Research), CIRAD (Centre de Coopération Internationale enRechercheAgronomique pour le Développement,

French Agricultural Research Center for International Development, AFZ (Association Française de Zootechnie, French Association for Animal Production) and FAO (Food and Agriculture Organization of the United Nations) – from the website accessed on 10-10-2019.

Nutritional requirements is synonymous to recommended dietary allowances (RDA) in human nutrition. Knowledge of the nutritional requirements about the fish or shrimp which is cultured is essential in formulation of feeds. Feed formulation in simple terms means blending of a variety of feed material based on the nutritional requirements in such a way that, the blend meets the nutritional requirements. Thus, knowledge of nutritional requirements is one of the pre-requisites to feed formulation. Some of the requirements available are tabled (Table 2) below.

Table 2: Protein requirements of some ornamental fishes

Common Name	Scientific Name	Dietary protein requirement (%)
Guppy	*Poecilia reticulata*	30-40
Gold fish	*Carrasius auratus*	29-53
Gold fish	*Carrasius auratus*	40
Gold fish	*Carrasius auratus*	40-45
Tinfoil barb	*Barbodes altus*	41.7
Discus	*Symphosidon aquifasciata*	44.9 – 50.1
Redhead cichlid	*Cichlasoma synspilum*	40.81
Dwarf gourami	*Colisa lalia*	25 - 45
Sword tail	*Xiphophorus helleri*	45
Angel fish	*Pterophyllum scalare*	45
Clown fish	*Amphiprion sebae*	45
Striped damsel	*Dascyllus aruanus*	38

After gaining a fair understanding of the feed stuffs and nutritional requirements the next step would be to formulate feeds. An online resource of both nutritional requirements of fish and feed ingredients database is available at www.iaffd.com. However, the nutritional requirement of ornamental fish is limited to gourami.

Feed formulation is a technique, basically mathematical, to arrive at the precise quantity/ies of the feed material to be mixed to arrive at the desired nutritional composition in the feed. This can be a simple mixture of two ingredients such as proteinaceous one (groundnut oil cake) with an energy rich (wheat flour) one. As the number of ingredients used and the nutrient specifications increase, the complexities in calculations also increase. Thus, calculations not possible on paper have to be done with calculators and computers. Now, feed formulation software packages are available for commercial purposes at a price and freely also to some extent. The simplest one worth mentioning here is the `Solver' which is a linear programming `add-in' in Microsoft Excel which can be used for feed formulation.

Feed technology deals with the processes and the machines used to produce feed. Its evolution was demand driven. When feed material broadcasted as a mash was found to go waste, mechanisms to make it water stable were devised. Thus, the mash was converted into a dough ball and fed minimising feed wastage. Till this stage, they were farm level improvisations. Pelletization is the first step in mechanization of feed production. By pelleting the feed material with the help of binder for water stability, technically known as hydrostability was improved. Pelletization initially was a cold process. Later on, cooking using steam was incorporated to obtain a cooked pellet which was nutritionally superior to a cold pellet.

As more and more species of fish and shrimp were cultured along with the growth of aquaculture worldwide, the aforementioned pelletisation technology was inadequate, because pelletization both cold and cooked could produce only sinking pellets which were suitable to feed only shrimp. Floating and slow sinking feeds were required to most of the freshwater carps, tilapia and marine fish. Besides this, feed consumption could be monitored visually and feed management was more cost-effective. Extrusion, the state-of-the-art in fish feed production became the most widely adopted technology for production aquatic feeds with different physical properties like floating and slow-sinking.

Extruders are of two types. They are, single screw extruders and twin-screw extruders. Single screw extruders are used to produce feed of more than 1.5 mm in pellet diameter for application in grow-out systems and twin-screw extruders are used to produce feeds of less than 1.5 mm known as micro-feeds. Micro feeds are used for feeding larval fish, ornamental fish and fish in their nursery phase.

Extrusion as technology was developed for production of various industrial products. It then found application in the ready to eat (RTE) foods and now used for aquatic feed production.

Feeding management. This is one of the neglected aspects in aquaculture nutrition. What to feed, how much to feed, how often are the questions to be answered here for cost-effectiveness and resource efficiency. In general, as thumb rule, it is said that any animal including the human being consumes 2-3% of their body weight as dry matter (excluding water) as food or feed. Bearing this in mind, feed should be made available to the cultured animals. Estimation of the standing stock biomass becomes crucial here. This involves observation and standardization of protocols to be followed. Feeding frequency is another aspect because, ration means feed required by an animal over a period of 24 hours. How this quantity of feed is chunked and fed. During earlier stages of growth it not unnatural that the fish and shrimp may consume up to 15% of the body weight as dry matter. Optimising all these aspects skilfully is extremely important for making feeding cost-effective and scientific.

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Fish Nutrition and Feed Technology

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Introduction

Fish is poikilothermic animal, extrinsic and intrinsic factor play an important role in the fish nutrition. Aquaculture sector is a major industry in many countries, and it will continue to grow as the demand for fisheries products increases, mainly due to the health beneficial effects. The fish is perishable commodity; it is known for its well-balanced nutrient composition. Good nutrition is of paramount importance for economic production of healthy and high quality product. In aqua farming, nutrition plays a key role mainly due to cost of feed which represents about 40-60% of the production costs. Fish nutrition research has advanced in recent years with the development of commercial diets that promote fish growth and health. Development of species-specific feed formulations support the aquaculture industry as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and seafood products. The in the field of aquaculture, growth of the fish / shell is of prime importance, the growth is affected either due to less intake of feed or under-utilization of feeds. Undernourished animal cannot maintain its health and be productive, regardless of the quality of its environment. The production of nutritionally balanced feed for fish requires efforts in research, quality control, and biological evaluation. Faulty nutrition obviously impairs fish productivity and result in a deterioration of health until recognizable diseases ensues. At present, information on fish feed is based on nutritional and diet development work carried out on temperate fish species of fish in advanced countries. Hence, the focus of the fish nutritionist should be on preparation of economically viable fish feed by utilizing locally available inexpensive fish feed ingredients.

Major Nutrient Groups

Energy-yielding Nutrients

Proteins, carbohydrates and lipids are distinct nutrient groups that the body metabolizes to produce the energy it needs for numerous physiological processes and physical activities. There is considerable variation in the ability of fish species to use the energy-yielding nutrients. This variation is associated with their natural feeding habits, which are classified as herbivorous, omnivorous or carnivorous. Thus, there is a relationship between natural feeding habits and dietary protein requirements. Herbivorous and omnivorous species require less dietary protein than some carnivorous species (NRC, 1993). Carnivorous species are very efficient at using dietary protein and lipid for energy but less efficient at using dietary carbohydrates. The efficient use of protein for energy is largely attributed to the way in which ammonia from deaminated protein is excreted via the gills with limited energy expenditure. The foods carnivorous species eat contain little carbohydrate, so they use this nutrient less efficiently.

In terms of energy density, proteins, carbohydrates and lipids have average caloric values of 5.65, 4.15 and 9.45 kilocalories per gram (kcal/g), respectively. These gross energy values are obtained by fully oxidizing the nutrients and measuring their heat of combustion in a calorimeter, with the energy released expressed as kcal/g or kiloJoule (kJ)/g (1 kcal = 4.185 kJ). Not all of the gross energy from nutrients is utilized because some of it is not digested and absorbed for further metabolism. Thus, the amount of digestible energy (DE) provided by a feed or feed ingredient is commonly expressed as a percentage of gross energy. A smaller fraction of the DE absorbed by the fish will be lost in metabolic wastes, including urinary and gill excretions, but these losses are relatively minor compared to the dietary energy excreted in the feces. Because it is hard to collect fish urinary and gill excretions, it is much more difficult to determine metabolizable energy (ME) values for aquatic organisms than for terrestrial animals. Therefore, ME values are not commonly reported for fish feeds or ingredients.

Proteins and amino acids. Proteins consist of various amino acids, the composition of which gives individual proteins their unique characteristics. Many of the biochemicals required for normal bodily functions are proteins, such as enzymes, hormones and immunoglobulins. Fish, like other animals, synthesize body proteins from amino acids in the diet and from some other sources. Amino acids that must be provided in the diet are called “essential” or “indispensable” amino acids. Quantitative dietary requirements for the ten indispensable amino acids have been determined for several fish species (Wilson, 2002). There are also ten “nonessential” or “dispensable” amino acids that the body can synthesize from other sources. These dispensable amino acids also may be found in dietary protein and used for synthesizing body proteins. Table 1 lists indispensable and dispensable amino acids. A deficiency of any one of the indispensable amino acids can limit protein synthesis, which often causes reduced weight gain and other specific symptoms.

Table 1: Two Major Classes of Amino Acids.

Indispensable (essential)	Dispensable (nonessential)
Arginine	Alanine
Histidine	Asparagine
Isoleucine	Aspartic acid
Leucine	Cystine
Lysine	Glutamic acid
Methionine	Glutamine
Phenylalanine	Glycine
Threonine	Proline
Tryptophan	Serine
Valine	Tyrosine

Meeting a fish’s minimum dietary requirement for protein, or a balanced mixture of amino acids, is critical for adequate growth and health. However, providing excessive levels of dietary protein is both economically and environmentally unsound because protein is the most expensive dietary component and excess protein increases the excretion of nitrogenous waste. Most herbivorous and omnivorous fish evaluated to date require a diet with 25 to 35 percent crude protein; carnivorous species may require 40 to 50 percent crude protein (Wilson, 2002). Commercial feeds are carefully formulated to ensure that protein and amino acid requirements are met.

Carbohydrates:

Carbohydrates are the least expensive form of dietary energy for man and domestic animals, but their utilization by fish varies and remains somewhat obscure. Warm water fish are able to utilize much higher levels of dietary carbohydrates coldwater or marine fish (Wilson, 1994). Fish do not have a specific dietary requirement for carbohydrates, but including these compounds in diets is an inexpensive source of energy. The ability of fish to utilize dietary carbohydrate for energy varies considerably; many carnivorous species use it less efficiently than do herbivorous and omnivorous species (Wilson, 1994). Some carbohydrate is deposited in the form of glycogen in tissues such as liver and muscle, where it is a ready source of energy. Some dietary carbohydrate is converted to lipid and deposited in the body for energy. The enzymes for the major carbohydrate metabolic pathways, such as glycolysis, tricarboxylic acid cycle, pentose phosphate shunt, gluconeogenesis, and glycogen synthesis, have been demonstrated (Shimeno, 1974; Cowey and Walton, 1989). The optimal requirement of dietary level of digestible carbohydrate varies among species as well within the species. In general, less than 20%digestible carbohydrate appears optimal for marine or cold water fish.

Carbohydrates of various size (carbon chain length) and complexity (one to several units bonded together) are synthesized by plants via photosynthesis. Cellulose and other fibrous carbohydrates are found in the structural components of plants and are indigestible to monogastric (simple-stomach) animals, including fish. In fact, the amount of crude fiber in fish feeds is usually less than 7 percent of the diet to limit the amount of undigested material entering the culture system.

Soluble carbohydrates such as starch are primary energy reserves found in seeds, tubers and other plant structures. Animal tissues such as liver and muscle contain small concentrations of soluble carbohydrate in the form of glycogen, which is structurally similar to starch. This glycogen reserve can be rapidly mobilized when the body needs glucose. Prepared feeds for carnivorous fish usually contain less than 20 percent soluble carbohydrate, while feeds for omnivorous species usually contain 25 to 45 percent. In addition to being a source of energy, soluble carbohydrate in fish feed also gives pellets integrity and stability and makes them less dense.

Lipids. This nutrient group consists of several different compounds. Neutral lipids (fats and oils), in the form of triglycerides, provide a concentrated source of energy for aquatic species. Dietary lipid also supplies essential fatty acids that cannot be synthesized by the organism (Sargent et al., 1999). Fatty acids of the linoleic acid (n-3) family are generally more essential to fish than those of the linoleic acid (n-6) family. Many freshwater fish can elongate and desaturate 18-carbon linolenic acid with one double bond to longer chains (20 and 22 carbons) of more highly unsaturated fatty acids (HUFAs) with five or six double bonds. In contrast, most marine fish must have HUFA in the diet.

In the body, HUFAs are components of cell membranes (in the form of phosphoglycerides, or phospholipids), especially in neural tissues of the brain and eye. They also serve as precursors of steroid hormones and the highly active eicosanoids produced from 20-carbon HUFAs (Sargent et al., 1995). Eicosanoid compounds include cyclic molecules such as prostaglandins, prostacyclins and thromboxanes produced by the action of cyclo-oxygenase, as well as linear compounds such as leukotrienes and lipoxins initially formed by lipoxygenase enzymes. Eicosanoids are responsible for blood clotting, immunological and inflammatory responses, renal function, cardiovascular tone, neural function, and other functions. A diet deficient in essential fatty acids reduces weight gain, but usually after an extended period. This is due to mobilization of essential fatty acids from endogenous tissue lipids.

Micronutrients

Minerals

This nutrient group consists of inorganic elements the body requires for various purposes. Fish require the same minerals as terrestrial animals for tissue formation, osmoregulation and other metabolic functions (Lall, 2002). However, dissolved minerals in the water may satisfy some of the metabolic requirements of fish.

Minerals are typically classified as either macro- or microminerals, based on the quantities required in the diet and stored in the body. Macrominerals are calcium, phosphorus, magnesium, chloride, sodium, potassium and sulfur. Dietary deficiencies of most macrominerals have been difficult to produce in fish because of the uptake of waterborne ions by the gills. However, it is known that phosphorus is the most critical macromineral in fish diets because there is little phosphorus in water. Because excreted phosphorus influences the eutrophication of water, much research has been focused on phosphorus nutrition with the aim of minimizing phosphorus excretion. Phosphorus is a major constituent of hard tissues such as bone and scales and is also present in various biochemicals. Impaired growth and feed efficiency, as well as reduced tissue mineralization and impaired skeletal formation in juvenile fish, are common symptoms when fish have diets deficient in phosphorus (Lall, 2002).

Chloride, sodium and potassium are important electrolytes involved in osmoregulation and the acid–base balance in the body (Lall, 2002). These minerals are usually abundant in water and practical feedstuffs. Magnesium is involved in intra- and extracellular homeostasis and in cellular respiration. It also is abundant in most feedstuffs.

The microminerals (also known as trace minerals) include cobalt, chromium, copper, iodine, iron, manganese, selenium and zinc. Impaired growth and poor feed efficiency are not readily induced with micromineral deficiencies, but may occur after an extended period of feeding deficient diets (Lall, 2002). The trace minerals and their metabolic functions in fish are shown in Table 2. The quantitative dietary requirements for some fish species have been established (Lall, 2002).Copper, iron, manganese, selenium and zinc are the most important to supplement in diets because practical feedstuffs contain low levels of these microminerals and because interactions with other dietary components may reduce their bioavailability. Although it is not usually necessary to supplement practical diets with other microminerals, an inexpensive trace mineral premix can be added to nutritionally complete diets to ensure an adequate trace mineral content.

Table 2: Trace Minerals and some of their Prominent Functions.

Trace mineral	Function
Copper	metalloenzymes
Cobalt	vitamin B12
Chromium	carbohydrate metabolism
Iodine	thyroid hormones
Iron	hemoglobin
Manganese	organic matrix of bone
Molybdenum	xanthine oxidase
Selenium	glutathione peroxidase
Zinc	metalloenzymes

Vitamins

Fifteen vitamins are essential for terrestrial animals and for several fish species that have been examined to date (Halver, 2002) (Table 3). Vitamins are organic compounds required in relatively small concentrations to support specific structural or metabolic functions. Vitamins are divided into two groups based on solubility.

Fat-soluble vitamins include vitamin A (retinol), vitamin D (cholecalciferol), vitamin E (alpha-tocopherol) and vitamin K. These fat-soluble vitamins are metabolized and deposited in association with body lipids, so fish can go for long periods without having these vitamins in the diet before they show signs of deficiency.

Water-soluble vitamins include ascorbic acid (vitamin C), biotin, choline, folic acid, inositol, niacin, pantothenic acid, pyridoxine, riboflavin, thiamin and vitamin B12. They are not stored in appreciable amounts in the body, so signs of deficiency usually appear within weeks in young, rapidly growing fish. Most of these water-soluble vitamins are components of coenzymes that have specific metabolic functions. Detailed information about the functions of these vitamins and the amounts fish need have been established for many cultured fish species (Halver, 2002).

Vitamin premixes are now available to add to prepared diets so that fish receive adequate levels of each vitamin independent of levels in dietary ingredients. This gives producers a margin of safety for losses associated with processing and storage. The stability of vitamins during feed manufacture and storage has been improved over the years with protective coatings and/or chemical modifications. This is particularly evident in the development of various stabilized forms of the very labile ascorbic acid (Halver, 2002). Therefore, vitamin deficiencies are rarely observed in commercial production.

Table 3: Vitamins and some of their Major Functions as Established in Fish

Fat-soluble vitamins	Function
vitamin A, retinol	epithelial tissue maintenance, vision
vitamin D, cholecalciferol	bone calcification, parathyroid hormone
vitamin E, tocopherol	biological antioxidant
vitamin K	blood clotting
Water-soluble vitamins	
thiamin, B_1	carbohydrate metabolism
riboflavin, B_2	hydrogen transfer
pyridoxine, B_6	protein metabolism
pantothenic acid	lipid & carbohydrate metabolism
niacin	hydrogen transfer
biotin	carboxylation & decarboxylation
choline	lipotrophic factor, component of cell membranes
folic acid	single-carbon metabolism
cyanocobalamin, B_{12}	red blood cell formation
ascorbic acid, vitamin C	blood clotting, collagen synthesis
inositol	component of cell membranes

What to know about fish or shrimp to be able to increase production through proper feeding:

- Biology of the species to be cultured.
- Nutrient requirements.
- Feeding habits of the fish, what food it prefers, how it takes in food, what time of the day it eats, what parts of the body are involved in the ingestion of food.
- Proper pond management.

Ways of developing feeds

- Imitation of natural diets which is possible when stocking density is low.
- Trial and error with existing cheap diets. This is attractive because development costs may be less.
- Controlled feeding with nutritionally defined diets. This method appears costly, time-consuming, and likely to lead to many problems. However, it is the best approach. Experience with other animals such as chicken and swine has shown that formulating cheap reliable feed is not possible until the nutrient requirements of the species and the interaction of these nutrients are known for the various life stages.

To achieve increased production through proper feeding, one has to:

- Study nutritional requirements
- Understand the digestive processes
- Evaluate feedstuffs
- Develop feeds
- Determine good feeding techniques or feeding management schemes.

Some basic concepts in nutrition

- Adequate nutrition is essential to good health.
- Nutrients in the body are in dynamic equilibrium, hence, a deficiency or over supply of one will affect the others.
- Dietary intake and nutrient needs should be known.
- Nutrient needs vary because of factors such as age, physical activity, body size, state of health, physiological processes like growth, reproduction, and pathological disorders.
- Nutrient content of food varies and diet preparations should aim to preserve the nutrient in the natural food.
- Nutrient requirements are known for some nutrients only and may differ from species to species, thus, requirements and allowances will have to be revised as new knowledge is obtained.
- A variety of feedstuffs is better than one source.
- The study of nutrition is interrelated with allied arts and sciences.
- Nutrition is also an art because there is no single approach to meeting the needs of the animal.

