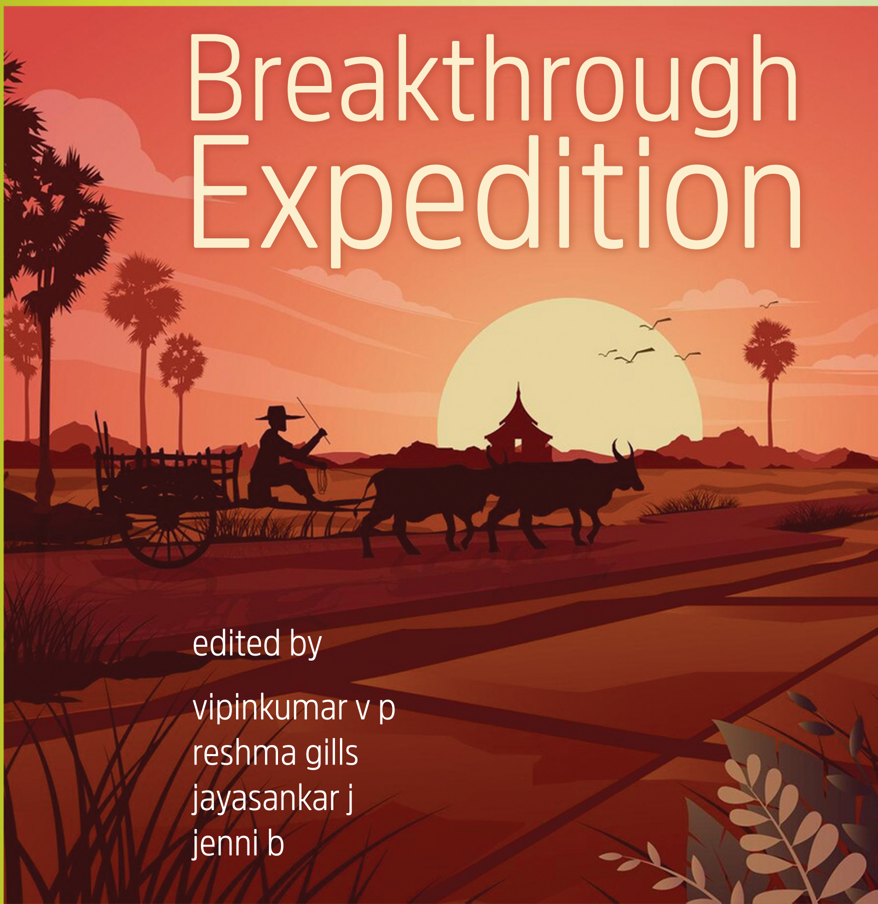

Science Camp Manual on

Experiential AgriAnalytics: Field-to-Lab Knowledge Pathways

(for BSc. (Agri) students, KAU, Thrissur)

ICAR-Central Marine Fisheries Research Institute
(Department of Agricultural Research and Education, Government of India)
P.B. No. 1603, Ernakulam North P.O., Kochi - 682 018

Breakthrough Expedition

edited by

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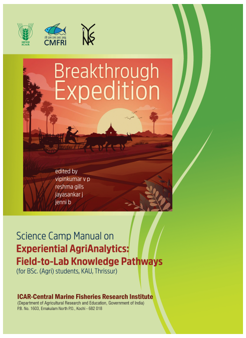
Front cover



Breakthrough Expedition: Science Camp Manual on Experiential AgriAnalytics: Field-to-Lab Knowledge Pathways for BSc (Agri) students of Kerala Agricultural University

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FOREWORD

It is with immense pleasure and profound satisfaction that I write this foreword for the Training Manual of the Science Camp titled "Experiential AgriAnalytics: Field-to-Lab Knowledge Pathways." This enlightening event, which took place from July 1st to July 5th, 2024, at the STI HUB Digital Training Hall, ATIC, CMFRI, Kochi, stands as a testament to the collaborative spirit and innovative approach to agricultural education.

Organized jointly by ICAR-CMFRI, ATIC, and INYAS-INSA, New Delhi, this Science Camp has been an invaluable platform for BSc Agriculture students from the College of Agriculture, Vellanikkara, Thrissur. The camp's central theme—integrating practical field experiences with advanced laboratory analytics—underscores our commitment to enhancing production practices and outcomes through a seamless knowledge continuum.

I would like to extend my heartfelt appreciation to Dr. Vipinkumar V.P., Principal Scientist & ATIC Manager, CMFRI, and Dr. Reshma Gills, Scientist, CMFRI & INYAS Member, whose dedication and meticulous efforts were pivotal in orchestrating this event. Their tireless work has not only made this Science Camp a success but has also set a benchmark for future educational initiatives.

The camp was designed to bridge the gap between theoretical knowledge and practical application, offering a range of enriching experiences including: Innovative Classes on cutting-edge topics in agriculture and fisheries, Hands-on Exercises to solidify learning through practical engagement, Field Exposure and Institutional Visits providing real-world insights, Access to Laboratories, Aquarium Collections, and the Museum at CMFRI, enhancing experiential learning and Interactive Sessions with farmers, fostering a meaningful dialogue between students and practitioners.

Such opportunities are invaluable as they enable students to experience the continuous flow of knowledge and data from the field to the lab, thereby facilitating real-time decision-making and innovation in production systems. We believe that these experiences will significantly enrich the students' educational journey and their future contributions to the field.

To all the students and faculty who participated in the sessions, I extend my warmest congratulations and best wishes. Your enthusiasm, curiosity, and commitment to learning are truly commendable. May the knowledge gained and the experiences shared during this Science Camp inspire you to pursue excellence in your academic and professional endeavors.

In closing, I am confident that this manual will serve as a valuable resource, reflecting the dedication and hard work invested in making this Science Camp a memorable and impactful experience.

Warm regards,

Dr.A. Gopalakrishnan
Director, ICAR-CMFRI
Kochi

PREFACE

It gives me immense pleasure to present this compendium that chronicles a unique and inspiring journey of knowledge "Breakthrough Expedition: Science Camp Manual on Experiential AgriAnalytics: Field-to-Lab Knowledge Pathways" for BSc (Agri) students of Kerala Agricultural University, organized from 1st to 5th July 2024 at ICAR-CMFRI, Kochi. Conceived as a transformative learning experience, this camp brought together enthusiastic B.Sc. Agriculture students from Kerala Agricultural University, Thrissur, to traverse the seamless continuum of field realities and laboratory precision.

In an era where agriculture is swiftly evolving into a data-driven, analytics-powered enterprise, this Science Camp served as a vibrant platform to immerse young minds in the dynamic interplay between traditional practices and cutting-edge innovations. Through an engaging blend of expert lectures, hands-on activities, field exposure, institutional visits, and farmer-student interactions, the programme aimed to cultivate curiosity, spark innovation, and ignite a lifelong passion for sustainable agri-based research and development with special emphasis on fisheries perspective.

Each of the ten chapters in this volume captures the essence of the camp's thematic pillars—ranging from integrative analytics and digital interventions to field diagnostics and marine agri-technologies. The contributions from a distinguished panel of subject experts and the enthusiastic participation of students created a synergy that truly reflected the spirit of experiential learning which was observable from the comprehensive report submitted by students as the last chapter of this manual.

The wholehearted support extended by INYAS-INSA, New Delhi added tremendous value to this initiative, helping bridge the academic-practical divide and nurture next-generation agri-scientists. The vibrant energy, scientific insight, and meticulous planning and tireless efforts brought in by Dr. Reshma Gills, Scientist, ICAR-CMFRI and esteemed INYAS Member, played a pivotal role in shaping the camp's success and enriching the overall learning experience for every participant and also to bring out this manual. The scholarly inputs, editorial finesse, and unwavering support of Dr. J.Jayasankar, The Head of the FRAEE Division and Dr. B.Jenni, The ACTO of ATIC as Co-editors of this compendium were also instrumental in transforming this initiative into a meaningful and enduring academic resource.

As the major editor and event coordinator, I believe this compendium stands as both a celebration of learning and a catalyst for further exploration in the fascinating confluence of agriculture and fisheries sciences though it is only a tip of the iceberg. May this volume inspire many more such collaborative endeavours in the years to come.

Dr. Vipinkumar V.P.
Principal Scientist & ATIC Manager,
ICAR-CMFRI

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Seed Production of Marine Fishes

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Introduction

It has long been recognized that a good source of juveniles is the most important prerequisite for fish farming. Non availability of the seed for stocking in quantity and quality at the right time, will affect the production plans. Most of the worlds fish aquaculture still depend on the fry almost comes exclusively from wild. Seed supply from the wild is often unpredictable and seasonal. Hatchery production of seeds of economically important finfish ensures a steady supply of quality seeds for aquaculture operations.

The successful hatchery production of marine fin fishes, depends on various factors like proper maintenance of broodstock, efficient live feed production systems, larval rearing protocols including water quality management, feed management and nursery rearing systems.

BROODSTOCK

Availability of adequate number of healthy broodstock is of prime importance in successful induced-breeding operations or artificial propagation, especially of the most important cultured species. There are two sources of finfish broodstock: wild-caught adults and those reared in ponds or cages. It is advantageous to use cultured broodstock as they are acclimatized to captive conditions, free from exogenous pathogens and diseases. The disadvantages of using wild stock are uncertainty of capturing them, the relatively large expenditure needed for their capture and transport, and the limited opportunities of obtaining good quality eggs. The selection bloodstock should based on the following criteria: fish movement should be active, fins and scales should be complete, and free from diseases and parasites. Upon arrival at hatchery, the fishes should be treated with approved antibiotics.

Age at maturity

The age at maturity varies for different species of fishes. Knowledge about the age at which the species matures is useful in the selection of right sized brooders for breeding purpose. Rabbitfish begins sexual maturation and spawning in one year of captivity. As Protandrous hermaphrodites, the seabass are mature males on the third year of captivity and became females on the following year. On the other hand, groupers, being protogynous hermaphrodites, are mature females after four years of its growth. It takes longer for them to be transformed to mature males. Both milkfish and snappers take 5 years to attain sexual maturity.

Determination of Sex and Maturity of Spawners

Determination of sex and the maturity of spawners are very important in the artificial propagation of marine finfishes. Determination the sex of spawners through examining the external morphology of the fish is often difficult and unreliable. Ripe males are easy to distinguish during the spawning season since milt oozes out from the urogenital l pore as its abdomen is pressed. If fishes are fully matured, the milt will be white and creamy; poor milt is watery and curdled. Milt which is not ripe will demand strong pressure and will be mixed with blood.

The commonly-used method to assess gonadal maturation of broodstock is through gonadal biopsy. Gametes are removed from either an anaesthetized or unanaesthetized fish by using a polyethylene cannula. The inner diameter of the cannula to be used varies with the size of eggs to be sampled. The cannula is inserted

4–15 cm into the gonad through urogenital pore and gametes are drawn into the cannula by aspiration as the cannula is slowly withdrawn. The distance to which the cannula is inserted varies with the length of the gonads. Samples from the middle portion, especially of the ovary, are generally considered to be the most representative.

The eggs collected through cannula are observed for its eggs diameter and the average egg diameter is determined from a batch of 50–10 by using a micrometer and their developmental stage is assessed under the microscope. Gonadal maturation is then expressed in terms of average egg diameter and the developmental stage of the eggs. The milt collected is removed from the cannula by blowing it onto a clean dry Petri dish. A small portion of this is mixed with a drop of seawater or brackishwater, depending upon the species, and examined immediately under the microscope. Sperm motility and vitality are then assessed.