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Disease surveillance in aquaculture

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Introduction

Fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world. World per capita fish supply reached a new record high of 20 kg in 2014, thanks to vigorous growth in aquaculture, which now provides half of all fish for human consumption, and to a slight improvement in the state of certain fish stocks due to improved fisheries management. Moreover, fish continues to be one of the most-traded food commodities worldwide with more than half of fish exports by value originating in developing countries. Recent reports by high-level experts, international organizations, industry and civil society representatives all highlight the tremendous potential of the oceans and inland waters now, and even more so in the future, to contribute significantly to food security and adequate nutrition for a global population expected to reach 9.7 billion by 2050 (FAO, 2016).

There is currently very little knowledge on the distribution and abundance of disease organisms in aquatic ecosystems making it difficult to know if diseases observed in aquaculture are native to the area or if they have been introduced. While aquaculture does not necessarily create disease, the high-density living conditions in aquaculture facilities and the increased animal stress due to overcrowding lead to outbreaks of diseases that normally occur at low levels in natural populations.

What is disease?

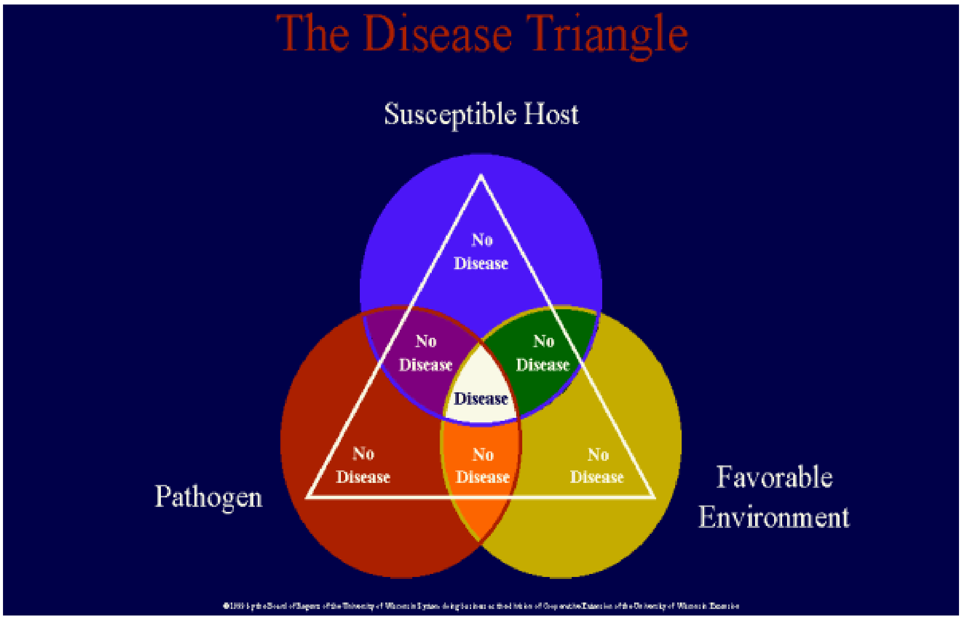
Diseases are abnormal conditions of organisms that impair bodily functions with specific symptoms and signs that result from genetic or developmental error, illness or sickness, infection, poisons, nutritional deficiency or imbalance.

Factors involved in the Disease occurrence

Occurs from the following three important factors such as susceptible host, pathogenic agent and the environment which is unfavourable to the host yet favourable to the agent.

What is Stress?

Stress is defined as a stimulus which disrupts *homeostasis* in an animal. Homeostasis is an organism's ability to maintain internal equilibrium. Causes animals to use more energy to maintain homeostasis rather than fight diseases. Is different among aquatic animals because they are always immersed in their environment and cannot escape it from pathogens which are already present in the water.



Types of diseases

May be categorized into the following categories: infectious, non-infectious. *Infectious diseases* are develops from an infection. Disease Potential relies on the following: number of organisms, infectivity (ability to get into host), virulence (ability to cause disease), host susceptibility.

Non-infectious diseases are due to non-living agents which include the following: nutritional diseases, neoplastic diseases.

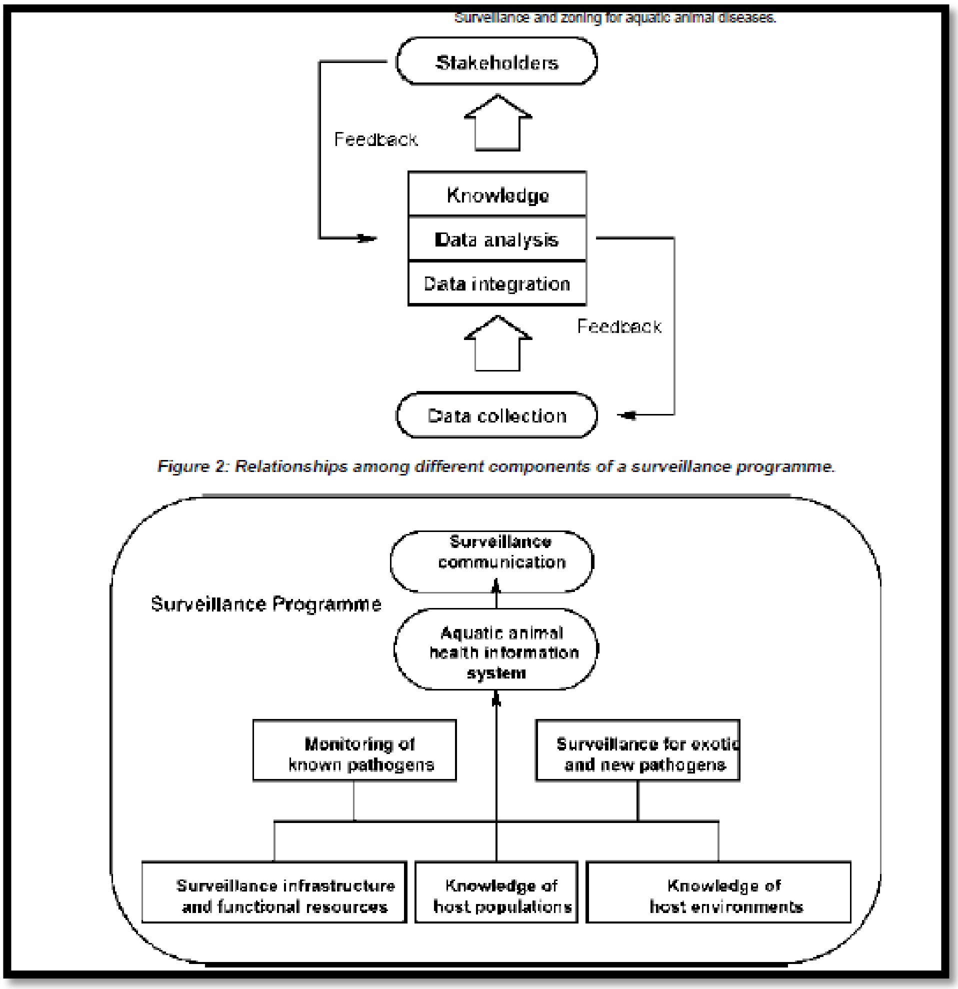
Host Pathogen relationship generally falls into any of these categories

- Symbiosis: a relationship between two organisms which may result in mutual benefit or dependence
- Commensalism: symbiotic relationship in which two organisms live together where one benefits and the other is unaffected
- Parasitism: symbiotic relationship in which the parasite metabolically depends on the host

Surveillance: Surveillance is systematic collection, analysis and dissemination of information in order to support the claim that a specified population is free from a particular infection or disease; or to detect an exotic or new disease for instituting control action quickly.

Passive or general surveillance is a typically a disease-reporting system wherein the Aquaculturists or fisher farmers notices a disease problem, report and recorded in a systematic fashion.

In **Active surveillance,** the users makes an active effort to collect the information needed for surveillance. Since the collection of information is controlled by the users, quality of the information will be high. Active surveillance involves surveys which gather reliable information quickly and inexpensively from a sample of a population rather as census in which the whole population is examined. Active surveillance will be performed with representative sampling units collected either by simple random sampling, stratified random sampling, systematic random sampling, two-stage sampling, Spatial sampling, Fixed distance weighted sampling etc.



(Source: FAO, 2004)

Fig. 1. Overview of disease surveillance

ICAR-CIFT role in National Surveillance Programme for Aquatic Animal Diseases

As per the requirement of this international animal trade (OIE- Aquatic animal health code and manual of diagnostic tests for aquatic animal diseases), India has in place the network program called "National Surveillance Programme for Aquatic animal diseases" funded by National Fisheries Development Board (NFDB) Since 2013. National Bureau of Fish Genetic Resource, Lucknow is the nodal agency for this network program. The first phase of the program is envisaged for five years up to 2017-18 and covering 16 states and 2 Union Territories of the Country. States covered under this project were Andhra Pradesh, Assam, Kerala, Karnataka, West Bengal, Tamil Nadu, Orissa, Uttar Pradesh, Bihar, Haryana, Tripura, Himachal Pradesh, Jammu & Kashmir, Maharastra, Uttarakhand, Andaman & Nicobar and Diu. Under this project, both active and passive surveillance were carried out in the project. Fisheries research institutions of the ICAR, colleges and other agencies viz., MPEDA etc were the collaborating centres for this program.

In National Surveillance Programme for Aquatic Animal Diseases (NSPAAD project), ICAR-CIFT has active surveillance for five districts of Kerala, viz Palakkad, Thrissur, Ernakulam, Alappuzha and Kottayam for finfish and shellfish pathogens. In each district, surveillance will be conducted on 10 farms. In each farm 12 pooled samples not exceeding 5 samples in each pool will be collected and transported to the laboratory. The sampling procedure will be repeated once again within a year. Under passive surveillance, any outbreaks are encountered the team will visit that farm and collect the samples for identify the causative agent. The program is functional since 2014.

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HACCP Concepts
(Hazard Analysis and Critical Control Point)

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Introduction:

A human health implication due to Food has raised a concern to consumers in 21st century. Food safety in relation to hazards viz. physical, chemical, biological, or allergens is an prime lookout for food safety authorities in each country. Each year, millions of illnesses along with fatal incidences may be attributed to contaminated food. Hence a food safety action aimed at ensuring that all food is as safe as possible. Food safety policies and actions need to cover the entire food chain, from production to consumption. The behaviour and awareness of consumers has been gradually changing. Food safety in twenty-first century is an international challenge requiring close cooperation between countries in agreeing standards and in setting up transnational surveillance systems. They currently require not only much higher dietary quality, hygiene and health standards in the products they purchase, but they also look for certification and reassurance of products' origins (national or geographical) and production methods. HACCP or Hazard Analysis Critical Control Points is a scientific and systematic approach to identify, assess and control of hazards in the food production process. With the HACCP system, food safety control is integrated into the design of the process rather than relied on end-product testing. Therefore HACCP system provides a preventive and thus cost-effective scientific approach in food safety.

Introduction of HACCP:

Hazard Analysis and Critical Control Point (HACCP) was developed in the 1960s in the United States to ensure food safety for the first manned National Aeronautics and Space Administration space missions (NASA). NASA required a 'zero defect' program to guarantee safety in the foods astronauts consumed in space.
HACCP is endorsed by the:

- FAO (Food and Agriculture Organization)
- Codex Alimentarius (a commission of the United Nations)
- USFDA (US Food and Drug Administration)
- European Union
- WHO (World Health Organization)

Historical time line in development of HACCP:

- 1959 - The Pillsbury Company developed concept for NASA.
- 1971 - HACCP, as we presently know it, took form at the US National Conference on Food Protection, where risk assessment was combined with the critical point concept (1st mention of HACCP).

- 1972 - The Pillsbury Company in the United States began the application of its HACCP concept to the manufacture of its consumer food products. Pillsbury published the first comprehensive treatise on HACCP in 1973.
- 1973- An HACCP system was adopted for the Low-Acid Canned Food Regulations following the Bon Vivant Vichyssoise Soup botulism incident, in which several people died after eating the soup, due to botulism poisoning.
- 1980 - WHO/ICMSF report on HACCP.
- 1983- WHO Europe recommends HACCP.
- 1997 - Codex Document on HACCP principles and application
- 1997 December- FDA's Seafood HAACP program becomes mandatory.
- 1998- FAO/WHO provide guidance for regulatory assessment of HACCP
- 1998 January - HACCP becomes mandatory for large meat and poultry manufacturers.
- 2003 - FAO/WHO developed HACCP guidelines.
- 2004 - EC 852/2004 requirement for all food businesses to adopt HACCP principles in EU.
- 2006 - Legal requirements to apply HACCP in food businesses (other than primary production) across EU
- After 2006 - Increased worldwide use of HACCP in food safety legislation.

HACCP- A global requirement for food safety assurance:

An effective food safety assurance method is required due to emergence of foodborne pathogens and foodborne diseases which has widespread public health problem. Increased knowledge and awareness of the serious and chronic health effects associated with unsafe food products had made HACCP indispensible in all exporting food processing industries. An effective food safety assurance method such as HACCP is important due to the followings:

- New food technologies and processing methods are introduced now and then
- Increased awareness of the economic consequences of foodborne disease
- Increase in the number of vulnerable people
- Industrialization and mass production
- Urbanization
- Changes in lifestyle
- Increase in tourism and international trade for foodstuffs
- Increase in consumer awareness about food safety

HACCP Concept:

It is important to always remember that the establishment of effective HACCP programs involves primarily the application of good common sense and preventive considerations to address situations before they become problems. The emphasis is on prediction rather than reaction, on getting the process right initially rather than correcting it after problems have occurred. It emphasized on identifying potential food safety problems and determining how and where these can be controlled or prevented.

Describing what to do and training the personnel, implementation, recording and assurance throughout the food chain are taken care under HACCP system.

The objectives of application of the HACCP system:

- Prevention of foodborne illness
- Reduction of losses due to product recall
- Protection of reputation
- Reduction of costs of food analysis
- More efficient quality assurance system
- Focuses on identifying and preventing hazards from contaminating food, based on sound science.
- Permits more efficient and effective government oversight, primarily because record keeping allows investigators to see how well a firm is complying with food safety laws over a period, rather than how well it is doing on any given day.
- Helps food companies to compete more effectively in the world market.
- Reduces barriers to international trade.

12 Steps in the application of HACCP system:

1. Assemble the HACCP team
2. Describe product
3. Identify intended use
4. Construct flow diagram
5. On-site verification of flow diagram
6. List all potential hazards, conduct a hazard analysis and determine control measures
7. Determine CCPs
8. Establish critical limits for each CCP
9. Establish a monitoring system for each CCP
10. Establish corrective actions
11. Establish verification procedures
12. Establish record keeping and documentation

1. <u>Assemble the HACCP Team</u>:

A multi-disciplinary HACCP team needs to include knowledge of the following aspects: Raw materials, specialist (quality assurance/technical), operation activities, engineering/equipment technical knowledge of HACCP, process, finished product, hazard expertise, environment (premises, property, surroundings)

2. <u>Describe the product</u>:

Describe the product giving detail of its composition, physical/chemical structure, and packaging, safety information, processing treatments, storage and method of distribution. Product name, composition, end product characteristics, method of preservation, primary packaging, shipping, storage conditions, distribution method, shelf life, special labeling, customer preparation

3. Identify the intended use:

Identify the intended use of the product, its target consumer with reference to sensitive population. Five sensitive groups in the population are categorized such as elderly, infants, pregnant, sick and immuno-compromised.

4. Construct a process flow diagram:

Details of all process activities including inspections, transportation, storage and delays in the process are to be given. Inputs into the process in terms of raw materials, packaging, water and chemicals and output from the process e.g. waste – packaging, raw materials, product-in-progress, rework and rejected products also need to be mention

5. On site verification of the process flow diagram:

It should be done by all members of the HACCP team during all stages and hours of operation. Validate process flow diagram by HACCP team, observe process flow, sampling activities, interview and outline / non routine operations.

Prerequisite Programs (PRP):

Prerequisite programs such as Good Manufacturing Practices (GMPs), Standard Operating Procedures (SOPs) and Sanitation Standard Operation Procedures (SSOPs) are the foundation for a food safety plan. The documents of PRPs detail the step-by-step information needed to perform all tasks within a plant.

PRP focus on employees, facilities, and equipment. Examples of prerequisite programs includes illness policy, cleaning and sanitizing procedures, garbage removal, pest control, equipment selection, employee hygiene.

An SOP should contain the information like:

- Purpose & frequency of the task
- Who will perform the task
- Describe all the steps needed to perform the task

An SSOP should comprise the following information:

- Pre-operation Sanitation
- Operational Sanitation
- Implementation
- Monitoring
- Corrective Actions

Principles of HACCP (CODEX):

There are seven principles in HACCP as per CODEX which are as follows –

1. Conduct a hazard analysis
2. Determine the CCPs
3. Establish critical limit(s)
4. Establish a monitoring system
5. Establish corrective actions
6. Establish verification procedures
7. Establish documentation

1) Conduct a hazard analysis:

Identify hazards associated with a specific menu item by prepare a flow diagram that outlines all handling/preparation steps from receiving to service. Listing of likely hazards associated with each step and identification of how to prevent the hazards at each step. Hazards can be biological, chemical, physical or allergens. Also a list of hazards need to be projected that are likely to occur and that will cause severe consequences if not controlled. Hazards that are low risk and are not likely may not need to be considered.

2) Determine CCPs:

A control point is any point, step, or procedure where biological, physical, or chemical factors can be controlled. A critical control point (CCP) is a point, step, or procedure where an identified hazard can be prevented, eliminated, or reduced to acceptable levels. Critical control points are monitored much more frequently than are control points.

3) Establish critical limits:

This step involves establishing criteria that must be met to prevent, eliminate, or reduce the identified hazard at the CCP so that the food is safe to eat. Examples of critical limits are temperature, time, physical dimensions, water activity, pH, and available chlorine. Critical limits can come from regulatory standards and guidelines, scientific literature, experimental studies, and consultation with experts.

4) Establish monitoring procedures:

Monitoring is a planned observation or measurement to determine if a CCP is under control. Examples of monitoring include visual observations, temperature measurements, time assessment, pH measurements, water activity measurements, etc.

5) Establish corrective actions:

Corrective actions focus on what to do when a food does not meet the critical limit. Example of a corrective action is temperature of a cooker, throwing out food might be a corrective action. Maintains records of all corrective actions taken.

6) **Establish verification procedures:**

Four phases of verification needed for a HACCP plan:

1. Determine that the critical limits at all CCPS are sound.
2. Make sure that the establishment's HACCP plan is being properly implemented.
3. Have regulatory personnel review the plan to make sure that it is being properly implemented.
4. Check the accuracy of all monitoring equipment.

7) **Establish record keeping:**

The following make up the records of a HACCP Plan

- List of HACCP team and their assigned responsibilities
- Description of each menu item
- Flow diagram for each menu item indicating CCPs
- Hazards associated with each CCP and preventive measures
- Critical limits
- Monitoring procedures
- Corrective actions plans
- Record keeping procedures
- Procedures for verification of the HACCP plan

Advantages of HACCP:

Most important advantages related to implementation of HACCP in food sector include:

- Identifying and preventing hazards that may render food unsafe
- Science based
- Permits more efficient and effective government oversight
- Responsibility for ensuring food safety appropriately on the food manufacturer or distributor
- Helps food companies compete more effectively in the world market
- Reduces barriers to international trade.

Conclusion:

HACCP forms the foundation of European and international legislation for the food industry and is a key component of international trade in food products. HACCP program to be successful need proper implementation and management. This depends largely on regularly scheduled verification activities. The HACCP plan should be updated and revised as requirement. An important aspect of maintaining the HACCP system is to assure that all individuals involved are properly trained so they understand their role and can effectively fulfill their responsibilities. Today food industry standards play a major role in assisting food businesses to achieve compliance with legislation and in many cases exceed legislative requirements. Many of these integrate business operations such as good manufacturing practices (GMP), GHP and HACCP; thereby, providing food businesses with a means to develop an integrated food safety management system. This may enable food business operators to ensure consistency in terms of product safety and quality with fair trade across globe. This is a scientific and cost effective system for controlling product safety and quality.

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Engineering tools and technologies for energy efficient fish processing operations

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Fisheries comprise a major economic activity within complex interactions between human beings and water - 'the first among equals' of the natural resources (Ahmed, 1992). Fisheries data assembled by the Food and Agriculture Organization (FAO) suggest that global marine fisheries catches increased to 86 million tonnes in 1996, then slightly declined. In the past three decades, employment in fisheries and aquaculture has grown at a higher rate than the growth of world population. The fishery engineering is evolving as an important domain in view of depleting stocks on both pre and post-harvest scenarios. It will also aid in fish processing technologies, optimizing energy and water use in seafood industries, mitigating climate change related issues and reducing carbon footprint. It is important to explore novel ways to obtain, quantify, and integrate industry responses to declining fishing stocks and increasing management regulations into fishery- and ecosystem-based management advice. The technological interventions help to reduce the wastage of fish, which is otherwise a highly perishable commodity by preservation technologies and converting it into value added products with higher shelf life. Use of appropriate technologies along the fish value chain will help in producing better quality products and fetch more markets and higher price.

Major areas of technological interventions in the field of fishery engineering cover design and development of fish processing equipment and machineries, energy efficient and eco-friendly solar fish dryers, fuel efficient fishing vessels and fiberglass canoes, indigenous electronic instruments for application in harvest and post-harvest technology of fish, quality improvement of Indian fishing fleet and energy and water optimization techniques for fish processing industries. Focused areas include development of cost effective solar dryers with LPG, biomass, Infra-Red or electrical back-up heating systems, fish descaling machines, Fish freshness sensor etc.

1. Technologies for fish processing and value addition

Post-harvesting processing of fish are important to reduce wastage, increase shelf-life, add more value to the products and ensure higher returns. The major engineering interventions for fish post-harvest operations, processing and value addition are given below:

1.1 Solar dryers

Out of total catch 30-40 % of fish is dried or processed for export and local consumption. Sun drying (open air drying) is the traditional method employed in most parts of the state to dry fishery products. It denotes the exposure of a commodity to direct solar radiation and the convective power of the natural wind. This form of energy is free, renewable and abundant in any part of the world especially in tropical countries. Also it offers a cheap method of drying but often results in inferior quality of product due to its dependence of weather conditions and vulnerability to the attack of dust, dirts, rains, insects, pests, and microorganisms. Solar drying is an alternative which offers numerous advantages over the traditional method and environmentally friendly and economically viable in the developing countries. In solar drying, a structure, often of very simple construction, is used to enhance the effect of the solar radiation. Compared to the sun drying, solar dryers can generate higher air temperatures and consequential lower relative humidity, which are conducive to improved drying rates and lower final moisture content of the final products. However, there exist some problems associated with solar drying i.e. reliability of solar radiation during rainy period or cloudy days and its unavailability during night time. To overcome this limitation, an auxiliary heat source and forced convection system are recommended for assuring reliability and better control, respectively.

In a hybrid solar drying system, drying can be continued during off-sunshine hours by utilizing backup heat source and stored heat energy of daytime sunshine. In this way, drying becomes continuous process and the product is saved from possible deterioration by microbial infestation. These types of Hybrid solar dryers find useful applications in developing countries where the conventional energy sources are either scarce or expensive and the heat generating capacity of the solar system alone is not sufficient. Further, to assist the drying process (forced convection) in a hybrid dryer, a small blower is attached in between solar collector and drying chamber or inside the drying chamber which is powered by solar PV panels installed on drying chamber. Moreover, power from PV panels can be used for street lighting purposes. In addition, if the proposed setup is not used for drying purpose (kept idle), then the same can be used to draw hot water for domestic use. Therefore, in a single set up it is envisaged to have multiple utilities i.e. drying of fish, hot water and electricity generation.

Design of solar dryer varies from simple direct dryers to more complex hybrid designs. Hybrid model solar dryers are having LPG, biogas, biomass or electricity as an alternate back up heating source for continuous hygienic drying of fish even under unfavourable weather conditions. ICAR-CIFT has developed different models and capacities of solar dryers for hygienic drying of fish. The capacity of these hybrid solar dryers varies from 6 to 110 m^2 of tray spreading area for drying of various quantities of fish varying from 10 kg to 500 kg.

The labour requirement is considerably reduced compared to open sun drying in beaches / coir mats because of the elimination of cleaning process due to sand and dust contamination. Re-handling process like spreading, sorting and storing because of non-drying or partial drying due to unfavourable weather conditions and spoilage due to rain is also not required. The drying time is reduced considerably with improved product quality. Improved shelf life and value addition of the product fetches higher income for the fisher folk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact on energy conservation.

ICAR-CIFT design includes small capacity dryers like solar tent dryers, natural convection dryers *etc.* which will be useful to dry fish hygienically during sunny days. Solar tunnel dryers, solar fish dryers with alternate electrical back up (SDE-10, SDE-20 and SDE-50) and solar fish dryers with fire wood or biomass alternate back up heating system (SDF-20, SDF-50) *etc.* can be efficiently used to dry fish using renewable solar energy which is abundantly and freely available. The details of solar dryers with different backup systems are given below:

a) Solar Dryer with LPG back-up: ICAR-CIFT designed and developed a novel system for drying of fish using solar energy supported by environment friendly LPG back up (Fig.1). In this dryer during sunny days fish will be dried using solar energy and when solar radiation is not sufficient during cloudy/ rainy days, LPG back up heating system will be automatically actuated to supplement the heat requirement. In the solar fish dryer with LPG back up heating system, water is heated with the help of solar vacuum tube collectors installed on the roof of the dryer and circulated through heat exchangers provided in the PUF insulated stainless steel drying chamber loaded with fish. Thus continuous drying is possible in this system without spoilage of the highly perishable commodity to obtain a good quality dried product.

This dryer is ideal for drying of fish, fruits, vegetables, spices and agro products without changing its colour and flavour. It helps to dry the products faster than open drying in the sun, by keeping the physico-chemical qualities like colour, taste and aroma of the dried food intact and with higher conservation of nutritional value. Programmable logic Controller (PLC) system can be incorporated for automatic control of temperature, humidity and drying time. Solar drying reduces fuel consumption and can have a significant impact on energy conservation.

Fig.1. CIFT Solar-LPG Dryer

b) Solar dryer with Electrical back-up: Effective solar drying can be achieved by harnessing solar energy by specially designed solar air heating panels and proper circulation of the hot air across the SS trays loaded with fish (Fig.2). Food grade stainless steel is used for the fabrication of chamber and perforated trays which enable drying of fish in a hygienic manner. Since the drying chamber is closed, there is less chance of material spoilage by external factors. An alternate electrical back-up heating system under controlled temperature conditions enables the drying to continue even under unfavourable weather conditions like rain, cloud, non-sunny days and in night hours, so that the bacterial spoilage due to partial drying will not occur. Improved shelf life and value addition of the product fetches higher income for the fisher folk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact on energy conservation.

Fig.2 CIFT Solar-Electric Dryer

c) Solar-Biomass Hybrid dryer: A dryer working completely on renewable energy was designed and developed for eco- friendly operation. Solar Biomass Hybrid Dryer consists of well insulated and efficient solar air-heating panels, drying chamber, SS mesh trays, photo-voltaic cells, fans and biomass heating system (Fig.3). Hot air is generated by virtue of solar energy inside the heating panels and passed into the drying chamber. Continuous flow of hot air is maintained with the help of PhotoVoltaic cells and fans to enable drying process. During cloudy days when sufficient solar energy is not available to maintain required temperature within the dryer, an alternate biomass heating system is manually actuated. Thus a fully green technology for fish drying is achieved by this.

Fig.3 CIFT Solar-Biomass Dryer

d) Solar Tunnel dryer: Solar tunnel dryer utilizes solar energy as the only source of heat for drying of the products. Heat absorbing area of 8 m^2 is made of polycarbonate sheet (Fig.4). Products to be dried are placed on nylon trays of dimension 0.8X0.4 m. The dimensions of the whole drying unit is 2.21X2.10X0.60 m. The capacity of the dryer is 5 kg. Drying takes place by convection of hot air within the drying chamber. Apart from fish, this dryer is also suitable for other agricultural products like fruits, vegetables and spices.

Fig.4 CIFT Solar-Tunnel Dryer

e) Solar Cabinet dryer with electrical back-up: This offers a green technology supplemented by electrical back up in case of lacunae in solar radiation. The dryer consists of four drying chambers with nine trays in each chamber (Fig.5). The trays made of food grade stainless steel are stacked one over the other with a spacing of 10 cm. The perforated trays accomplish a through flow drying pattern within the dryer which enhances drying rates. Solar flat plate collectors with an area of 7 m^2 transmit solar energy to the air flowing through the collector which is then directed to the drying chamber. The capacity of the dryer is 40 kg. Electrical back up comes into role once the desired temperature is not attained for the drying process, particularly during rainy or cloudy days.

Fig.5. CIFT Solar-Cabinet Dryer with Electrical back-up

f) Infrared drying – CIFT has recently developed an Infra Red (IR) dryer heat transfer is happening by radiation between a hot element (infrared lamps) and a material (to be dried). Thermal radiation is considered to be infrared in the electromagnetic spectrum between the wavelength of 0.78 μm and 1000 μm. Infrared emitters offer efficient heat and much more advantages compared to other conventional heat technologies:

- No direct contact with the product High drying/heating rate
- Infrared radiation can be focused where it is needed in a defined time,
- Cost savings thanks to high overall efficiency and optimal infrared heaters lifetime.

1.2 Fish Descaling Machines

a) Fish descaling machine with variable drum speed: Fish descaling machine is designed and fabricated for removing the scales of fish easily. This equipment can remove scales from almost all types/sizes/ species of fish ranging from marine to freshwater species like Sardine, Tilapia to Rohu. The machine is made of SS 304 and has 10 kg capacity. It contains a 1.5 HP induction motor and a Variable Frequency Drive (VFD) to vary the speed of the drum depending on the variety of the fish loaded. The drum is made of perforated SS 304 sheet fitted in a strong SS Frame. Water inlet facility is provided in the drum for easy removal of the scales from the drum so that area of contact to the surface will be more for removal of scales. The water outlet is also provided to remove scales and water from the machine. An Electronic RPM meter was attached with the descaling machine which directly displays the RPM of the drum. Speed of the drum is a factor influencing the efficiency. The machine takes only 3-5 minutes to clean 10 kg fish depending on the size.

Fig.6 Fish descaling machine with variable drum speed

b) Fish **descaling machine with fixed drum speed- table top:** Fish descaling machine is designed and fabricated for removing the scales of fish easily. This equipment can remove scales from almost all types/sizes/ species of fish ranging from marine to freshwater species like Sardine, Tilapia to Rohu. This machine is made of SS 304 and has 5 kg capacity. It contains a 0.5 HP AC motor with proper belt reduction mechanism to achieve required drum speed of 20-30 rpm. Body is fabricated in dismantling type one-inch square SS tube with a suitable covering in the electrical parts. The drum is made of perforated SS sheet fitted in a strong SS Frame having suitable projections to remove the scale and provided with a leak proof door with suitable lock.

c) Fish descaling machine hand operated: Fish descaling machine is designed and fabricated for removing the scales of fish easily. This equipment can remove scales from almost all types/sizes/ species of fish ranging from marine to freshwater species like Sardine, Tilapia to Rohu (Fig.7). This machine is made of SS 304 and has 5 kg capacity. Body is fabricated in dismantling type 1 inch square SS tube. The drum of 255.5 mm diameter and 270 mm length is made of perforated SS sheet fitted in a strong SS Frame having suitable projections to remove the scale and provided with a leak proof door with suitable lock. A pedal is fitted in the side to rotate the drum manually.

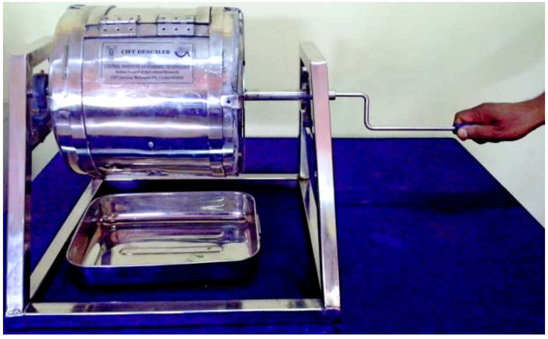

Fig.7 Fish descaling machine hand operated

1.3 Fish meat bone separator:

A Fish Meat Bone Separator with variable frequency drive (VFD) to separate pin bones from freshwater fish was designed and developed. This can be used at a range of 5-100 rpm. With a unique belt tighten system developed; the new machine can be easily adapted to any species and need not be customised for specimen during the design stage. In existing imported models, only two speeds are possible which restricts the yield efficiency in a single span operation and also limits easy switching of the system for utilising specimen other than for which the yield has been originally customised. The meat yield of this machine was about 60% against 35% in imported models. Capacity of the machine is 100kg/hour.

1.4 Modern Hygienic Mobile fish vending kiosk:

Most of the fisher folk across India sell fish in an open basket without any hygienic practices. The fish is kept in an open bag or container, it loses its freshness. They use ice purchased at high cost for temporary preservation and at the end of the day, if the fish is not sold, they give it at a low rate to customers with little or no profit. More over fish gets contaminated under unhygienic handling practices. The fish vending persons, especially women folk find it difficult to carry the fish as head load and subsequently sell it in the local markets or consumer doorsteps. In this context, the ICAR-CIFT have designed and developed a mobile fish vending kiosk for selling fish in the closed chilled chamber under hygienic conditions at consumer doorstep (Fig.8).

Fig.8 Refrigeration enabled Mobile Fish vending kiosk

The major advantages of the new Kiosk are as follows:

- The mobile kiosk was designed considering the maximum weight that a man pulls on rickshaw.

- The mobile unit is mounted on frame with wheels at the bottom. The kiosk can carry 100kg fish with 20kg under chilled storage display in glass chamber and remaining in insulated ice box (developed by CIFT).
- The main components of the kiosk are fish storage & display chilled glass chamber, hand operated descaling machine and fish dressing deck with wash basin, water tank, cutting tool, waste collection chamber and working space.
- The vending unit has been fabricated mainly using stainless steel (SS 304 Food Grade) and frame and supports are made with MS and GI sheets.
- The kiosk main part *i.e* chilling unit & display for fish storage which was envisaged to power by solar energy through solar PV cells,however presently powered by AC current.
- The stored fish is covered with a transparent glass cover through which consumers can see the fish and select according to their choice of purchase.
- Kiosk is attached with hand operated descaling machine for removal of scales. The fish coming out of descaler is free of scales, dirt or slime.
- It also reduces human drudgery and avoids cross contamination, consumes less time. Fish dressing deck with wash basin also designed conveniently to prepare fresh clean fish under hygienic conditions.

Chilling of fish using electricity/PV cells or by adding large quantity of ice adds to cost to the selling price. Since this technology has well insulated storage space for fish with provisions for refrigeration, it reduces the ice melting rate and its cost, thereby reducing the selling price. The unit also extends the keeping quality of fish for 4- 5 days and increases marginal benefit to fish vendors. It also helps change the practice of unhygienic handling and marketing of fish.

1.5 Electronics and Instrumentation:

ICAR-CIFT identified the vast scope of electronics and instrumentation for fisheries technological investigations and started research and development activities. This resulted in a series of instruments for systematic monitoring, analysis and assessment of the marine environment including the performance of the machinery used for harvesting the resources and post-harvest technology. Basic technologies developed in ICAR-CIFT include more than five dozens of electronic instruments with fully indigenous technology and more than 50 sensors with novel features and designs. The notable achievement is the development of indigenous sensors, which are rugged to withstand hostile marine environment and enable us to monitor field data from remote areas. The total instrumentation is built up around these sensors, with required electronics, new signal processors and other peripherals for solid-state data storing, compatibility to PC, wireless transmission to distant points *etc*.

Some of the instruments, which has got great attention and acceptance are as follows: environmental data acquisition system, freezer temperature monitor, salinity temperature depth meter, hydro meteorological data acquisition system, warp load meter, solar radiation monitor and integrator, ship borne data acquisition system, water level recorder, ocean current meter, remote operated soil moisture meter, water activity meter, rheometer and micro algae concentration monitor. Since the instruments are designed to be compatible with computers and solid-state memory module, the information can be stored for long duration and retrieved at our convenience.

By effective use of efficient and appropriate engineering technologies which are cost-effective, adaptable and environmentally friendly, the fishermen community as well as seafood industry can reduce the harvest and post-harvest expenses and losses, add more value to the products, ensure better fish value chain dynamics and thereby obtain more income. The use of green and clean technologies also ensures less carbon and water footprints.

2. Commercialization and Agri-Business Incubation

Agri-Business Incubators (ABI) open new entry points in the agricultural value chains, which in turn can use to access new markets. They afford leverage through these entry points to accelerate agricultural development and offer the unique potential to develop small and medium-sized enterprises (SME's) which can add value along these chains in ways which other development tools do not offer. There is no single "right way" to perform agribusiness incubation. Rather the work of agribusiness incubation depends on the state of development of the agribusiness ecosystem and changes over time as that ecosystem matures and develops. In its earliest phases, incubators demonstrate the viability of new business models and look to create and capture additional value from primary agricultural products. In underdeveloped agricultural economies, incubators help by strengthening and facilitating linkages between enterprises and new commercial opportunities. They open new windows on technologies appropriate to agribusiness enterprises and help agricultural enterprises discover new, potentially more competitive ways of doing business. In subsequent phases of development, incubators operate as network facilitators: they link specialized service providers to agribusinesses and link separate agribusinesses to one another. Finally, in a more advanced state of business development, incubators operate as conduits for the exchange of technology, products, inputs and management methods across national borders.