Factors Affecting Gonad Development

Nutrition

Poor nutrition can result in poor or no reproductive performance and that lack of vitamin supplement could affect sperm quality. Mere reliance on natural food may lead to poor or variable reproductive performance. Fish broodstock diets are now formulated to include high levels of n-3 fatty acids which include enhanced levels of both docosahexaenoic acid and eicosapentaenoic acid. Eggs considered to be of better quality have higher content of these fatty acids. Furthermore, successful embryonic development in fish has been shown to be dependent on the balance of aminoacids present in the egg. However broodstock fed on 'natural diet/s' often produce eggs of better quality than those on formulated commercial diets. Thus it appears that different fish species may have different dietary requirements and that diets of broodstock should be tailor made to ensure good egg quality.

Environment

Photoperiod

One of the factors considered being of great importance to the inducement of sexual maturation and spawning is photoperiod. Photoperiod manipulation is now being employed to alter the normal reproduction of a few cultured species. The greatest advantage of altering the spawning time of the cultured species is the availability of fry for stocking in ponds, pens and cages throughout the year.

Temperature

Water temperature is another important factor which influences the maturation and spawning of fish. In some species of fish functional maturity is directly controlled by temperature; in others, the time of spawning is regulated by the day-length cycle such that it occurs when the temperature is optimum for survival and the food supply is adequate.

Salinity

Salinity is related to maturation and spawning especially for the spawning which shows spawning migrations.

Other environmental factors

In addition to photoperiod, temperature and salinity, there are other less obvious factors which may affect the maturation and spawning of broodstock. These less obvious factors, which include rainfall, stress, sex ratios, stocking density, isolation from human disturbance, dissolved oxygen, social behaviour of fish, presence of heavy metals and pesticides also influence maturation in fishes.

SPAWNING AND FERTILIZATION

Selection of Spawners

The selection of spawners from the broodstock should be done months before the beginning of natural spawning to allow ample time for the fish to be conditioned to environmental and diet controls. Spawners are normally selected based on the following criteria:

- fish should be active
- fins and scales should be complete
- fish should be free from disease and parasites
- fish should be free from injury or wounds
- males and females of similar size are preferred

Spawning

After the selection of spawners, the fishes are transferred to spawning tanks. The ratio of male : female in spawning tanks 1:2. Water in spawning tanks should be clean and in good condition.

Two major techniques are used in the spawning of finfishes namely natural spawning by environmental manipulations and hormonal induction of spawning.

Natural Spawning by Environmental Manipulation

The method involves the simulation of the natural spawning environment in which temperature, artificial rainfall and tidal fluctuation are manipulated.

At the beginning of the new moon or full moon, the water temperature in the spawning tank is manipulated by reducing the water level in the tank to 30 cm deep at noon and exposing to the sun for 2–3 hours. This procedure increases water temperature in the spawning tank to 31°–32°C. Filtered seawater is then rapidly added to the tank to simulate the rising tide. In effect, the water temperature is drastically decreased to 27°–28°C.

The fish spawn immediately the night after manipulation (18.00–20.00 h) or, if no spawning occurs, manipulation is repeated for 2–3 more days until spawning is achieved.

Hormonal induction of spawning

All of the cultured species exhibit spontaneous spawning but this is seasonal and at times unpredictable. Thus induced spawning to ensure availability of eggs, to meet fry demand and as a supplement to natural spawning may be undertaken.
Manipulations of various environmental parameters, such as temperature, photoperiod, salinity, tank volume and depth, substrate vegetation, etc. can often improve the reliability of spawning. However, in some species hormonal treatments are the only means of controlling reproduction reliably. Over the years, a variety of hormonal approaches have been used successfully. These methods began with the crude use of ground pituitaries from mature fish—containing gonadotropin (GtH.—which were injected into broodstock to induce spawning Today, various synthetic, highly potent agonists of the gonadotropin-releasing hormone (GnRHa) are available as well as sustained-release delivery systems for their controlled administration These methods have contributed significantly to the development of more reliable, less species-specific methods for the control of reproduction of captive broodstocks.

Agents used for induced spawning in fishes

SPH - acetone-dried pituitary gland homogenate

It was found that pituitaries collected during the spawning season were more effective in inducing spawning.

Human chorionic gonadotropin (hCG)

Unlike pituitary extract, Human chorionic gonadotropin (hCG) is often given in a single dose, which ranges between 100 and 4000 international units (IU) per kg body weight.

Gonadotropin-releasing hormone (GnRH) and agonists (GnRHa)

Studies in female broodstocks indicated that GnRH and GnRHa were effective in inducing ovarian development, FOM and ovulation in doses ranging from 1 to 15 mg GnRH kg^{-1}or 1 to 100 mg GnRHa kg^{-1}. GnRH and its agonists can be used again in subsequent spawning seasons with no reduction in their efficacy. GnRH acts at a higher level of the hypothalamus–pituitary–gonad axis. Consequently, GnRH can provide a more balanced stimulation of reproductive events by directly or indirectly affecting the release of other hormones necessary for successful FOM, spermiation and spawning.

Sustained-release delivery systems for GnRHa

Repeated handling of broodstock requires substantial labor, time and monitoring. A variety of GnRHa-delivery systems have been developed and tested for the sustained release of hormones.

Fertilization and incubation

The fish that are induced to spawn by hormone injection will be ready to spawn within 9–12 hours after the final injection. The schedule of injections for subsequent spawning must be synchronized with the natural spawning time of the fish which occurs in late evening between 18.00 and 24.00 h. On the other hand, in the stripping method, it is still necessary to sample the eggs from gonads by cannulation and examine them under the microscope.

Determination of egg and larval quality

Several parameters are used to assess fish egg and larval quality. These include the rates of egg viability, hatching and normal larvae. Chemical composition of eggs are also analysed and of the egg chemical constituents, fatty acids, amino acids, ascorbic acid, yolk protein and DNA and RNA have been reported to have an influence on egg and larval quality.

LARVAE-REARING

The rearing tanks are usually made of plastic, fiberglass or concrete. The shape of the tanks can be rectangular or circular. Volume ranges from 1 to $10m^3$. The tanks are usually protected from sunshine and heavy rain.