A more pragmatic system for business incubation and promoting start-up companies with respect to agricultural technologies have been evolved in recent times within the ICAR-CIFT. The Agri-Business Incubation (ABI) center along with Institute Technology Management Unit (ITMU) seeks to provide business consulting services to agriculture-related businesses and helps to develop a strategic business plan. ABIs facilities for incubation of new business ideas based on new agricultural technologies by providing cheap space, facilities and required information and research inputs. The Agribusiness Incubator Program also seeks to provide business consulting services to agriculture-related businesses and helps to develop a strategic business plan.

The Engineering Division of ICAR-CIFT has commercialized its technologies like solar fish dryers, fish descaling machines, refrigeration enabled fish vending machines etc through the ABI. On non-exclusive license mode, 10 firms have been empanelled to manufacture/fabricate machineries as per CIFT design and commercialize it to needed customers by paying royalty to the institute. In the financial year 2018-19 itself, 15 entrepreneurs have taken up Solar fish drying technology and three start-ups came up by establishing CIFT designed fish vending kiosks. Five fish descaling machines were also successfully handed over to sea-food industries located both in Andhra Pradesh and Kerala. Apart from these, 10 numbers of fish dryers of 10 kg capacity were distributed among women SHG groups located in Kerala, Manipur and Assam for demonstration purposes. Furthermore, 28 incubatees (one physical and two virtual) have already registered under ABI in the current year for using engineering technologies. Apart from these, an MOU was signed between ICAR-CIFT and Society for Assistance to Fisherwomen (SAF), Directorate of Fisheries, Govt of Kerala, for fabrication and installation of 20 numbers of Refrigerated fish vending kiosk for the benefit of fisher women SHGs.

3. Energy and Water Use Optimization in Seafood Processing Industry

Energy consumption in seafood or any food processing plant depends largely upon the age and scale of the plant, level of automation, intensity and type of processing operations, plant management practices, plant layout and organization, equipment efficiency and range of products manufactured. The cooking and canning are very energy-intensive processes, whereas the filleting consumes less energy. Thermal energy, in the form of steam and hot water, is used for cleaning, heating, sterilizing and for rendering. The operation of machinery, refrigeration, ventilation, lighting and production of compressed air uses high amount of electricity (Fig. 9). Similarly, seafood industry consumes significant amounts of water in each stage of processing (Fig.10). It also produces a large quantity of waste water. The CIFT have installed energy meters in three industries within Kochi cluster for monitoring the daily energy consumption pattern.

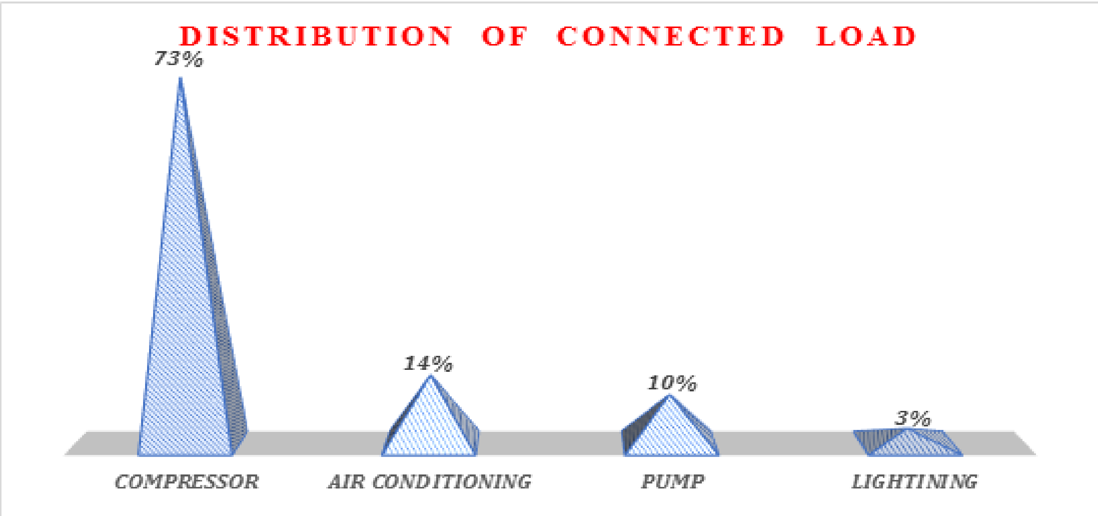

Fig. 9 Distribution of connected load in seafood processing units of the Kochi cluster (Source: BEE, 2015)

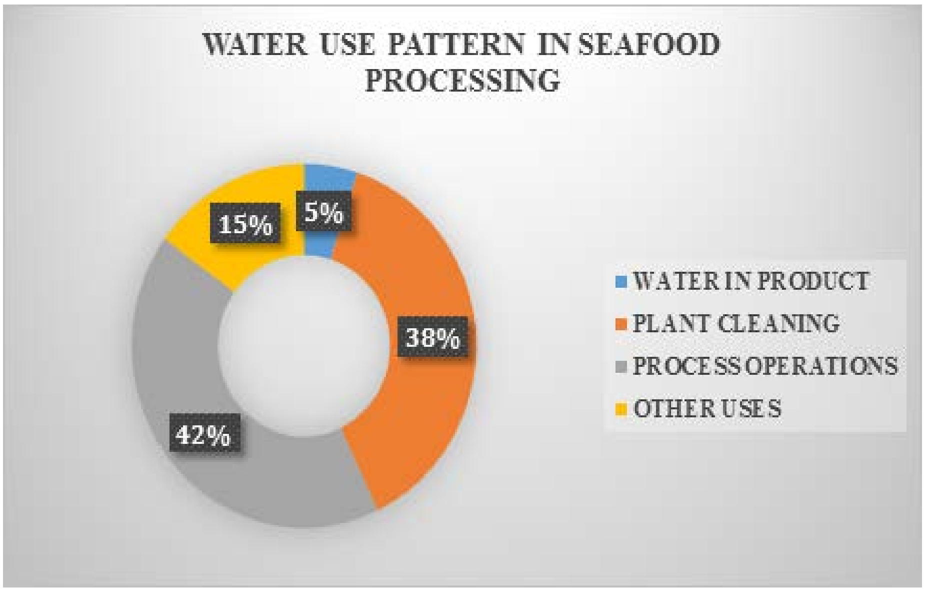

Fig. 10 Water use pattern in a typical seafood processing unit. (Source: BIM, 2017)

3.1 Energy optimization methodologies

Energy optimization methodologies can be broadly classified in the following six categories:

i **_Automation of existing process line:_** Energy wastage in the seafood industry can be greatly reduced by precisely controlling the working of all equipment in the process line. Merely by controlling the timely switching on and off equipment can save a lot of energy, which can be practically impossible in manual operation.

ii **_Sensitize the labor about energy conservation:_** The operation level labor's attitude and behavior have a major impact on the energy optimization point of view. Awareness among the labors regarding energy wastage that can occur due to mere negligence or ignorance has to be created. Instructions can be given to them regarding reducing energy wastage, for example, the chill room doors should be closed immediately after loading or unloading to prevent temperature rise inside etc.

iii **_Equipment upgrade:_** Existing equipment should be monitored for their efficient working through periodic repair and maintenance. Regular servicing and if required replacement of worn out parts should be done. This can actually improve the processing efficiency of the equipment and in turn of the whole plant. The usage of plate freezers considerably reduces the energy consumption in seafood freezing.

iv **_Replacement of out-dated equipment and technology:_** Latest technologies and sophisticated and energy saving equipment can be explored to reduce the energy consumption of plant. For example, reciprocating and centrifugal type compressors can be replaced by a screw compressor, which can give higher processing efficiency or Replacement of existing V-belt drive with synthetic energy efficient flat belt drive in the compressor motor. The direct contact water condensers can be replaced by Evapco type condensers. Installation of Variable Frequency Drive (VFD) for condenser water Pumps. These are relatively capital intensive method but high reduction in energy consumption can be obtained.

v ***Energy auditing and budgeting:*** Effective reduction in energy consumption can be achieved through proper energy auditing of the seafood industry. Energy audits can give an idea about the extent of energy utilized for various purposes in the industry and accordingly energy conservation measures can be executed. The energy auditing can be made easy through software like Energy Datamatrix which periodically check the energy consumption in seafood processing sectors.

vi ***Use of renewable energy and green industry concept:*** Switching to renewable energy sources from conventional sources are of great advantage not only to the industry but also to the environment as a whole. Nowadays, the green industry is a trending concept which emphasizes on those activities and measures which help curb environmental depletion, swapping to renewable energy.

3.2 Water Optimization Methodologies

Substantial reduction in water consumption of a seafood processing industry can be brought about by adopting some of the below-mentioned methods.

i ***Automation of equipment and process-line:***The extent of reduction in water consumption possible by automating the equipment cannot be overlooked. Conventional taps may be replaced by self-closing ones. Cut-off valves, flow diversion valves etc. are dependable accessories which may be installed in the process-line to reduce water wastage. Sensor based solenoid valves may be fitted to the water supply system which can be operated automatically or by means of an Internet of Things (IoT) system.

ii ***Monitoring water use pattern:***Close monitoring of the industry's water use pattern can give a lot of insights. Sensors may be installed in relevant points in the process-line for the same. This can be especially helpful in detecting any leaks by observing the sensor readings during the night. Even though this can incur some initial expenses to the industry, the savings both in terms of money and resources are exceptionally high. Many researchers have successfully developed system for online water monitoring based on different algorithms and tools like genetic Algorithm, Artificial neural networks, ZigBee, GPRS etc.(Liu et al, 2013; Yu et al., 2016).

iii ***Recirculation and recycling:*** Considering the safety standards a seafood industry should maintain and there are some constraints in adopting recycling of water in the process line. Nevertheless, opportunities for possible recirculation of water may be explored to reduce water consumption. Recirculated water can be used for employee wash rooms, Effluent Treatment Plant (ETP) operations and direct groundwater recharging. According to the literature, it is anticipated that a recycling unit in thawing equipment can reduce water consumption by 60 %.The different methods used for the treatment of wastewater in seafood industries are dissolved air floatation, dual media filter, activated carbon filter, sand filtration and tank stabilization, flash mixer, clariflocculator, secondary clarifiers and sludge drying beds, etc. Coarse material and settleable solids are removed during primary treatments by screening, grit removal and sedimentation.

iv ***Updating or modifying conventional systems:***Minor changes may be incorporated into the existing system to utilize the available resources smartly. For example, trigger action shut off devices or nozzles can be fitted onto the hose, the addition of timers or pedals to ensure water, adjusting the flow to the minimum required to maintain performance etc. This can be relative very cheap in investment but can tremendously improve the cleaning potential of water since it is pressurized during application. Almost 40% reduction in water usage can be attained by this method.

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Responsible fishing and its strategic implementation for sustainability

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Introduction

India is situated north of the equator between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude, is the largest peninsular country in the world bordered by Arabian Sea in the west, Indian Ocean in the south and the Bay of Bengal in the east. India has a coastline of 8118 km and 0.5 million sq. km continental shelf endowed with 2.02 million sq. km of Exclusive Economic Zone (EEZ). It has a catchable annual fisheries potential yield of 4.41 million t occupying third rank in world marine fish production (Table 1). India's territorial waters extend into the sea to a distance of 12 nautical miles from the coast baseline. The vital details on marine capture fisheries of India are given in table 1.

Table 1. Marine capture fisheries of India

	India
Length of coastline (km)	8,118
Continental shelf (km^2)	5,30,000
Exclusive Economic Zone(km^2)	20,20,000
Annual potential yield from EEZ(metric t)	4.41
Fishing villages (No.)	3,432
Fish landing centres (No.)	1,535
Fishermen families (No.)	8,74,749
Fisher population (No.)	40,56,213
Marine fishing fleet (No.)	1,99,141
Mechanised fishing vessels (No.)	72,749
Motorised fishing vessels (No.)	73,410
Non-motorised fishing vessels (No.)	52,982
Fish production (2016) (million t)	3.63

Source: GOI (2011a); DADF (2012); CMFRI (2012, 2013a, 2016)

The contribution to foreign exchange earnings by the fishery sector substantially increased from `46 crores in 1960 - 61 to 30,420.83 crores (US$ 4.7 Billion) in 2015-16. Seafood exports from India, during 2015-16, has been 1.05 million t (MPEDA, 2016). USA and South East Asia continued to be the major importers of Indian seafood as in the previous year. Frozen Shrimp was the major export item followed by frozen fish (Fig.1)

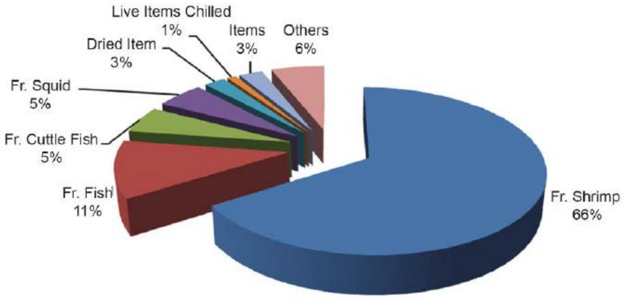

Fig 1. Item wise exports 2015-2016 (Value in USD) Source: MPEDA (2016)

Fishery resource potential and production

Fish production in India has shown an increasing trend during the last six decades. Globally, India ranked second in world total fish production. The total fish production in the country increased twelve fold from 0.74 million t in 1950 to 10.07million t in 2014-2015 (FAO, 2016). India, with its highly productive fishing area has registered 3.63 million t marine fish production during 2015-16. Indian mackerel became the highest contributor with 2.49 lakh tonnes as the declining trend in Indian oil sardine landings continued. The summary of the potential resources in the different realms and depth zones are given in Table 2 and 3

Table 2. Potential yield for different realms

Realm	Potential(t)
Pelagic	2,128,424
Demersal	2,066,763
Oceanic	216,500
Total	**4,411,687**

Source: GOI (2011b)

Table 3. Potential yield for different depth zones

DepthZone	Potential(t)
Upto100m	3,821,508
100-200m	259,039
200-500m	114,640
Oceanic	216,500
Total	**4,411,687**

Source: GOI (2011b)

Fish harvesting systems

Fishing gears and practices ranging from small-scale artisanal to large-scale industrial systems are used for fish capture in India. Most important among these are trawls, purse seines, lines, gillnets and trap systems. Some of the traditional gears have also evolved into large and more efficient versions. The mechanisation of indigenous vessels enabled the fishermen to fish in distant off-shore waters, which were previously inaccessible to them (Chidambaram, 1956). Introduction of small mechanised vessels, motorisation of country vessels, introduction of resource specific vessels and introduction of fishing fleet with state of the art equipment for fish detection and capture were the four development phases (Edwin et al 2014).

Synthetic materials have been the mainstay in the production of fisheries gear since the past half century, the main synthetic fibre being used for fishing are Polyamide (PA), Polyethylene (PE), polypropylene (PP) etc. Now, the entire mechanised fisheries sector uses only synthetic fibers for net making. Twisted netting yarns and braided netting yarns of different sizes are available in the country. Polyamide (PA) monofilament is being extensively used as an import substitute for tuna and shark longlines. The development of combination wire rope for deep-sea fishing is a recent innovation which has now been commercialised. CIFT has standardised specifications for the use of PP multifilament netting yarn with lower specific gravity and better tenacity than nylon.

There are about 1, 99,141 fishing vessels in the sector, of which nearly 72,749 are mechanised vessels (36.5%), 73,410 are motorised (36.9%) and the rest 52,982 non-motorised (26.6%) (Table.4).

Table 4. Fishing vessels in India

State/Union Territory	Mechanised Vessels	Motorised Vessels	Non Motorised Vessels	Total Marine Fishing Vessels
West Bengal	14,282	0	3,066	17,348
Odisha	2,248	3,922	4,656	10,826
Andhra Pradesh	3,167	10,737	17,837	31,741
TamilNadu	10,692	24,942	10,436	46,070
Puducherry	369	1,562	662	2,593
Kerala	4,722	11,175	5,884	21,781
Karnataka	3,643	7,518	2,862	14,023
Goa	1,142	1,297	227	2,666
Maharashtra	13,016	1,563	2,783	17,362
Gujarat	18,278	8,238	1,884	28,400
Daman&Diu	1,000	359	321	1,680
Andaman & Nicobar Islands	61	1491	1637	3189
Lakshadweep Islands	129	606	727	1462
Total	72749	73,410	52,982	1,99,141

Source: DADF (2012)

Advances in satellite-based technologies such as global positioning system (GPS) have positively influenced the precision in fishing, and Global Maritime Distress Safety System (GMDSS) based rescue system have facilitated safety of fishermen. Satellite remote sensing application in Indian fisheries helped to make maps of Potential Fishing Zones (PFZ), which in turn helped the fishermen to reduce search time and significantly increase catch per unit effort (Solanki et al., 2003).

The increase in fish production over the years has been the result of increased vessel number and capabilities, availability of large and more efficient gear systems, developments in electronic, navigational and acoustic detection equipment which increased the area of operation of the mechanised fishing fleet.

The FAO Code of Conduct for Responsible Fisheries

The Code of Conduct for Responsible Fisheries (CCRF) sets out the principles and international standards of behaviour for responsible practices to ensure long term sustainability of living aquatic resources, with due respect for the ecosystem, biodiversity and environment. It covers conservation; management and development of fisheries; capture, processing and trade of fish and fishery products; aquaculture; fisheries research; and integration of fisheries into coastal area management. The key principles of the Code include (i) management of stocks using the best available science; (ii) application of the "precautionary principle," using conservative management approaches when the effects of fishing practices are uncertain; (iii) avoiding overfishing and preventing or eliminating excess fishing capacity; (iv) minimisation of bycatch and discards; (v) prohibition of destructive fishing methods; (v) restoration of depleted fish stocks; (vi) implementation of appropriate national laws, management plans, and means of enforcement; (vii) monitoring the effects of fishing on the ecosystem; (viii) working cooperatively with other states to coordinate management policies and enforcement actions; (ix) recognizing the importance of artisanal and small-scale fisheries, and the value of traditional management practices.

Article 8 of CCRF: Fishing operations

Article 8 in the Code of Conduct of Responsible Fisheries is elaborated in *FAO Technical Guidelines for Responsible Fisheries 1: Fishing Operations* (FAO, 1996a). Article 8 contains 11 Sections and 52 sub-sections dealing with the Code of Conduct for Responsible Fishing Operations. The Article 8 include Sections (8.1) Duties of all states, (8.2) Flag State duties, (8.3) Port State duties, (8.4) Fishing operations, (8.5) Fishing gear selectivity, (8.6) Energy optimization, (8.7) Protection of aquatic environment, (8.8) Protection of the atmosphere, 8.9) Harbours and landing places for fishing vessels, (8.10) Abandonment of structures and other materials, and (8.11) Artificial reefs and fish aggregation devices.

Article 8 of the Code of Conduct for Responsible Fisheries which covers Fishing Operations and Article 12 on Fisheries Research have a number of provisions which are of direct relevance to the fishing gear research, design, development and operations. Section 8.4 on Fishing operations, says that states should ensure that fishing is conducted with due regard to the safety of human life relating to the organisation of marine traffic, protection of marine environment and prevention or loss of fishing gear. It also seeks to prohibit destructive fishing practices such as dynamiting and poisoning, it also explains the need to minimise loss of fishing gear and ghost fishing effects of lost and abandoned fishing gear through development of technologies, materials and operational methods; and emphasises the need for environmental impact assessment prior to the introduction of new fishing gear and practices to an area.

Section 8.5 on Fishing gear selectivity focuses on the development and wide spread adoption of fishing gear and methods which would minimise waste, discards, catch of non-target species. The article on Fisheries Research, also seeks to ensure investigations on selectivity of fishing gear, the environmental impact of fishing on target species and behaviour of target and non-target species in relation to fishing gears. (Boopendranath, 2010).

Section 8.6 deals with appropriate standards and guidelines which would lead to the more efficient use of energy in harvesting and post harvesting activities within the fisheries sector and Section 8.7 deals with the pollution and disposal of waste generated during the vessel operation

Section 8.11 seeks to promote the development and use of artificial reef and fish aggregation devices. Responsible fishing technologies have been reviewed by Boopendranath (2009) and Boopendranath and Pravin (2009).

CIFT's initiatives in Responsible fishing

Fishing vessel design

Fishing craft mechanization in India progressed through four stages, beginning with motorization of some of the existing designs of traditional crafts, followed by introduction of mechanised craft, introduction of more specialized crafts, broadening to a full-fledged fishing fleet. ICAR-CIFT in collaboration with FAO naval architects introduced several standard designs of fishing crafts for different types of fishing operations. Twelve standard designs of wooden fishing boats in the size range of 7.67 to 15.24 m were developed and introduced by ICAR-CIFT, which gave a major fillip to the mechanization programme of Indian fisheries. It has been estimated that over 80% of the mechanized wooden fishing crafts in the Indian fishing fleet conformed to the popular ICAR-CIFT designs or its later adaptations. Designs of boats for fishing in rivers and reservoirs, pole and line fishing vessel, trawler-cum-carrier vessel, steel trawler-cum purse seiner, gillnetter were also developed by ICAR-CIFT. Design of a steel fishing trawler (15.5 m) with energy saving features has also been introduced by the Institute.

Solar powered FRP boat for inland waters

Institute has recently developed a solar powered FRP boat which can be operated in reservoirs, small rivers, and aquaculture ponds and can also be used for recreational fishing activities. The boat is capable of running for 2.5 to 3.0 hours after full charge and attains a speed of nearly 4.0 knots in calm waters. Considering the 240 days of fishing in a year the fuel saved compared to an equivalent diesel powered boat is about Rs. 48,000. The boat has wider space, a canopy for protection from rain and sun, low rolling characteristics during fishing, and also has provision of navigational lights to facilitate fishing in the night.

Fuel efficient multi-purpose fishing vessel

ICAR-CIFT has been instrumental in introducing designs of commercial, research and multipurpose vessels as per requirements of Governments and other organizations. Latest in these initiatives has been the introduction of fuel efficient multi-purpose fishing vessel FV Sagar Harita. The vessel built under the project "Green Fishing Systems for the Tropical Seas" (GFSTS) funded by National Agricultural Science Fund (ICAR-NASF) was officially launched on 18 April, 2016. The hull of this vessel is made of marine grade steel and the cabin and wheelhouse is made of FRP to reduce weight and to improve the carrying capacity and speed. The main engine power is 400 hp which is about 20% lower than vessels of comparable size. The fishing gear handling equipment such as split trawl winch, long line setter and hauler, and gillnet hauler designed at ICAR-CIFT with hydraulic power were installed onboard. RSW tanks (0 ^{o}C to -1 ^{o}C) of 2 tonne capacity have been provided for fish preservation onboard. A 600 watt solar power panel has been installed for emergency lighting and navigational aids to promote the utilization of renewable energy resource and conserve the diesel consumption. Acoustic fish detection and trawl monitoring system with underwater sensors have also been installed onboard.

'Target catch' is the species or species assemblage primarily sought in a fishery, 'incidental catch' is the retained catch of non-targeted species and 'discarded catch' is that portion of catch returned to the sea because of economic, legal or personal considerations (Alverson et al., 1994). Bycatch includes both discarded and incidental catch. In addition to the non-targeted finfishes and invertebrates, bycatch also involve threatened and protected species like sea turtles.

Responsible Fishing Gear

ICAR-CIFT has been in the forefront of developing technologies for responsible fishing and fisheries conservation.

Eco-friendly trawls

Demersal trawls are generally non-selective and a large number of non-target species and juveniles are landed during trawling, in addition to its impact on benthic communities. Resource specific trawls for semi-pelagic resources have comparatively low impact on the benthic biota. CIFT Semi-pelagic Trawl System (CIFT-SPTS) otherwise known as the off bottom trawl system has been developed as an alternative to shrimp trawling in the small-scale mechanized trawler sector, after extensive field-testing (Fig. 2). The system consists of an 18 m four panel semi-pelagic trawl with double bridles, front weights and vertically cambered high aspect ratio otter boards of 85 kg each. It is capable of attaining catch rates beyond 200 kg h^{-1} in moderately productive grounds and selectively harvest fast swimming demersal and semi-pelagic fin fishes and cephalopods, which are mostly beyond the reach of conventional bottom trawls, currently used in commercial trawl fisheries in India.

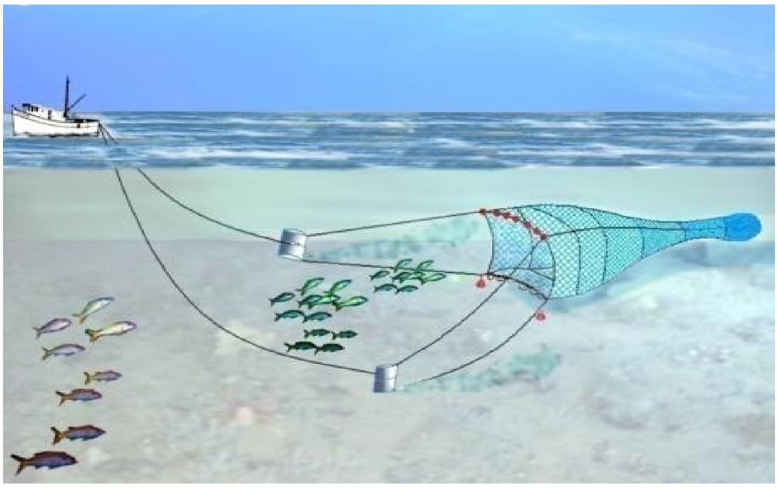

Fig 2. Eco-friendly off bottom trawl system

Selectivity of fishing gears

Information on fishing gear selectivity is important in biological investigations, fish stock assessment, fisheries management and for fishing gear design and development. Selectivity characteristics such as mean selection length, selection range, selection factor and selection curve of square mesh and diamond mesh with respect to demersal catch components have been determined through covered codend experiments.

Bycatch Reduction Technologies

Among the different types of fishing, shrimp trawling accounts for the highest rate of bycatch, of which a significant portion is constituted by juveniles that are generally discarded. Further, higher the quantum of bycatch the less will be the economic benefit accruing from the fishing operation. Bycatch is unavoidable in any fishing operation and only its quantities vary according to the type of the gear and its operation. Therefore, one of the important areas of research of the institute has been the development of bycatch reduction technologies. Devices developed to exclude the endangered species like turtle, and to reduce the non-targeted species in shrimp trawling are collectively known as Bycatch Reduction Devices (BRDs). These devices have been developed taking into consideration variation in the size, and differential behaviour pattern of shrimp and other animals inside the net. BRDs can be broadly classified into three categories based on the type of materials used for their construction, viz., Soft BRDs, Hard BRDs, and Combination BRDs. Soft BRDs make use of soft materials like netting and rope frames for separating and excluding bycatch. Hard BRDs are those, which use hard or semi-flexible grids and structures for separating and excluding bycatch. Combination BRDs use more than one BRD, usually hard BRD in combination with soft BRD, integrated to a single system. Oval rigid grid BRD, Fish eye BRD, Big eye BRD, Sieve net BRD which have given bycatch exclusion rates of 11-63% with an accompanying shrimp loss of 1-8%, have been recommended for shrimp trawls, for bycatch reduction and protection of juveniles. Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) is a Smart Gear award winning design (WWF) developed by CIFT for protecting juveniles and for pre-sorting of the catch (Boopendranath et al., 2008; WWF, 2009).

Square mesh codend

CIFT has for long been advocating the use of square meshes for trawl codend as a conservation measure. As the meshes in the square mesh codends remain open under tension during trawling, water flow will not be restricted and filtration will be efficient and resultant drag will be comparatively less which minimizes fuel consumption. As the mesh lumen remains open, it is easy for small fishes and juveniles to escape through the meshes which reduces the quantum of bycatch enabling the conservation of aquatic resources. In addition to these benefits, the quantity of net required for fabricating square mesh codend is less than the requirement for diamond mesh codend of the same dimensions, resulting in lower fabrication costs. As per CIFT recommendations, Gujarat Marine Fishing Regulation Act (GMFR Act-2003) has prescribed the use of 40 mm square mesh codends in the trawl nets. The use of square meshes have been successfully demonstrated by CIFT in the Sindhudurg District of Maharashtra under a UNDP – GEF project. Most recently the Govt. of Kerala has adopted 35 mm square mesh cod end for fish trawl and 25 mm cod end for shrimp trawl through amendment of the Kerala Marine Fisheries Regulation Act.

Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD)

Trawl fishermen in India and other tropical fisheries depend on both finfish catches and shrimp catches to keep the commercial operations economically viable. CIFT has developed a unique solution for this issue by developing Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD), which retains mature shrimp in the bottom portion of the net while allowing juvenile shrimp to swim out through the mesh unharmed. The device also retains mature finfish in the upper codend of the device, while allowing small sized fish of low commercial value and juveniles of commercial species to be safely excluded. JFE-SSD has bycatch exclusion rate of 43% with a shrimp retention of 96-97%. The sorting of the shrimp and the finfish between the lower and upper parts of the net enhances profitability because it reduces sorting time on the deck which increases the useful fishing time of the trawler fishermen, and it prevents shrimp from becoming crushed under the weight of fish and bycatch hauled on deck which increases the shrimp's market value.

Turtle Excluder Device (TED)

Sea turtles are endangered species. Incidental catches of turtles have been reported in the trawl landings of India particularly from West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and southern parts of Kerala. CIFT has developed an indigenous design of the turtle excluder device which is appropriate for the Indian conditions. CIFT-TED is a single grid hard TED with top opening of 1000x800 mm grid size for use by small and medium mechanized trawlers operating in Indian waters. In the TED developed by CIFT, great care has been taken to ensure 100% escapement of the turtles while exclusion of fish and shrimp is at the minimum possible level. MPEDA, Kochi has adopted the technology and distributed about 2900 CIFT-TEDs to trawler fishermen and operators in states affected by sea turtle mortality, *viz*., West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and Kerala. Demonstration cum training on fabrication, installation, operation and maintenance of CIFT-TED were conducted at several centres in West Bengal, Orissa, Andhra Pradesh and

Kerala, in collaboration with MPEDA, Department of Fisheries, Department of Wildlife and NGOs.

Bycatch reduction in gillnets, purse seines, hooks and lines, and traps

Bycatch in drift gill nets may include marine mammals, sea turtles and sea birds, in addition to non-targeted fish species. Optimisation of gill net mesh size and hanging coefficient according to the target species and size group and judicious deployment of gill net in terms of fishing ground, fishing depth and season in order to minimise the gear interaction with the non-targeted species are important bycatch mitigation measures for gill net fisheries. One approach to minimise ghost fishing by lost gill nets, is to use biodegradable natural fibre twines or time release elements to connect the netting to floats (Hameed and Boopendranath, 2000).

Bycatch incidence in purse seine is said to be mostly due to accidental pursing of juvenile shoals. Selection of mesh size for the purse seine appropriate for the target species, proper choice of fishing area, depth and season could also lead to better selectivity of purse seines. Special escape panels known as Medina panels, which are sections of fine mesh that prevent dolphins from becoming entangled in the gear, and back down manoeuvre have been deployed to prevent capture of dolphins in purse seines (Ben-Yami, 1994). Optimized hook design and size and selection of bait type and bait size appropriate for the target species and size class, proper choice of fishing ground, depth and time of fishing are approaches for mitigation of bycatch issues in hook and line fisheries and minimise gear interaction with other species. Optimised trap design according to the target species and provision of escape windows for juveniles and non-target species in the design side and appropriate choice of bait type, fishing area, fishing depth, fishing time also help to minimise juvenile catch in traps.

Green Fishing Concept

The green fishing concept encompasses energy conservation in fishing and minimising environmental impact of fishing gears in all fisheries.

Energy conservation in fishing

Motorised and mechanised fishing operations are dependent on fossil fuels, which are non-renewable and limited. Fossil fuels produces increased levels of carbon dioxide in atmosphere contributing to green house effect and other pollutants which are detrimental to the environment and human health. Green house effect leads to irreversible climatic and oceanographic changes. Moreover spiraling oil prices may severely affect the economic viability of fishing as a means of food production. World capture fisheries consumes about 50 billion litres of fuel annually (1.2% of the global fuel consumption) releasing an estimated 134 million tonnes of CO_2 into the atmosphere at an average rate of 1.7 tonnes of CO_2 per tonne of live-weight landed product (Tyedmers et al.,2005). Annual fuel consumption by the mechanized and motorized fishing fleet of India has been estimated at 1220 million litres which formed about 1% of the total fossil fuel consumption in India in 2000 (122 billion litres) releasing an estimated 3.17 million tonnes of CO_2 into the atmosphere at an average rate of 1.13 tonnes of CO_2 per tonne of live-weight of marine fish landed (Boopendranath, 2009).

Studies on GHG emmission from fishing vessel conducted in CIFT has shown that the fuel consumption is the major factor contributing to GWP in both single day and multi day trawler operations and hence offers scope for impact reduction through operational fuel savings. The GWP was incrementally higher for multi-day trawler operation corresponding to increase in size of trawlers. Global warming potential ranged from 2165 to 4328 kg CO_2 Eq. in wooden trawlers and from 2824 to 6648 kg CO_2 Eq. in steel trawlers depending on the size. The GWP was higher in very large trawler due to inorganic emission to air especially carbon dioxide. The GWP had a negative value for renewable resources i.e., wood for construction, wooden otter board, marine plywood and cotton. Among the materials used for construction of a 40 m trawl net GWP was maximum for iron sinker (64.6%) followed by high density polyethylene (HDPE) webbing (17.0%), polypropylene (PP) rope (10.3%), HDPE float (5.0%) and lead sinker (3.1%).

Various approaches to energy conservation in fish harvesting such as (i) fishing gear and methods; (ii) vessel technology; (iii) engines; (iv) reduction gear, propeller and nozzle; (v) sail-assisted propulsion; (vi) adoption of advanced technology; (v) conservation, management and enhancement of resources, have been discussed by May et al. (1981), Gulbrandson (1986), Wileman (1984), Aegisson and Endal (1993), Boopendranath (1996), Wilson (1999, Boopendranath (2009). Other methods of energy conservation can be through use of Fish Aggregating Devices (FAD) the Institute has developed and standardized low-cost designs of floating FADs and benthic Artificial Reef (AF) modules, based on experiments off Andhra Pradesh coast, in order to make the fishing operations energy efficient and cost-effective, for the benefit of traditional fishermen operating fishing gears such as gill nets and lines. Potential fishing zone (PFZ) advisory is important service, since fishermen can use less time and fuel in searching for areas of fish abunadance. PFZ advisory mainly rely on Chlorophyll and sea surface temperature retrieved from satellite. Fishing Technology Division, ICAR-CIFT has been working on this aspect for 8 years. The main objectives are to provide *in-situ* database on chlorophyll, coloured dissolved organic matter, detritus and nutrients along with other physical parameters of coastal waters of Kochi, validate the *in-situ* measured Chlorophyll, coloured dissolved organic matter and detritus with satellite data and development of regional algorithms based on these *in-situ* and satellite data to improve PFZ advisory.

Minimising environmental impact of fishing gears

Dragged gears as trawls, particularly when they are heavily rigged, could cause severe damage to benthic fauna and flora, which occupy the bottom substratum and contribute to the productivity of the region. Direct and indirect impacts of bottom trawling on marine environment and benthic communities are well known (Hall, 1999; Kaiser and de Groot, 2000; Barnes and Thomas, 2005; Meenakumari et al., 2009 and others).

Conclusion

The implementation of responsible fishing methods starts with the research on design, development and operation of fishing vessel and fishing gear. A country like India has already a wide range of technology for bycatch reduction, minimising environmental impact and energy conservation based on FAO- CCRF. Creating awareness among stakeholders with suitable incentives will result in faster adoption of such technologies. Policy initiatives and amendment of existing legislation will facilitate sustainable fishing in India.

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Scope of entrepreneurship development in Fisheries

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Introduction

Fish is a source of valuable animal protein and is now considered a health food. This has resulted in increased consumer demand. Fish is now more expensive than meat and other animal foods. Being a highly perishable commodity, fish require immediate processing and various options are available for the value addition of fish. Fish processing, particularly seafood processing and marketing have become highly complex and competitive and exporters are trying to process more value added products to increase their profitability. Value can be added to fish and fishery products according to the requirements of different markets. These products range from live fish and shellfish to ready to serve convenience products. In general, value-added food products are raw or pre-processed commodities whose value has been increased through the addition of ingredients or processes that make them more attractive to the buyer and/or more readily usable by the consumer. It is a production/marketing strategy driven by customer needs and perceptions.

According to the recent statistics, the annual capture and culture based fish production in India is around 90, 00000 MT. Seafood export sector is one of major foreign exchange earner in India. In 2015-16, India has exported 945892 MT of Seafood worth Rs.30, 420 crores. USA and South East Asia are continued to be the major importers of Indian seafood. Frozen Shrimp continued to be the major export item followed by frozen fish. Marketing of value added products is completely different from the traditional seafood trade. It is dynamic, sensitive, complex and very expensive. Market surveys, packaging and advertising are a few of the very important areas, which ultimately determine the successful marketing of a new product. Most of the market channels currently used is not suitable to trade value added products. A new appropriate channel would be the super market chains which procure directly from the source of supply of the products and control most of the components of production and supply chain like packaging, advertising and retail marketing. Appearance, packaging and display are all important factors leading to successful marketing of any new value added product. The retail pack must be clean, crisp and clear and make the contents appear attractive to the consumer. The consumer must be given confidence to experiment with a new product launched in the market. Packaging requirements change with product form, target group, market area, species used and so on. The packaging technology needs to be evolved which should be attractive, convenient and adding to the shelf life of the processed products.