Five hours before hatching, the developing eggs are transferred to larvae-rearing tanks. The tanks are provided with mild aeration. The larvae start to hatch 16–25 h after fertilization depending on temperature and species. The usual stocking density of developing eggs is 100–200 eggs/l.

- Type of food
- Food density
- Water quality
- Environmental factors

The most important environmental factors affecting larval growth and survival are: (1) light, (2) temperature, and (3) salinity.

(1) Light. The effect of light intensity and photoperiod on the growth and survival of larvae has received little attention in the past. Generally, fish larvae are reared either under continuous light or under day and night conditions.

Light is of primary importance since most marine fish larvae are visual feeders. Nevertheless, the larval eye at first feeding is very simple, with no capabilities of distinguishing between different illuminations. High light intensities of about 1000–2000 lx at the water surface are commonly used in hatcheries. [15]The reflections from surfaces in a tank are very important for the light distribution in the . Black tanks are best suited to reproduce natural illumination conditions. White-walled tanks should be avoided since they would be a perfect wall trap due to the phototaxis of the larvae. Green water and dark walled tanks seems to be beneficial, as growth, survival and nutritional condition are usually enhanced.

(2) Temperature. Temperature can be either beneficial or detrimental to fish larvae. Temperature regimes outside the tolerance limits of a particular species will cause mortality of larvae while temperature regimes within the range that give good survival may be used to accelerate or even maximize growth of the larvae. High temperatures will shorten the time from hatching to metamorphosis, and consequently, mortality may be reduced.

The effects of temperature on the growth and survival of fish larvae must be determined for each species. Apparently, the eggs and larvae of tropical and subtropical species are generally stenothermal.

(3) Salinity. The effect of salinity on the growth and survival of fish larvae is primarily on larval osmoregulation. Survival of larvae of many species may be better at low salinities than higher salinities since low salinities are isosmotic to body fluids.

REARING ENVIRONMENT

Good quality seawater at 30–31 ppt is required for larvae rearing. Water temperature is also important and should range from 26° to 28°C to promote fast growth of larvae.

Larval tanks are prepared one to two days prior to the transfer of newly-hatched larvae. Filtered seawater is added to the tanks and very mild aeration is provided. After stocking, unicellular algae (*Tetraselmis* sp. or *Chlorella* spp.) are added to the tank and maintained at a density of 8–10 × 10 or 3–4 × 10 per ml for *Tetraselmis* sp. and *Chlorella* spp., respectively. These algae serve a dual purpose: as a direct food to the larvae and rotifer and as a water conditioner in the rearing tank.

Green water and clear water

Microalgae affect the microbiology, nutrition, feeding and behaviour of larvae. The addition of microalgae to the tanks during early rearing of the larvae may affect rearing performance. Microalgae addition rapidly affects the biochemical composition of the rotifers in the larval tanks. Larvae from green water tanks showed higher survival and growth, and less gut contents than larvae reared in clear water. The growth and survival of fish larvae can also be affected by the type of microalgae used. Dead or dying would increase the substrate.

Fish larvae can be reared under stagnant or open-system conditions. Generally, partial water changes are provided and microalgae are supplied to the rearing tanks during the initial stages of culture. Low exchange rates of water may affect the retention time of prey in the larval tanks and changes may occur in the biochemical composition of the prey before being consumed by the larvae. Algal addition is advantageous since the prey can continue feeding. Consequently, in clear water systems, there is a progressive decrease with time in prey quality. This loss of prey quality can be partially avoided by reduction of the prey residence time through an adequate adjustment of the prey density and the prey/larvae ratio.

The day following stocking, the bottom of the larvae-rearing tank should be cleaned and every day thereafter. This is done by siphoning off unfertilized eggs, faeces, dead larvae and uneaten food accumulating on the bottom of the tank. About 20% of the tank water is changed daily for the first 25 days of the rearing period, then increased to 40–60% per day for the remaining culture period. Since seabass can also be cultured in freshwater, it is recommended to reduce the salinity of rearing water when the larvae are still in the hatchery, before transfer to a freshwater environment. Beginning from the twentieth day, salinity can be gradually lowered until freshwater condition is reached on the twenty-fifth day.

FEED AND FEEDING

Prey size

Prey size may affect the prey ingestion by early fish larvae. It has been reported that the use of small sized rotifers significantly improves the initial feeding performance of fish larvae at the earlier developmental stages. The effect on feeding of using small sized rotifers is mainly due to an increase in feeding incidence rather than in ingestion rates. Therefore, small rotifer supply would improve the incorporation of the larvae to the exogenous feeding from opening. In spite of this, only large rotifers are commonly used in hatcheries for some species. Small sized nauplii of various copepod species were found to very useful for the larval rearing of marine finfishes especially for the species with small larval mouth openings.

Prey density

Maintenance of appropriate feed density in the larval tanks is most important. Since the marine finfish larvae are visual feeders, availability of the prey in the vicinity increases the chances of feeding and saves energy of larvae used for searching the prey.

LARVAL DIETS

Most species of marine fish that have been cultured are reared on a sequential diet of rotifers, brine shrimp nauplii and dry supplemental diets.

Microalgae are the customary food given to zooplankton that will be fed to larval fish. The type of culture, temperature, nutrients, other conditions and growth phase all can affect the nutritional value of microalgae to zooplankton and to the fish larvae eating them.

Rotifers

The rotifers are considered as an important live feed in hatchery operation due to their planktonic nature, tolerance to a wide range of environmental conditions, high reproduction rate (0.7-1.4 offspring/female/day), small size and slow swimming nature. More over the filter-feeding nature of the rotifers facilitates the inclusion of specific nutrients essential for the larval predators through bioencapsulation into their body tissues. As a result it became a suitable prey for fish larvae that have just resorbed their yolk sac. The availability of large quantities of this live food source has contributed to the successful hatchery production of more than 60 marine finfish species and 18 species of crustaceans worldwide.

Two main species of rotifer have been used are *Brachionus plicatilis* (large size) and *Brachionus rotundiformis* (small size).