Technology developments in fish processing sector offer scope for innovation, increase in productivity, increase in shelf life, improve food safety and reduce waste during processing operations. A large number of value added and diversified products both for export and internal market based on fish, shrimp, lobster, squid, cuttlefish, bivalves etc. have been identified. However, the commercialisation of fish products still pose lot of challenges to the entrepreneur and researcher in terms of optimization of technologies and ultimately developing the technologies into a commercially viable business plan. In this regard, the Indian Council of Agricultural Research (ICAR) has started a Business Incubation Unit at the Central Institute of Fisheries Technology (CIFT) exclusively for the Fisheries sector through the World Bank funded National Agricultural Innovation Project (NAIP). It is designed to accelerate the growth and success of entrepreneurial start-up efforts through the mobilization of an array of business resources and services. Later in 2016 an Agri-Business Incubation Centre (ABI) was established in CIFT under the XII plan scheme of National Agriculture Innovation Fund (NAIF) of ICAR. The role of the ABI Centre is to facilitate the innovator and the researcher to turn their ideas into commercial ventures with focus on incubation and business development programme, including entrepreneurship, skill development and grassroot innovators activities.

Health benefits of fish

As a rich source of nutrients, fish provide a good balance of protein, vitamins and minerals, and a relatively low caloric content. In addition fish are excellent sources of Omega-3 polyunsaturated fatty acids which appear to have beneficial effects in reducing the risk of cardio- vascular diseases and are linked with positive benefits in many other pathological conditions particularly, certain types of cancer and arthritis.

Fish represents an excellent option as a major source of nutrients. On a unit caloric basis fish can provide a broad range of nutrients. A high intake of fish is compatible with a reduction of both calorie and saturated fatty acid intakes. Coronary heart disease, hypertension, cancer, obesity, iron deficiency, protein deficiency, osteoporosis and arthritis are contemporary health problems for which fish provide a number of nutritional advantages and some therapeutic benefits. Nutritional factors of importance are calories, proteins, lipids, cholesterol, minerals and vitamins.

Conventional finfish and fishes potentially provide from 100 to 200 kcal/100g, which is mainly attributed to the protein and fat contents of fish. The amount of carbohydrates in fish is very small. Finfish usually contains less than 1% carbohydrate whereas shellfish have very low fat content. Compared to other muscle food, they contribute very low fat calories to the average diet. For example, each gram of fish muscle provides only 0.05 – 0.2g of fat compared to 0.25 – 0.5 fat per gram of red meat. The most important constituent of fish muscle is protein. The protein content in fish varies from 17 to 25%, though values as low as 9% are sometimes encountered as in the case of Bombay Duck. Fish protein is highly digestible because of very low stroma protein and has an excellent spectrum of essential amino acids. Like milk, egg and mammalian meat proteins, fish protein has a high biological value. Cereal grains are usually low in lysine and/ or the sulfur containing amino acids, whereas fish protein is an excellent source of these amino acids. In diets based mainly on cereals, fish as a supplement can, therefore, raise the biological value significantly.

Fish oil contains primarily the Omega -3 series of fatty acids. The polyunsaturated components of fish lipids can be effective in reducing plasma lipids. Epidemiological data from Japan and the Netherlands indicate that frequent consumption of fish even in quantities as low as 30g/ day may have beneficial effects in reducing heart disease.

Consumption of medium (100g) to large amounts especially triglycerides, prevent thrombosis and ameliorate ischemic heart disease. These effects are mediated by the Omega -3 PUFA of fish lipids which alter the production of certain biologically important components called eicosanoid. The efficiency of the Omega -3 PUFA components is influenced by the amount ingested and the concentration of other unsaturated fatty acids in the diet, especially Omega -6 PUFA. Squalene, an isoprenoid molecule present in shark liver oil in higher quantities, has been reported to possess antilipidemic, antioxidant and membrane stabilizing properties. Fish and shellfish, particularly anchovies, clams, oysters and sardines are rich sources of vitamin B 12.

Fish consumption is compatible with optimum dietary practices / recommendations and that substitution of fish for other foods can help to maintain a balanced nutrient intake compatible with a low fat consumption. In addition, the consumption of fish- or more precisely, fish lipids – may provide significant health benefits.

Entrepreneurship Initiatives in Fisheries Sector

Fisheries sector with its important role played in the socio-economic development of the country has become a powerful income and employment generator, and stimulates the growth of a number of subsidiary small, medium and large scale industries. In order to translate the research results arising from the field of fisheries and other agricultural sectors, ICAR have set up an innovation based Business Incubation Centre (BIC) at the ICAR-Central Institute of Fisheries Technology (CIFT), Cochin. BIC is managed by Zonal Technology Management – Business Planning and Development (ZTM-BPD) Unit and aims at establishment of food business enterprises through IPR enabled ICAR technologies.

BIC supports operations on business projects as a measure of enhancing the foundation for new technology based industries and establishing a knowledge-based economy. It focuses on finding new ways of doing business in fisheries and allied agricultural fields by finding doors to unexplored markets. The Centre helps prospective entrepreneurs, by providing pro-active and value-added business support in terms of technical consultancy, infrastructure facility, experts' guidance and training to develop technology based business ideas and establish sustainable enterprises. It acts as a platform for the speedy commercialization of the ICAR technologies, through an interfacing and networking mechanism between research institutions, industries and financial institutions. The Incubator at ICAR-CIFT differs from traditional Business Incubators as it is tailored specifically for technology based industries and is operational at an area with a high concentration of fish production. This industry-specific incubator also allows new firms to tap into local knowledge and business networks that are already in place. BIC offers their services to industries not only in Cochin, but also all over India through virtual incubation. Beyond promoting business growth, the Centre is also trying to bring its benefits to all the fisheries communities in India.

This unique Business Incubator is now known as a "One Stop Shop", where entrepreneurs can receive pro-active, value-added support in terms of technical consultancy, and access to critical tools such as entrepreneur ready technologies, vast infrastructure and other resources that may otherwise be unaffordable, inaccessible or unknown. With the aim of transforming the incubator into a symbol of entrepreneurship and innovation, the ZTM-BPD Unit has created an environment for accessing timely scientific and technical assistance and support required for establishment of technology based business ventures. The activities of the ZTM-BPD Unit focuses on finding creative and innovative ways for linking public sector resources and private sector initiatives within and across regional and national boundaries for promoting economic growth. The Centre uses the right expertise in relevant fields to identify and analyze the constraints and barriers hindering the growth of a business, and devise appropriate strategies. It explores the various structures and strategies to help small enterprises to grow and ensure a promising future in the global market. It fosters corporate and community collaborative efforts, while nurturing positive government-research-business relationships.

Process of Incubation

The Business Incubation Centre targets entrepreneurs, from fledgling start-ups in need of basic small scale processing capacity to sophisticated businesses in need of R&D back up, office infrastructure and pilot / test market processing facility for the development of new products. It possesses good infrastructure facilities suitable for providing direct incubation of nine entrepreneurs in a corporate environment within the premises of ICAR-CIFT, at a time. The purpose of direct incubation is to support emerging companies through their infancy. BIC apart from being a multi-tenant facility with on-site management that delivers an array of entrepreneurial services to clients operating with the facility, it also serves clients that are not located in the facility through virtual incubation or incubation without walls.

The Centre regularly conducts industry interface and technology promotional programmes for sensitization of entrepreneurs and to identify interested potential candidates for physical and virtual incubation. The Clients at BIC gets the privilege of meeting Scientists, Business Manager and Business Associates directly, to discuss and finalise the strategies to be adopted to take the business forward. It is also the peer-to-peer relationships that develop within the incubator, that ensures the delivery of basic services such as how to actually incorporate a business; what are the legal issues; how to take intellectual property protection; how to do basic accounting and cash flow; how to do business presentations etc. Those kinds of skills are what are transmitted as part of the incubation process.

The residency period for direct incubatees is normally for two years, extendable by another year in special cases, depending on the progress of incubation. As the business venture becomes mature enough, the concessions and the facilities provided to the incubatee companies will be gradually withdrawn. Each incubatee of the Unit will have to pay to the Institute a charge for utilization of space, at a rate concessional to the benchmark rate which is the prevailing market rent realizable. Incubatee mentoring will continue in virtual mode after graduation, on need basis.

Services and facilities offered by ICAR-CIFT Business Incubator

The Centre through its business support services provides links to supporting industries; upgrade technical / managerial skills; provide scientific / technical know-how;

assist in market analysis, brand creation and initial test marketing; protect IP assets; and find potential investors and strategic partners.

Incubation facilities under one roof are:

- Furnished office suites within the premises of ICAR-CIFT, with shared facilities like secretarial assistance, computing, copying, conferencing, video conferencing, broad band internet and communication services.
- Pilot level production lines
- Culinary facility
- Access to modern laboratory facilities for product testing and quality control
- Access to well-equipped physical and digital libraries

Pilot Level Production Lines

A state-of-the-art generic semi-commercial production facility is made available to incubating entrepreneurs for developing value added products from fish . BIC provides access to these facilities along with support of manpower, and assists the entrepreneurs in production and testing of new product formulations. For the tenants, the pilot plant is an ideal testing arena to determine the commercial viability of new products. The plant also serves as a process lab, a place to see how processing equipment impacts food products under varying conditions. There are production lines for pre-processing, cooking, retort pouch processing, canning, sausage production, extruded products, chitin & chitosan, smoking, curing & drying, breading & battering and product packaging. By providing access to these resources, the Centre greatly reduces one of the major barriers to the commercialization of institute technologies by smaller firms - the high capital cost of intermediate or large scale process equipment.

Business Services

The business oriented services offered by BIC include assistance in complying with business regulations and licensing procedures, financing, information services, marketing, and tailor-made services designed for the various tenant enterprises. Incubator clients can also gain special advantage in terms of tax savings through special regulations for Business Incubators. BIC also offers a wide variety of services, with the help of strong associations throughout the Business Incubation Network

Conclusion

Fish processing and value addition has evolved over the years as the sunrise sector in Agriculture domain. Globally many new species are being introduced in the Aquaculture sector. A comprehensive study on the suitability of these species for value addition has to be carried out to propose optimized utilization protocols. Functional fish products will be in much demand in future; the challenge will be to retain the functional benefits of fish & shellfish meat by way of adopting product specific processing protocols or alternate delivery systems for sensitive components. These issues offer ample scope for Innovation coupled with entrepreneurial skills for the creation of wealth and employment in fisheries sector.

Innovative Extension Approaches for Sustainable Technology Dissemination in Fisheries

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Trends in aquaculture and fisheries

Global fisheries have made rapid strides in recent years by establishing its strong hold over increasing food supply, generating job opportunities, raising nutritional level and earning foreign exchanges. These benefits become more important when placed in the context of current challenges in food production, nutritional security, social transitions and growing climate uncertainties. Fish and fishery products are the most traded food commodities in the world accounting for 1% of world merchandise trade in value terms representing more than 9% of total agricultural exports all over world (FAO, 2014). About 38% of the global fish production enters international trade in various forms and shapes, generating an export earning of nearly US$148.1billion with a record import at US$140.6 billion during 2014. Mostly the developing countries that account for over 60% of global fish catch, which has continued to expand at an average annual rate of 8.8% (FAO, 2009 & 2012) and play a major role in the global trade of fish and fish products contributing around 50% of fishery exports in value terms and more than 60% in quantity terms supplied by them (World Bank, 2011). At the same time, demand for fish products are likely to rise as a result of rising populations that are expected to reach 9.3 billion by 2050.Developing countries have a positive trade balance due to their increasing involvement in global fisheries trade. Developing country like India may have higher proportion of population growth but its impressive economic growth over the past two decades has resulted in steady increase in per capita income in real terms that in turn increases the purchasing power of people resulting in increasing demand for food to feed & ensure nutritional security of the population. As a result of which it brought inconsistency in fish consumption pattern across the coastal, marine and hill region.

It is estimated that fish production generally contributes 0.5 – 2.5 % of GDP globally (Allison 2011). In spite of that globally an estimated population of more than 1.3 billion people are in extreme poverty (2016), 795 million people (2015-16) are estimated to be in chronic hunger and an estimated one third of children in the developing world under five years of age are stunted (Conway 2012). Fish is considered as the most affordable and frequently consumed animal-source food in low income food deficit countries in sub-Saharan Africa, Latin America and Asia (World Bank,2006). It is an important source of a wide range of intrinsic micronutrients, minerals and fatty acids. It accounts for about 17 % of most affordable, easily digestible, high-quality animal protein and 6.7 % of all protein, all essential amino acids, essential fats (e.g. omega-3 fatty acids), vitamins and minerals thus contributing to a great extent to food and nutrition security in many Asian and African countries where large proportion of population are still in hunger and under nourished (Kent,1987). Besides small-sized fish species are excellent source of many essential minerals such as iodine, selenium, zinc, iron, calcium, phosphorus, potassium, and vitamins such as A, D and B. About 150 g of fish provides about 50–60 % of daily protein requirements for an adult. On an average, fish provides about 20–30 kilocalories per person per day. In addition, dietary diversity of the region is mainly influenced by different quantitative and qualitative attributes viz., income, price, preference, market, type and quality of products, cultural traditions, beliefs as well as various geographical, environmental, social and economic factors that influences the fish consumption pattern.

Despite the significant contributions by the sunrise sector, global debates on fisheries issues and policies appear to be dominated by concerns over environmental sustainability, overfishing and overcapacity. In this context, it is alarming to note that the sector has not received adequate attention from the social scientists to understand its various socio-economic dynamics to prove the sunrise sector as a potential driver of local and national economic development.

Major concerns in fisheries

Food security has become the prime concern with the increasing trend of population growth in a country. Over the last fifty years, the food grain production in India has increased considerably, but the advantage of this increase in food grain production has not been reflected in the per capita availability of food grains. As per estimate, the human population and food grain production in India has grown up by 2.09% and 2.36%, respectively from 1961 to 2011, whereas the annual per capita availability of food grains has come down from 171.1 kg in 1961 to a level of 169 kg in 2011 showing a decreasing trend of 1.17 %. In case of fish, Asia accounts for almost two-thirds of global fish consumption i.e. 21.4 kg per capita per year in 2011 – a level similar to Europe (22.0 kg/cap/yr) and North America (21.7 kg/cap/yr), and close to the levels of Oceania (25.1 kg/cap/yr), whereas Africa, Latin America and Near-East have lowest per-capita consumption (10.4, 9.9 and 9.3 kg/cap/yr in 2011, respectively). Although annual per capita apparent consumption of fish products has grown steadily in developing regions (from 5.2 kg in 1961 to 17.9 kg in 2011) and in Low Income Food Deficit Countries (LIFDCs) that increases from 4.4 kg in 1961 to 8.6 kg in 2011, it is still considerably lower than in developed regions (from 17.1 kg in 1961 to 23.0 kg in 2011). It is clearly evident that rising population is nullifying the effect of growth in food grain production, keeping aside several other factors which determine the access to food grains. In this context, increasing fish production to meet the challenges of nutritional security has drawn the attention of the planners and policy makers. Hence, aquaculture is considered as a promising food production sector for high quality protein food and providing livelihood to the rural populace, which needs to be more efficient and cost-effective. However, there is multitude of challenges associated with the growth of this industry.

The fishery sector is a major foreign exchange earner for any developing countries. In India, its foreign exchange earnings were estimated to increase by 16 to 20 per cent in 2005 and 26 to 42 per cent by 2015. Nearly 85 per cent of the export benefits are projected from shrimp export alone. Because of its potential and rich source of animal protein, fish demand has been rising in both the developed and developing world at more than 2.5 percent per year (Peterson and Fronc, 2007) and demand levels were raised in proportion to increase in income in highly populated countries like China and India, (Garcia and Rosenberg, 2010).In view of higher production in fisheries, producers may lose from price fall in the domestic market; where prices were estimated to fall by 15 to 20 per cent by 2005 and 27 to 54 per cent by 2015. In spite of the phenomenal success of the sector, still there are some major issues related to the economic and nutritional conditions of fisher folk in addition to some important concerns in the context of rising environmental hazards, depressing prices world over, emerging new economic challenges following establishment of WTO, IPR & SPS issues, compliance of several multilateral agreements, etc.

In the post- harvest front, the processing industries face multifarious problems like complicated exporting procedures, high shipping costs, cut-throat competition in the industry, changing quality standards of importing countries, irregularity in supply of raw materials, hygiene problems and non-availability of quick transportation facilities from the fishing port to the processing units, etc. As a result of which trade-driven commercial fish farming is suffered that reduces the livelihood opportunities of small scale dry fish processors, petty traders within the communities of poor fishermen.

Environmental degradation poses a challenge to the phenomenal success of the fishery sector in promoting food security and adversely creates impact on nutritional rights and livelihood status of the fishermen communities for whom fish and fishery products are critical for their health benefit and wellbeing. As per directives of international conventions like Kyoto Declaration and Code of Conduct of Responsible Fisheries, this trade-driven, resource depletion sector can be sustained through by-catch reduction and juvenile fishing ban. The benefit of this may be accrued through policy level intervention by institutions within the legal framework.

Small-scale fisheries are normally characterized by low capital input activities, low capital investments, lack of equipment and labor-intensive operations followed by traditional fishers. They also usually operate as semi-subsistence, family-based enterprises, where a share of the production is kept for self-consumption (Garcia *et al*., 2008). Traditional fishers dominate the marine sector and they are socially deprived, educationally weak with very high occupational rigidity. There is inequity in the distribution of yield and effort in marine fishing in case of traditional fishing communities. They are unorganized with least social security. The informal social security system in the form of sharing of earnings among the community prevailing in the traditional fishing is hardly seen in the mechanized fishing. There are also huge regional variations in productivity among them.

Technologies are the main drivers of growth. Hence, systematic technological interventions backed by appropriate policy and institutional support are vital for making the aquaculture operations sustainable and economical. Generally, the technologies and trade interventions reinforce each other which can be characterized as skill-based, cost effective, capital intensive which can bring a change in the performance of the sector. Keeping eye upon this, following strategies have been suggested for an accelerated fishery development with focus on poverty alleviation of poor fishers:

- Commodity-centered approach
- System approach
- Prioritize technology on the basis of needs and problems at micro and macro levels
- Skill development/upgradation of the fishers

- Monitoring the technology demonstrations programs and assess the impacts.
- Innovate and strengthen institutions and policies
- Enhance investment and reorient policies to facilitate percolation of benefits to all sections of the society.
- Follow ecological principles
- Emphasize on domestic market demand and consumers' preferences
- Strengthen database and share it for a better planning and policy making in the sector.

Extension systems for sustainable development

Unlike India, the economy of developing and underdeveloped countries in sub Saharan Africa, Latin America, Asia inclusive of 22 Low Income Food Deficit Countries (LIFDCs) is predominantly agrarian economy, where agriculture inclusive of fisheries provides employment and livelihood to majority of the rural households, but the condition of both farmers/fishers and farming is in alarming state.