Artemia

Among the live diets used in the larviculture of fish and shellfish, nauplii of the brine shrimp *Artemia* constitute the most widely used food item. the unique property of the small branchiopod crustacean *Artemia* to form dormant embryos, so-called ‘cysts’, may account to a great extent to the designation of a convenient, suitable, or excellent larval food source that it has been credited with. In marine finfish larval rearing, artemia feeding is done when larvae is big enough to capture larger preys. Artemia is usually given after 5-10 days of initial rotifer feeding. *Artemia* nauplii are maintained in the larval culture tank at densities of 0.5 to 2 per ml for most species of finfish.

Copepods

Copepods were found to be best alternative and most appropriate for marine fish larvae in which rotifers are an unsuitable first feed. Copepod nauplii are a common natural feed for marine fish larvae species. Small size of copepod nauplii make them suitable for small marine fish larvae at first feeding.

Feed quality

Enormous efforts has been done on improving the quality of both live foods and formulated diets for larval fish by better understanding of the nutrient requirements of larval fish. Enrichment of live foods has been a major area of emphasis. Artemia can be low in several fatty acids and various products and protocols have been investigated to improve artemia nutrient quality. Rotifers, a commonly given first food, are often enriched in an attempt to improve their nutrient quality. There are a number of commercial products are now available for fatty acid enrichment of live foods. The appropriate concentration of a specific fatty acid and how it interacts with other fatty acids is to explored for a better management of feed quality.

Compound larval feeds

The three main types are microencapsulated, microbound and microcoated diets. Early marine fish larvae have difficulty in accepting and digesting microcapsules and microparticulates. Microencapulsted feeds provide an alternative way to administer vaccines and therapeutic agents to larvae. During early stages, larvae have difficulty in recognizing inert particles as feed

Feed management

Newly hatched larvae are usually not given food on the first day because they derived their nourishment from the yolk and the eyes and mouth are still non functional. During the initial days the larvae were given enriched rotifers at a density of 5-20 rotifers/ml depending upon the species and age of the larvae. As the larvae grows bigger, freshly hatched brine shrimp nauplii at a density of 1-10 1induviduals /ml depending upon the species and age of the larvae. As the feeding of brine shrimp progress the rotifer density is slowly decreased and finally stopped. As the larvae grow bigger, compounded feeds were given to larvae at a rate of 1-4g/t.

Water management

Siphoning of the tank bottom to remove dirt, dead larvae, wastes and decaying uneaten food should be done every day starting from the second day of rearing. Daily water exchange from as high as 70% of the tank volume to as low as 30% is undertaken prior to feeding. The percentage of water exchange is dependent on the age of the larvae.

Fry harvest/packing /transport

At the end of larviculture, fry can be harvested and transported to fish farms. Transport is usually done in cool periods of the day. Fishes are transported in oxygenated bags places inside carton boxes lined with thermocol sheets. The transport densities depend upon the size of the fish, species of the fish, distance to be traveled etc. Reducing the temperature and salinity during transport help to improve the survival.

Conclusion

The hatchery phase is one of the bottlenecks for aquaculture expansion. Broodstock development and Induced spawning techniques have improved drastically over years for a number of species by administering gonadotropin releasing hormones via injection or implantation. Advances have been made in broodstock diets, specifically in the use of fatty acids to improve egg quality and quantity to equal that of brooders given natural diets. Advances in the larval rearing systems, better understanding of rearing environment has improved the growth and survival of larvae in captivity. Better understanding of nutritional requirements and by improving the larval feed quality made the hatchery production marine finfishes more successful. Improvements in formulated diets for larval fish have reduced the dependence on live foods at earlier and earlier stages in the life history. Co-feeding during the larval stages helps to reduce the need for live foods and facilitates the transition to formulated diets. Recent advances in hatchery management have resulted in a much better control of critical life stages of fish. These advances will continue until the science of aquaculture is on a level with that of the other animal sciences.

2

Cage Culture Systems & Management

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Introduction

India possesses extensive marine fisheries resources, including an 8,118 km long coastline, a territorial sea spanning 193,834 km^2 (extending 12 nautical miles or 22.2 km from the shoreline), and a marine fisher population of approximately 4.0 million residing in 3,432 marine fishing villages across 66 coastal districts in 9 maritime states and 2 Union Territories, in addition to the Island Territories of Andaman & Nicobar and Lakshadweep. The infrastructure available consists of 6 major fishing harbours, 40 minor fishing harbours, and 1,537 marine fish landing centres. The relatively shallow inshore waters along the extensive coastline of the mainland and island territories provide potential for sea cage farming, particularly in sheltered areas such as bays, lagoons, and semi-exposed and exposed coasts with minimal wave action. The existing marine infrastructure and fisher population serve as complementary resources. Cage culture, a proven method for cultivating marine finfish, has been practiced for many years in countries like Australia, Norway, Chile, and several Asian nations since the 1950s. The growing demand for cultivating various marine finfish, driven by their high consumption value, has led to a global increase in marine aquaculture demand. In India, sea cage farming was initiated by CMFRI with support from the Ministry of Agriculture & Farmers Welfare and the National Fisheries Development Board (NFDB). It is gaining traction as a commercial seafood production system in the country. Numerous R&D programs in cage culture, along with demonstrations and participatory cage farming, have led to the development of an economically viable farming method, popularizing the technology.

Site selection

Effective cage culture depends on careful site selection, ensuring the chosen location is designed and operated to maintain optimal water quality and minimize stress conditions. Before finalizing a site for cage culture, it is essential to consider water and sediment quality, as well as gather relevant biological and natural distribution information for the targeted species. The various factors involved in site selection are as follows:

Physical factors

Physical criteria are crucial considerations in cage culture systems, including parameters such as current movements, turbidity, and water temperature. Turbidity, increased by heavy monsoons and freshwater runoff, makes water unsuitable for cage culture during such periods. The optimal water temperature depends on the species being cultivated; most tropical species prefer a range of 27–31°C, while temperate species thrive in temperatures between 20–28°C. In the Asian region, annual temperature variations range from 20–35°C in tropical countries to 2–29°C in temperate countries. Selecting an appropriate site for cage culture requires a thorough evaluation of these physical factors to ensure the success and well-being of the cultivated species.