Hence, there is an urgent need to reform that agriculture allied sectors in holistic, scientific and systematic approach to meet the recent challenges due to climate change and global competitiveness so as to achieve sustainable production and growth under different agro-climatic conditions.

As per the report of world commission on Environment and Development (1987), sustainable development meets the needs of the present generation without compromising the ability of future generation to meet their requirements. The FAO committee on Fisheries (1991) defines sustainable development more elaborately as the management and conservation of national resource base and the orientation of technological and institutional intervention to ensure the attainment of human needs for present and future generation including fulfilment of social and economic demands and conserving the natural resource base. In response to that FAO developed a code of conduct for Responsible Fisheries (FAO,1995) that provides principles and guidelines for ensuring sustainable exploitation of marine resources. Sustainable fisheries can be possible through responsible fishery, which envisages rational fishery management that address a range of issues dealing with resource status, environmental health, post-harvest technology, trade and export, socio-economic benefits, legal and administrative support. Sustainable agricultural systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound. Hence, the agriculture research system must place emphasis on generation of resource conservation technology (RCT) along with strong forward-backward linkage between research-extension system. It involves design and management procedures that work with natural processes to conserve all resources, promote ecosystem resilience and self-regulation, minimize waste and environmental damage, while maintaining or improving farm productivity and profitability (MacRae et al., 1990).

The role of extension in fisheries cannot be ignored. Strong extension system is the key to bring the desired changes to meet the present day challenges related to sustainable fisheries. Basically, the end product of the fisheries extension system is to work with fisheries within an agro-climate and economic environment by providing suitable technologies to enrich knowledge and upgrade skills to improve better handling of natural fish resources and applying the cutting-edge technologies to achieve desired production level. Extension system plays a pivotal role in empowering fishers and other stakeholders to make fish farming more participatory, demand-driven, knowledge intensive and skill supportive for disseminating most appropriate technical, management and marketing skill to improve profitability in fisheries that can overcome the emerging challenges and concern, thus developing a synergistic pathway for enhancing productivity along with quality produce in order to sustain production base and ensure ecological and livelihood security. The extension system needs to disseminate a broad array of information starting from farm to fork in an integrated manner for safe delivery from field to the consumer considering all the aspects of conservation and production technologies, post-harvest management, processing and value addition. Such knowledge based decision should be incorporated in reshaping of extension approaches. In present scenario, the extension system envisages a transformation from technology driven to market driven extension, where fishers would give emphasis on commercialization of fish and fish based products, maintenance of quality, fulfilling consumers' demands, etc., in the program planning process for the effectiveness of any extension programme.

Further, with the advent of global competitiveness and market liberalization, our prevailing extension system has to be strengthened with innovative extension approaches to tackle the recent challenges in fisheries *viz.*, climate change, weather aberrations, dwindling resources and quality and safety of products; so that fishers can adjust their production portfolio keeping eye upon the emerging trends in food consumerism in domestic as well as global markets. Grooming fishers with proper information support for taking right decision related to fish production essentially requires a strong network of extension systems, supported with government initiatives and strong linkage among extension scientists and functionaries working for fishery sector development. This would ensure the livelihood security of millions of fisher communities by improving the quality production and creating better job opportunities, which intends to bring out planned changes to meet the needs of the present generation without compromising the future generation's requirements.

Innovative extension approaches for technology dissemination in fisheries

Earlier in developing countries, the extension personnel were involved in diffusion of farm technologies generated by public research organizations, mostly disseminated through appropriate mechanism, viz., On Farm Trials (OFT), frontline demonstrations (FLD), field visits, fishers' meetings, media use, etc. This process had the conceptual backup from the 'diffusion of innovation' model. But in the last two decades, the paradigm shifts in development pivots to the enhanced concern for future generations to meet their basic needs, accordingly the nature, design and integration of fisheries technologies are drawing attention of the extension professionals and practitioners across the globe. In India, different models for transfer of technology have been tested and some robust extension approaches have been validated. Furthermore, the frontline extension system of the country has been revisited and sharpened through fishers oriented approaches for technology adaptation and dissemination. The extension system in India has been designed to move beyond technology and beyond commodity through reciprocal fishers-research-extension linkages. Fish farmers still suffer from lack of access to appropriate services like credit, inputs, market, extension, technologies etc. Keeping eye upon this, the World Development Report has focused on need to restructure and revamp agricultural extension system as a tool for realizing the growth potential of farm sector against the widening demand–supply pressures for ensuring sustainable fisheries, inclusive, pro-poor socio-economic development. Therefore, participatory technology development and participatory extension approaches emerged as a part of integration of the '*interdependence model*' and the '*innovation systems framework*' that offered more inclusive ways of involving the institution in technology generation, customization and diffusion. Extension approaches have to be redefined depending upon the components involved for sustainable growth and livelihood security of the farmers for which a conceptual framework has to be developed in response to recognizing and considering different livelihood assets viz., *human, social, physical, natural and financial resources*. Some of the following innovative extension approaches originating from multiple sources must be adopted on trial basis to make fisheries more lucrative and sustainable which can be replicated in the fishery sector interwoven with numerous challenges like increased production with sustained natural resources, growing market demand for processed products having entrepreneurial opportunities, protection and conservation of environment, and promoting international trade.

An analysis of national extension systems in the Asia and Pacific region by Qamar (2006) observes that agricultural extension is undergoing a major transformation as a result of failure of public extension systems perceived to be outdated in the context of globalization, decentralization, and information technology revolution. Extension systems in many developing countries are undergoing a paradigm shift to more fishers -oriented approaches based on rural innovation that emphasize the importance of interactive, integrated and multidisciplinary oriented mutual learning between formal and informal knowledge systems(Friederichsen, 2009).

a. Asset Based Community Development (ABCD) approach

As per the traditional approach to development, poor people see themselves as people with special needs that can only be met by outside supporting agencies. But Asset Based Community Development (ABCD) approach intends for the development of community based on the principle of identifying and mobilizing individual and community 'assets', rather than focusing on problems and needs. It is an extension approach in which a community's micro-assets are linked with its macro environment. It believes that communities can initiate and sustain the process of growth and development themselves by recognizing and harnessing the existing, but often unrecognized assets, and thereby promoting local economic potential to drive its development process (Rans & Green, 2005). The approach is optimistic in nature, because the focus is on *'what is possessed by the community, rather than the problems of the community."*

The focal point in this approach is asset and not the need of the community. Assets of individuals, associations and institutions are identified after an extensive survey and assets are then matched with the need of the people to empower communities to control their futures and create tangible resources such as services, funds and infrastructures etc.

(Foot and Hopkins, 2010. In fishery, ABCD approach gives greater emphasis on reducing the use of external inputs and on a high degree of social mobilization in which the assets of the poor (*social, physical, financial as well as human*) can be utilized to bring sustainable livelihoods in fisheries through number of different fishery related activities.

Five Key Assets in ABCD

As per ABCD approach there are 5 categories of asset inventories such as individuals, associations, institutions, physical assets and connections

1. **Individuals**: Every individual has got certain assets, gifts and qualities; such individual is at the center of ABCD approach.
2. **Associations**: Groups of people working with a common interest are critical to community mobilization.
3. **Institutions**: The assets of institutions help the community capture valuable resources and establish a sense of civic responsibility.
4. **Physical Assets**: Physical assets such as land, buildings, space, and funds are other assets that can be used.
5. **Connections:** These are the exchange between people sharing their assets by various methods.

b. Rural advisory services (RAS)

Rural Advisory Services (RAS) refer to all the different activities that provide the information and services needed and demanded by farmers and other actors in rural settings, to assist them in providing their livelihoods by developing their technical, organizational and management skills and practices (GFRAS, 2011; FAO, 2010). RAS designers and implementers must recognize the diversity of actors in extension and advisory fields (public, private, civil society); the need for extending support to farmers' producer organizations (FPO) and rural communities (beyond technology and information sharing) including advice related to farm, organizational and business management; and explaining the role of facilitation and brokerage in rural development and value chains. In the case of aquaculture, large-, medium- and small-scale fishers need different types of RAS support. The large aquaculture farms are mostly self-reliant and need only regulatory support, while medium-sized farms need mobilization and facilitation support in addition to regulatory support. Small aquaculture farms need more education and input provision alongside facilitation (Kumaran, 2014).Timely sharing of research recommendations can address the problem of disseminating information to fishers. In this direction, innovative strategies are being formulated keeping the fishers' needs and capacities in mind to pass on appropriate technologies by combining Internet, telecommunications, video, and print technologies that may bridge the information gap and empower fishers to make better production and marketing decisions (McLaren et al. 2009).

In fishery sector, RAS helps in

⇨ Providing management and business development support appropriate to the scale, resources and capacities of each fisherman.

- ⇨ Better understanding markets (prices, products, seasonality, standards, value addition etc.) related to fish and fish products.
- ⇨ Linking fishers to other stakeholders involved in provision of varied support and services.
- ⇨ Creating platforms to facilitate interaction and sharing among the various stakeholders including FPOs to ensure coordinated support to fishers.
- ⇨ Exploiting information communication technologies (ICTs) to provide fishers with a range of information related to weather, prices, extension programmes and generic information regarding fisheries.
- ⇨ Facilitating the formation of FPOs and also collaborate with FPOs to strengthen the demand and supply side of RAS.
- ⇨ Promoting institutional and policy change to enable and support small-scale fishery.

  RAS encourages the formation/ organisation of groups by involving individual fishers, who have little influence over the social, economic and political processes affecting them, but as a group/ organizations and networks they can deal with their specific challenges and make their voice heard. Such groupings can act as platforms to articulate concerns, exchange knowledge, influence policies and engage in collective action so that their agriculture remains sustainable and profitable. Effective formation of Rural Resource Centres (RRCs), Fishermen Cooperative Society, Farmers producers Organisations(FPOs) can be instrumental by galvanizing collective action in order to ensure better access to markets and to support innovation by their members in related activities (Sundaram, 2014).

c. Model Village System of Extension (MVSE) approach

MVSE is an integrated and holistic extension approach where *community participation* is prioritized for suitable technological interventions in the fisheries to bring all-round development in fisheries sector in terms of *socio-economic upliftment, technological empowerment, self-governance* thereby enhancing the futuristic knowledge base and skills through *participatory framework.* MVSE emphasizes on involvement of all stakeholders in the process to converge their activities with a stake in the food value chain *linking producer to consumer.* Nevertheless, MVSE is an action research taken up in fishers' farm based on the principle of leveraging the activities, investments and resources from outside agencies/ externally aided projects resulting higher productivity, ensuring food security and sustainable improvement in overall quality of life by promoting leadership, self-dependency of the community in food chain. Economically viable, ecologically compatible and socially acceptable suitable technologies are successfully intervened in a cluster approach through participatory mode by integrating the multi-disciplinary research. The cluster of villages is adopted as model village, the success of which is later replicated to other villages. The village is developed as a commodity village branding for a particular commodity in the market.

MVSE approach works on the following principles:

- Promotes self -governance among the fishers
- Skill improvement and leadership development among the fishing community.
- Establishing linkage through pluralistic convergence of various stakeholders associated in the sector.

- Encouraging the market opportunities through commodity based village development (CBVD).

d. Farmers Field School (FFS) approach

The FFS extension approach is an alternative to the top down extension approach which was evolved as a method to solve complex field level issues in fisheries sectors. FFS aims to build fishers' capacity to analyze their production systems, identify problems, test possible solutions, and eventually encourage the participant member to adopt the practices most suitable to their farming systems (FAO, 2003 c). This is a learning-by-doing approach which emphasizes group observation, discussion, dissection, modification, and promotes field-based experimentation, analysis for collective decision making followed by actions. The FFS approach is an innovative, participatory and interactive learning approach that emphasizes problem solving and discovery based learning. FFS also provides an opportunity to fisher sto practice and evaluate sustainable resource use technologies, and adoption of new technologies by comparing with their conventional technologies developed in congruent with their own tradition, culture and resource use pattern. The goal of FFS approach is such that, after observing and comparing the results of field level experimentation fishers will eventually "own" and adopt improved practices by themselves sidelining the conventional ones without any external compulsion. Field day is being organized at the end of the season to give visibility to the entire activities to convince the non-adopters. Exchange visits with other FFS is also encouraged to learn by association and comparison A group of 20-25 fishers can form a Farm School under the guidance of a FFS facilitator. Extension workers, NGO workers, fishermen co-op members or previously trained fishers can become Farmer Field School (FFS) facilitators. The facilitators are trained by master trainers, who have expertise in the particular subject matter. FFS is a time bound activity usually covering one production cycle or a year.

It is also significant to note that irrespective of the merits of the technology, the acceptance to technologies is influenced by the extension method. Farmer Field School (FFS) model has been accepted as a good methodology because it is exclusively participatory. A special feature of this extension approach was that it reached poor and female-headed households and lower-caste households much better than the regular extension services (Tiwari et al. 2010). FFS was also found to be effective in avoiding barriers like socio-economic constraints, infrastructure problem and incompatibility of technology for the adoption of sustainable fishery practices.

The basic component of FFS is setting up of a Participatory Comparative Experiment (PCE), commonly referred to as Participatory Technology Development (PTD), whereby the fishers put the FFS concept into practice under close monitoring and supervision by the FFS members. A PCE can be developed in the field of agriculture, livestock, fishery, forestry, agro-forestry, livelihood system and others.

Principles of Farmer Field School(FFS)are as follows: -

- Field is the learning place.
- Emphasizes hands on and discovery based learning.
- Farmers become experts.

- Integrated and learner defined curriculum.
- Doing is better than learning/ seeing.
- Experiences are the start of all learning.
- Link to actual field situations and should be relevant to local needs and problems.
- Participatory monitoring and evaluation.
- Fishermen are decisionmakers.

e. Market Led Extension (MLE) approach

In order to make farming more enterprising, extension professionals need to be pro-active beyond the regular objective of maximizing the productivity of the fishers by transferring improved technologies rather fishers should be sensitized on various aspects of farming like culture, harvest, quality, processing and value addition, consumer's preference and market intelligence. This will help the fishing community to realize high returns for the produce, minimize the production costs, and improve the product value and marketability that may lead to realize the concept of doubling farmers' income(DFI).With the globalization of agriculture, emphasis on productivity and profitability to the farm enterprises has been increased and, therefore the demand- driven agriculture (and allied sectors) has led to the paradigm shift from production-led extension to market- led extension. There are many challenges in the agricultural marketing system, which can be resolved through the efforts of market- led extension models.

In this approach, fishers are viewed as 'Fish-entrepreneurs' who expects high returns 'Rupee to Rupee' from his produce by adopting a diverse baskets of package of practices suitable to local situations/ farming systems with optimum cost benefit ratio (C:B ratio) ensuring maximum share of profit by exploring the market demand. Goal of market led extension is to facilitate fishers to get better price. Market led extension focuses on harnessing the ICT tools to access market intelligence including likely price trends, demand position, current prices, market practices, communication network, etc. besides production technologies.

For farmers, as the extension system is more credible source of farm technologies, the extension personnel ought to be knowledge- and skill-oriented in relation to production and marketing of agricultural goods. Thus, revamping the extension system will have a catalytic role for ushering in farmer-led and market-led extension; which can subsequently alleviate poverty and ensure livelihood security. In the light of this, the challenge remains to motivate the extension personnel to learn the new knowledge and skills of marketing before assigning them marketing extension jobs to establish their credibility and facilitate significant profits for the fishing community. SWOT analysis of the market, Organization of Farmers' Interest Groups (FIGs), capacity development, establishing linkage and synergy, harnessing ICTs, digital marketing etc are the competencies required by the extension personnel in order to effectively implement market led extension.

f. Digital Extension approach

Extension reforms brought a transformation in fishery extension system through introduction of Information and Communication Technologies (ICTs). The ICT-enabled extension system referred to as Digital Extension has the potential for enabling the empowerment of fishing communities by improving their access to information and sharing knowledge with innovative e-agriculture initiatives (Saravanan, 2010a).

With the phenomenal growth in information and communication technology, use of IT application in agriculture will bring remarkable change in the attitude and knowledge level of user. Basic requirement is to provide most appropriate information in such a capsule that can be easily understood and used by them. This approach will strengthen the extension system for better dissemination of technology. As acase study the contribution of Digital Green, a NGO that uses an innovative digital platform for community engagement to improve lives of rural communities across South Asia and Sub-Saharan Africa is remarkable. Digital Green associate with local public, private and civil society organizations to share knowledge on improved farmers practices, livelihoods, health, and nutrition, using locally produced videos and human mediated dissemination. As per the study, the Digital Green project (participatory digital video for agricultural extension) increased the adoption of certain farm practices seven times higher compared to traditional extension services and the approach was found to be 10 times more cost-effective per dollar spent. Hence, along with ICT-based advisory services, input supply and technology testing need to be integrated for greater impact and content aggregation from different sources require to be sorted in granular format and customized in local language for rapid adoption of technologies (Balaji et al., 2007&Glendenning and Ficarelli, 2011).

The effectiveness of this innovative extension approach depends on capacity building, people's participation along with government initiative to provide strong infrastructure to be worked with the cutting edge technologies. The farmer friendly technology dissemination process needs to be handled with careful planning by the incorporation of information communication technology. The use of ICT application can enhance opportunities to touch the remote farmers to live in close proximity of the scientific input. The computer based web portals namely aAQUA, KISSAN Kerala, TNAU AGRITECH Portal, AGRISNET, DACNET, e-Krishi, ASHA, India Development Gateway (InDG) portal, Rice Knowledge Management Portal (RKMP), Agropedia, KIRAN, AGMARKNET, ITC-e-Choupal, Indiancommodities.com, Mahindra Kisan Mitra, IFFCO Agri-Portal, Agrowatch Portal, iKissan, etc.along with some mobile based Apps likemKRISHI® Fisheries, riceXpert, Pusa Krishi, Krishikosh, m4agriNEI, CIFTFISHPRO, CIFT Lab Test, CIFTrainingetc. launched in India are some of the successful digital intervention for technology dissemination.

The use of internet, mobile and video- conferencing assists the IT enabled farmers to utilize the facilities for their favors for which the most suitable permanent infrastructure is the basic requirement. Strong linkages need to be established between direct ICT interventions and it should be part of the national level program on holistic agricultural development.

g. Disruptive Extension approach:

Recently, a new extension approach christened as 'disruptive extension' comes into limelight which is considered as an innovative extension approach that creates a new paradigm of extension that eventually disrupts an existing approach followed by extension professionals in the field of agriculture and allied sectors.It is an entrepreneurial oriented sustainable extension system that can able to transform every link in the food chain, from farm to fork. It is a cost-recovery extension approach the fulcrum of which lies between resource exploitation on one side and resource conservation on another side that influence the livelihood security and technology sustainability for small scale farm holders. It deals with the following principles:

- Importance of good governance in agriculture (and allied fields) that considers the resource rights of the farmers.
- Emphasis on growing interest among the stakeholders by explicit analysis of field level issues for technology adoption.
- Potential to resolve the social conflicts for equal access to community resources through Memorandum of Understanding (MOU).
- Based on cost recovery mechanism.
- Ensure commitment to optimum resource management and maximum economic benefit to improve food security.
- Provision of community based social insurance.
- Maintaining the sustenance of the technology supports through custom hiring approach.
- Focus on pluralistic convergence of different partners to build a network of linkage with various entities around the farm households.
- Encouraging the farmers-scientist interaction for technology development, assessment and application through Farmers' FIRST approach.

Global agriculture embraces diverse actors in its endeavour to feed about 10 billion people in the planet by the end of 2050. The small, marginal & landless farmers are extremely vital for food security due to shrinking of resource day by day. The contribution of women fishers also cannot be ignored particularly in on-farm operations, harvesting, post-harvest management, processing etc., especially in fishery and animal husbandry sector. Hence, in today's scenario innovation in agriculture extension is the key to address the growing challenges, which need to be validated, integrated and scaled up and further recommended for large scale implementation by the policy makers. The innovative extension approach should be based on capacity building, skill development, people's participation along with government initiative to provide policy support to be worked with the cutting-edge technologies. Much effort has been initiated in going beyond the farm and the fishers and focus on beyond the technology to a wider innovation system.

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Processing of farmed aquaculture species and live fish transportation

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Introduction

Present day aquaculture places great emphasis on culture techniques with the aim of enhancing growth rates and production efficiency. However, the importance of harvest as the final stage in production is often overlooked. Ideally, harvest should be a process where fish are treated with the greatest care to minimise stress prior to slaughter. The consequences of failing to manage pre-slaughter stress leads to degradative changes in post-mortem muscle biochemistry ultimately subsiding final value of the product.

Post-harvest management in Aquaculture

The sustainability of aquaculture in filling the gap between an ever-increasing demand for fish and dwindling supplies from wild capture fisheries depends to a greater extent on the execution of an efficient post-harvest management plan throughout the supply chain. Post-harvest loss has long been a concern in fisheries sector. It has been estimated that 10 percent by weight of world fish catch is lost by poor handling, processing, storage and distribution (FAO 2010). Unlike in capture fisheries, which primarily relay multiday fishing operations and hence the retention of freshness is a major issue, the processors can procure the cultured varieties at 'zero storage time'. However, the importance of good manufacturing and handling practices in aquaculture are overlooked and undervalued. Undoubtedly, good post-harvest handling practices increase the market value of the harvested resources, increasing the economic value of culture fisheries overall. Optimisation of gear and harvesting practices, onfarm-handling and storage protocols, pre-conditioning and pre-processing requirements, transportation requirements etc. are inextricable, nevertheless least studied and documented.

The harvesting protocols play a crucial role in the post-mortem changes of fish. Several practices are being suggested for harvesting the crop from cage, pen and pond systems. Segregation prior to harvesting is a general protocol suggested for fish reared under captivity, to avoid the muddy flavour which is commonly encountered in most of the bottom dwelling fresh water species. Additionally, a sufficiently long starvation period is necessary to ensure that gut contents are evacuated. This is critical as in heavily fed animals, the bacterial enzymes liberated in the digestive tract may cause intense post-mortem autolytic changes, leading to the generation of off- odour, flavours, texture and discolouration and also visible colour changes in the abdominal area. Feeding interruption is crucial if further processing steps are intended. Starvation is also helpful in preventing faces trailing from the anus. The method of slaughtering is another important parameter which affect the quality and shelf life of harvested fish. In farmed fish, the most popular practice is by way of cold shock by plunging the fish directly into ice-cold water resulting in slowing process of various post-mortem biochemical reactions during storage.

The quality characteristic such as onset and progress of rigor mortis, nutritional profiling, biochemical and textural characteristics of fish meat, sensory characteristics, microbial profile and safety issues of harvested fish etc. are a few important parameters to be carefully assessed in this context. As farmed fish becomes a major contributor to world fish supplies, it is important to maintain the high nutritional quality of the product to meet the dietary demands of the consumer.

On-farm handling protocols are the back bone of the good management practices in aquaculture. The effect of bleeding is controversial although the majority consensus is that fish should be bled as soon as possible for a minimum of 30 min. There is not a common opinion on the impact of the gutting practice on farmed fish. Several studies concluded that evisceration and vacuum packaging along with icing considerably increased the shelf life of fish during chilled storage. Evisceration or gutting of fish reduces the load of intestinal microorganisms and endogenous enzyme associated with protein and lipid degradation. In addition to enhanced quality aspects, evisceration adds value to the final products which enables better price realization in the retail markets.

Filleting is considered as the first step in primary processing of many culinary preparations. Filleting yield is a major factor affecting the economics of processing operations. In farmed fish, filleting yield can be affected by farming conditions (feeding, water temperature, type of pond, and so on). For instance, commercially farmed fish species, tilapia (*Oreochromis* sp.) has the lowest fillet yield (33%) as compared to salmon (*Salmo salar*)(>50%) and channel catfish (*Ictalurus punctatis*)(>38%). Eventhough there is a general agreement that the optimum temperature for filleting is lesser than 17 °C to avoid gaping in fillets, the specific temperature threshold is species-dependent. Filleting is traditionally performed after the resolution of rigor mortis, as the fish filleted in rigor deliver poor yield with significant gaping. Also, there may be extensive loss of weight and proteins during subsequent storage if fish are filleted pre-rigor. However, it is impractical to industrially monitor and control the onset and resolution of rigor in bulk catches of wild species, whereas fish farming set forth the unique advantage of manipulating all those parameters that culminate in rigor.

Preservation and processing, is a crucial part of commercial fisheries. Ideally, any method of preservation and processing should ensure minimum quality loss and maximum nutritional retention. Traditionally, low temperature preservation such as icing and chilling is the most accepted method of preservation. Minimally processed foods with characteristics closer to that of the fresh products are gaining importance in recent years and have led to interventions in fish-processing sector for extending the shelf life with minimal use of preservatives or severe heating procedures. Cook-chill technology, which allows minimal heating followed by quick-chilling, has been conveniently used for this purpose which preserves freshness characteristics and offers extended shelf life to the product. Cooking at elevated temperature for a long period ensures microbial safety to some extent, but quite often deteriorates the sensory characteristics of fish meat. High Pressure Processing (HPP) is a recently conceived non-thermal food processing method. This is effective to achieve microbial inactivation without significant changes in texture, color, or nutritional value of food.

Seafood processing demands smart and dynamic packaging solutions that guarantee high quality products. A number of advancements are being reported in this area with the urge for high quality and safe, minimally processed seafood commodities. Some of the promising packaging techniques that need funding support for large scale adoption are vacuum packaging (VP), modified atmosphere packaging (MAP), active packaging, antimicrobial packaging, intelligent packaging and more recently smart packaging.

Conclusively, the wholesomeness of the harvested fish depends on how fast and effectively these operations being carried out. In this context, there exist huge intra and inter-regional variations in the post-harvest practices conventionally being followed in aquaculture.

Live fish transportation

Different methods of processing and preservation of seafood guarantees quality and safety to different extent. Of this, one of the most obvious method that can be adopted is keeping them alive till it reaches the table. Marketing of fish in live condition not only attracts customers for its quality but also provide an important avenue for farmers to obtain high profit margins. However, survival of fish is a major concern with respect to the live fish transportation. Fish are transported live for several purposes viz., re-stocking, live marketing, or delivered to processing plants for slaughter. This transportation stage is decisive due to the labor as well as cost involved and hence at most care is required to prevent the commodity loss on account of mortality or injury as it influences the profit margin. Stress associated with the live fishes is one of the greatest concerns affecting the health status as well as its survival during transportation and storage. Addressing this issue can effectively improve the survival rate and allied biochemical quality changes. Careful handling practices coupled with thorough knowledge on the tolerancy conditions of fishes are mandatory for effectual transportation and storage protocol. The quality criteria of customers are to be met in the target species for successful delivery of live commodity.

Harvesting of live fish: Harvesting of fish/shell fish in the early morning or night hours is recommended as the ambient temperature is lower to avoid drastic temperature swings. Capture techniques like line fishing or trapping should be adopted for harvesting fishes as these are the least damaging techniques, thus less stressful to the species. Further the time period for which they are left in gear should be minimized to prevent damage. The fishes should be handled gently while transferring from net to captive tanks. On harvesting, the fish should be held in proper conditions to minimize stress and maximize survival. In this regard, an elementary prerequisite for captive fish is the ample supply of clean oxygenated water. This is essential as the captured fish will be highly stressed affecting its respiration rates, and may cause secretions like mucous as well as excreta affecting the water quality of the holding tank. Lowering of temperature helps to reduce the metabolic rate and brings about a state of lethargy making handling easier and less stress to the species. Hence transferring the species to a well aerated tank with lower temperature is desirable. Live fish are commonly held and starved for a period of time, generally 24 to 48 hours prior to packing and transport, a procedure known as 'purging'. The objective of starving is to reduce the water quality degradation on account of faecal matter excreted by the organisms which further leads to bacterial decomposition and associated ammonia accumulation.

Transportation techniques: For effective live fish transportation, in-depth understanding on the optimal environmental condition for minimal stress and maximum survival is required. When the fish leaves its natural environment, it must be in a self sustainable environment that supplies necessary vital needs such as optimal temperature, oxygen etc. However modifications in existing environmental conditions during transportation viz., waterless system, may require additional care and adaptation procedures. In general, the methods used for fish transportation must ensure marketing of high-quality fish in a safe mode, satisfying all state and federal regulations. Commonly, there are three transport systems for live fish/shell fish: the closed water system where fish is transported in a self sustained closed bag or container with water (Fig. 1) ; the open system or tank method wherein water-filled containers of different types with requirements for survival supplied continuously from outside sources are employed (Fig. 2) ; and the modified waterless system without any water, except for being kept damped by using pre-chilled sawdust or wood shavings (Fig 3). The choice of this transportation system depends on the quality and quantity of the transported species, transportation facility available, transportation duration, size of market etc.

Future scope: Studies on live fish transportation have suggested the relevance of considering variations in osmoregulatory and water-quality sensitivity among different fishes viz., marine as well as fresh water species, during the designing of live transportation protocol. The individual diverseness within species is also accountable and depends various factors like health status, life stage etc. Hence the procedures prior to, during as well as after transportation play an important role in addressing the success of live-fish transports.

Collectives for employment and livelihood : examples of action-research interventions

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A collective is a form of organization or a group that shares atleast one common goal or objective. They are usually formal but can also be loosely formed informal groups too. Several forms of collectives have been observed in fisheries and agriculture which include cooperatives and Self Help Groups. These are useful for solving common issues like credit and marketing that most fishers face.

This communication presents two cases of action-research interventions of ICAR-CIFT, Cochin in two fishing villages in Kerala, India, which included attempts to make collectives to tackle specific problems.

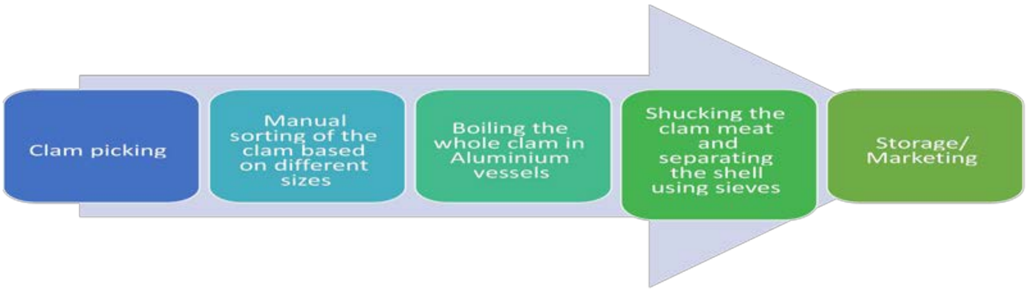
Value chain development: The first intervention was part of a larger project for developing the value chain of selected species of marine fishes. The intervention discussed is that which was done for marine fishermen in Chellanam village of Ernakulam district of Kerala. The fishers were ring seine fishermen and the women were involved in traditional processing and marketing of fish. The target species were sardine, mackerel and anchovies. The level of intervention was in the marketing aspect in trying to improve livelihoods and incomes of women. The intervention intended setting up a processing unit which the women would man and the product from the unit would cater to the domestic market. The products included cleaned, cleaned and marinated

and dried products which were packed and labeled attractively. The intimal attempts included discussing the intervention with the target population through a series of interactions. A local village fishermen Cooperative Society, which was a partner in the project, was involved in the process. After the initial meetings, the women who evinced interest with a full understanding of the project activity were selected for further capacity building on value addition, account

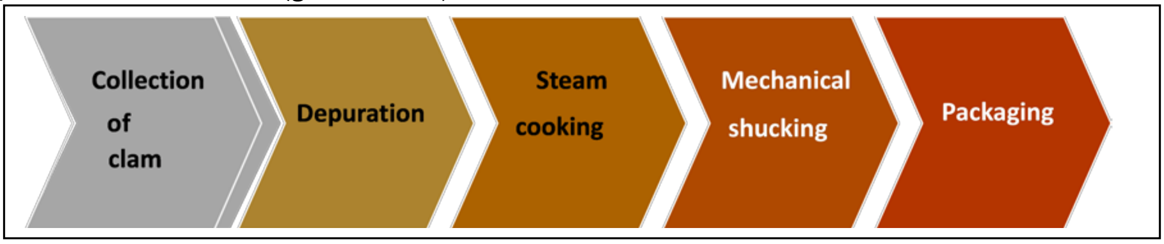
keeping and other basic requirements in running a processing facility. The facility was set up and the women took over the day-to-day management of the same. They sourced the fish from the harbours, established marketing linkages with a little hand-holding from the project team, and began processing and marketing the fish products.

Setbacks that affected the functioning of the unit included the internal dynamics of the group that ran the unit with differences cropping up on the management as well external factors like difficulty in sourcing raw material, lack of timely credit, lack of ice and water shortage. The intervention resulted in valuable lessons learnt on the need to manage the internal dynamics of groups and to ensure that they are trained in crisis management as well. The ability to make alternate plans is an important aspect in running any enterprise. Fisherwomen are constrained for resources like credit and there is need to have policies that can support enterprises.

Clam cluster development: The second intervention was in an island village, Perumbalam in Alappuzha district of Kerala. This island has about 250 families that are dependent on clam fishery for their livelihoods. The intervention was for livelihood improvement as well as to improve the quality and safety of the clam product. The existing process was first identified (given below).



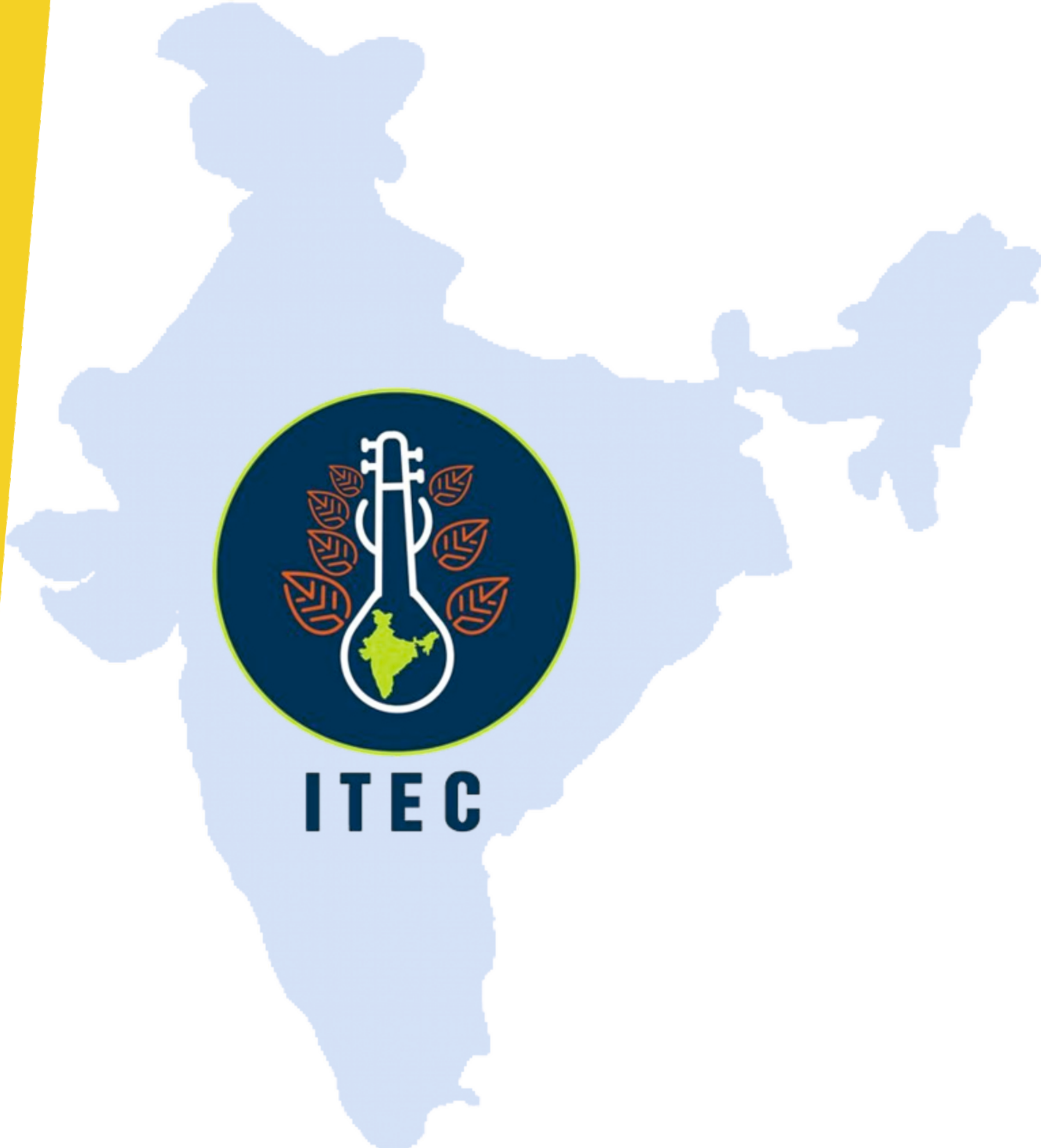
This was followed by a participatory exercise where the interventions to improve the process was discussed and finalized. The scientific interventions were explained in detail and the final process was arrived at (given below).



The entire project had the participation of the local self-government (the Perumbalam Panchayat) and an NGO (a Farmer's Club). The process followed for the intervention was the same as that of the earlier example, with initial discussions with stakeholders, capacity building and then setting up of an integrated facility which mechanized the process and reduced the drudgery of the women involved in clam processing.

The advantages were the local participation in the process of implementation of the project with major decisions taken in consultation with the Panchayat and ably assisted by the Farmer's club. The unit has been formally handed over to the community in November 2019.

In conclusion collectives can be an important from of association to solve common issues. The fishers ace issues of access to resources including credit and technology and problems in marketing. These can be addressed to some extent by participatory organizing and capacity building.



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