Chemical factors

The assessment of water quality in cage systems is heavily dependent on the chemical parameters of marine waters used in cage culture. Key chemical factors in this context include salinity, dissolved oxygen, pH, ammonia, nitrates, and nitrites. Different species of fish have varying oxygen consumption rates; for example, pelagic fish like snapper and seabass require more oxygen than demersal species like grouper. Tropical species typically thrive in optimal salinity similar to normal-strength seawater and show intolerance to low salinities, such as 10–15 ppt. Therefore, a suitable cage culture site should maintain salinities between 15–30 ppt to allow flexibility in changing cultured species based on market demands. The preferable pH range for most marine species is between 7.0 and 8.5. Ammonia-nitrogen levels in the water should be kept below 0.5 ppm, with measurements recommended during neap tide when the water current is slow. Nitrite levels in a suitable cage culture area should not exceed 4 mg/liter, while nitrate levels should remain below 200 mg/liter. Although toxic blooms from a few tropical marine species of Cyanobacteria (e.g., Lyngba and Oscillatoria, Moore, 1982) are uncommon, various marine algae groups, including diatoms, cyanobacteria, and dinoflagellates, may form blooms.

Topographical factors

Topographical criteria are crucial for the successful establishment of cage culture. For stationary cages, it is important to select a site where wind velocity stays below 5 knots, while floating cages require wind speeds not exceeding 10 knots. Wave heights should be limited to 0.5 m for stationary cages and 1.0 m for floating ones. Strategic placement away from navigation routes is recommended to minimize the impact of vessel-induced waves. Ensuring sufficient depth beneath the cage is vital for optimal water exchange, preventing oxygen depletion, and mitigating the accumulation of debris and noxious gases from waste decomposition. Ideal bottom conditions should include a firm substrate combining fine gravel, sand, and clay to enhance productivity in cage culture. Additional site selection criteria should consider accessibility to the cages and the ability to relocate them in response to potential threats like algal blooms or low dissolved oxygen events. Fouling tends to occur more rapidly in areas with low current velocities, high temperatures, high turbidity (enriched water), and high salinity. Therefore, an ideal culture site should be near the shore, preferably with a jetty for boat connection to farms, and close to a good road for land transportation.

Cage fabrication

The Central Marine Fisheries Research Institute (CMFRI) has been a pioneer in introducing open sea cage culture in Indian waters. The institute is actively promoting this innovative method at selected locations across all maritime states in collaboration with the fishing community. The refinement of cage design and mooring technology is an ongoing process, driven by the dedicated efforts of CMFRI scientists. Through their persistent work, CMFRI aims to enhance the effectiveness and sustainability of open sea cage culture, contributing to the advancement of marine fisheries in the region.

Design

The low-cost cage developed by CMFRI is constructed using high-quality 1.5" GI pipe (B class). With a diameter of 6 m and a height of 120 cm from base to railings, the cage is designed for durability and strength. All joints are double-welded to ensure extra strength. After fabrication, the structure undergoes a protective treatment, receiving a coat of epoxy primer and two coats of epoxy grey paint to prevent rusting. The meticulous attention to detail in both design and finishing results in a sturdy cage weighing approximately 700-800 kg.

Floatation

A puff or foam-filled High-Density Polyethylene (HDPE) cage is naturally buoyant, allowing it to float on the water surface. In contrast, a metal cage requires additional flotation, which is achieved by using 10 plastic barrels with a capacity of 200 liters each, filled with air. These inflated barrels not only ensure the cage's flotation but also create a stable platform around it. This stable platform provides a secure area where fishermen can stand and safely perform various tasks such as net clearing and replacement. The combination of buoyancy and stability enhances the functionality and safety of the cage system during operational activities in the water.

Advantage of the low cost cage

The design differences between HDPE cages and low-cost cages significantly impact their functionality and cost-effectiveness. The HDPE cage floats on the water surface, positioning the outer net at water level, which creates a potential entry point for predatory fishes between the outer and inner nets. In contrast, the low-cost cage has its outer net positioned 60 cm above the water level, preventing predatory fishes from entering the middle space.

Structurally, the HDPE cage can sink if more than three people climb on the side frame, while the low-cost cage can safely support the weight of 10-15 people on its platform. The cost distinction is also substantial. The HDPE cage, including netting and mooring, costs over Rs. 6,00,000 and requires multiple crops (4 to 5) to recover the input cost. In contrast, the low-cost cage, with all components included, costs only Rs. 1,50,000, allowing for quicker recovery of investment, potentially in a single crop.

Despite these differences, both cages have similar performance area-wise, with a diameter and net depth of 6 meters each. The advantages of the low-cost cage lie in its affordability, buoyancy, and potential for faster cost recovery.

Disadvantages

In contrast to HDPE cages, metal cages experience greater wind action because they float on barrels. Therefore, without robust mooring, floating in open sea conditions during the monsoon can be challenging. Apart from this, the performance of metal cages surpasses that of HDPE cages.

The sea cage frame is designed with flotation properties and consists of two collar rings and a middle ring functioning as a catwalk in between them (Fig. 1). When using HDPE, the pipe ends are fused together through a plastic fusion welding process. The two flotation collar rings can be filled with either polyurethane foam (PUF) or thermocol. Various support pipes, brackets, and T-joints secure the two collar rings, the middle catwalk ring, and the handrail ring in their positions. The handrail pipe, which is devoid of PUF, incorporates galvanized steel brackets for corrosion resistance, matching the pipe diameter. The handrail's maximum height should be around 100 cm, shorter than the shortest person. Essential for operational and maintenance activities such as feeding, cleaning, monitoring, and grading, the service systems (catwalk, handrail, etc.) are integral components. The catwalk's minimum width is approximately 60 cm. Brackets and base supports, along with vertical and diagonal supports, not only connect the collar rings, catwalk ring, and handrail but also enhance the overall stability and sturdiness of the frame structure.

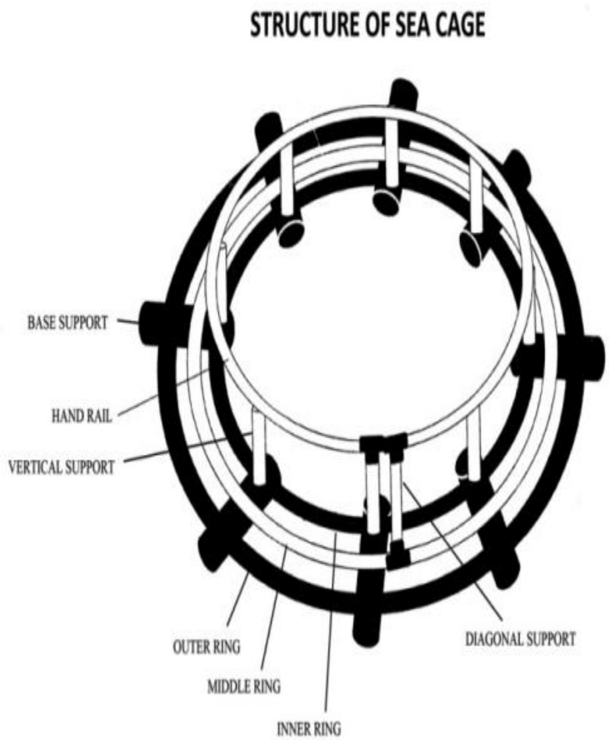

Fig. 1. Plan View of HDPE Sea Cage Frame – Collar Rings and Handrail

To maintain the shape and structure of the net bags (Fig. 2), the ballast pipe serves as another necessary support system. Typically, a 1.5-inch (38 mm) diameter HDPE ballast pipe, featuring holes at regular intervals for water flow, is utilized. Metal lines are inserted inside the pipe to increase weight, ensuring that the ballast remains submerged in water.

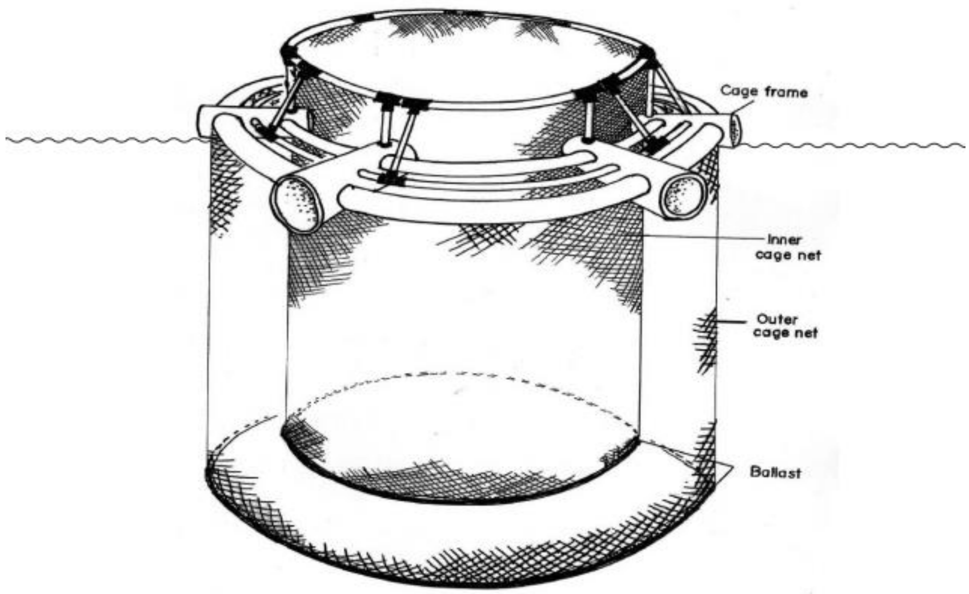

Fig. 2. Layout of HDPE Sea Cage – Frame and Net Cages (inner & outer)

Mooring system

Mooring system/assembly holds the cage in desired position and at desired depth using mooring lines, chains and anchors. Individual cages can be moored using single-point mooring system (Fig 3).

Single-point Mooring System components required for 10 cages:

(a) Anchors (embedment type) / Gabion Boxes – 100 kg each, 10 nos.

(b) D-Shackles – for 12.5 tonne SWL (Safe Working Load), 3 x 10 = 30 nos.

(c) Mooring Chains – 38-42 mm thick, length four times the depth at site, 10 nos.

(d) Buoys – 200 litre buoyancy, 4 x 10 = 40 nos.

(e) Anchor Marker Line – poly-steel rope of 36 mm diameter and 37 m length.

(f) Mooring Rope – poly-steel rope of 48 mm diameter, 3-4 strands, and 100 m length. Also splicing, steel thimble and oval ring of 22 mm at one end, 10 nos.

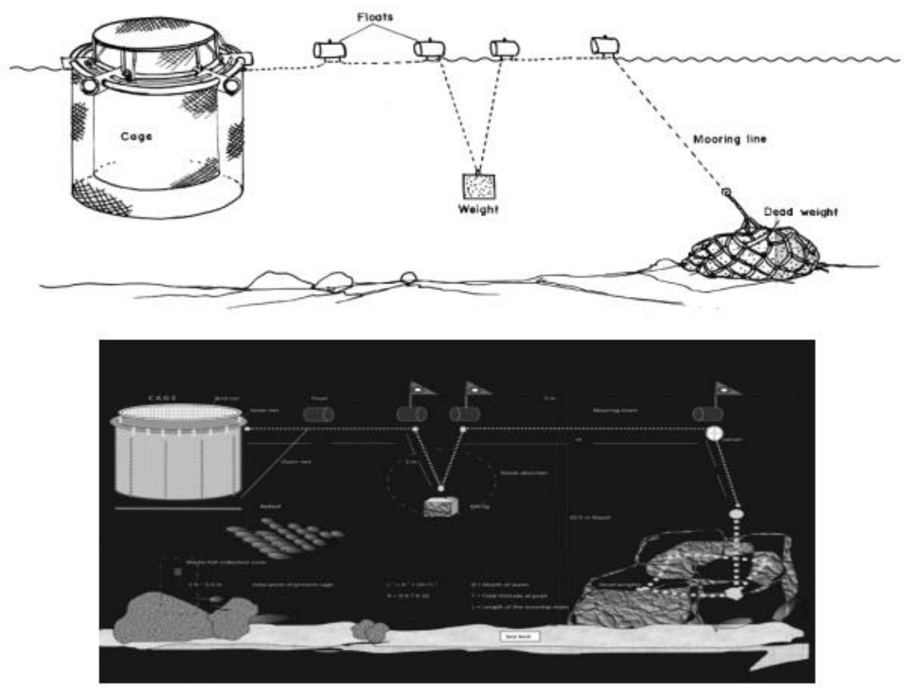

Fig. 3. Single-point mooring system for Sea Cage: Schematic diagramme (above) and Artist's view (below)

Netting Materials

Nylon (PA) and Polyethylene are the most important and widely used synthetic fibers, especially in the fabrication of fishing gear. The mesh size for net cages must be chosen based on the species of fish being farmed and to ensure optimal water exchange. Proper water flow is crucial as it enhances water quality, reduces stress, improves feed conversion, and allows for holding more fish. Net cages should match the dimensions of the cage frame and the depth of water at the site, and they must be securely fastened to the cage frame. For sea cage farming, three types of nets are essential:

(i) Outer Predator Net

Due to the turbulent sea conditions and the presence of carnivorous animals, it is important to use a suitable outer net cage to prevent predators from entering the sea cage culture. A braided UV-treated HDPE netting with a thickness of 3 mm and a mesh size of 80 mm is recommended for its strength, durability, and cost-effectiveness. The suggested dimensions for the predator net cage are a diameter of 7 m and a depth of 5 m, with the entire structure submerged.

(ii) Inner Fish Rearing Net

For constructing the inner net cage for fish rearing or grow-out, twisted HDPE netting with a thickness of 0.75-1.5 mm and a mesh size of 16 to 40 mm, depending on the size of the cultivable species, is appropriate. The recommended dimensions for the fish rearing net cage are a 6 m diameter and 5 m depth, with 4.0 m submerged and the remaining 1.0 m extending up to the handrail, resulting in a total volume of 113 cubic meters.

(iii) Bird Net

A protective bird net is necessary to prevent predatory birds from preying on the fish. The ideal material for the bird net is HDPE twisted and UV-treated twine with a thickness of 1.25 mm and a mesh size between 60 and 80 mm. High-Density Polyethylene knotted netting is preferred for constructing net cages, and the mesh size is determined by the size of the individual farmed fish. Three sets of net cages, each with different mesh sizes (18 mm, 25 mm, and 40 mm), are required for the farming operation. To maintain the cylindrical shape of the net cages, it is important to use appropriate ballasts. Concrete blocks tied at suitable intervals or an HDPE pipe with a diameter of 1.5 inches (38 mm) filled with MS chain or a 10 mm thick wire rope can be used for this purpose.

Nets suitable for open sea cage culture

Selecting the appropriate mesh size for fish nets in cage fabrication is crucial for factors such as the species being farmed, water exchange requirements, and predator prevention. Aeration is essential for improving water quality, reducing stress, enhancing feed conversion, and supporting a higher fish population in the cages, especially under open sea conditions.

For predator prevention in open sea cage culture, it is important to use a suitable net. A braided UV-treated HDPE net with a thickness of 3 mm and a mesh size of 80 mm is recommended due to its strength, durability, and cost-effectiveness. This netting effectively withstands turbulent sea conditions and provides protection against cannibalistic animals.

The cage diameter can be adjusted based on specific needs, ranging from 6 m to 8 m, with a depth of 5-7 m for ease of handling. Stability in the water is ensured by mounting the cages to floating circular frames using ropes and rings.

The inner cage, which directly contains the cultivable species, can be constructed from twisted HDPE with a thickness between 0.75 mm and 1.5 mm, depending on the size of the species. The mesh size for the inner cage typically varies from 16 mm to 28 mm, with recommendations for sea bass being between 1.25 mm/26 mm and 1.5 mm/30 mm. Periodic cleaning of the inner cage is necessary to maintain its durability.

To prevent predatory birds, protective nets made from HDPE twisted and UV-treated material with a thickness of 1.25 mm and a mesh size ranging from 60 mm to 80 mm are recommended. These nets protect the fish population from aerial predators and contribute to the overall success of open sea cage culture.

Selection of fish species

Cobia (*Rachycentron canadum*), Silver Pompano (*Trachinotus blochii*), Seabass (*Lates calcarifer*), Snappers (*Lutjanus* sp.), Groupers (*Epinephelus* sp.), and Spiny Lobster (*Panulirus* sp.) are all highly suitable for sea cage farming. When selecting a species for cultivation in cages, several key factors should be considered:

To manage the high production costs associated with net cage farming, it is advisable to choose species with high market value. It is essential to select species that are hardy, can tolerate confined and crowded conditions, and are resilient during handling for net cage maintenance. Net cage stocking densities significantly exceed those of pond culture, with marine carnivore fish culture in ponds accommodating about 5 fish per square meter compared to 40 fish per square meter in net cages. The frequent competition for food in the crowded environment of net cages increases physical contact and stress among fish. Species such as groupers and seabass are well-suited to these crowded conditions.

Within the net cage environment, where small fish serve as the primary food source, it is important for selected species, especially carnivorous ones, to be adaptable to alternative food sources. Although dry feed is commonly used, it often results in significant feed loss. A practical approach is to use feeding trays suspended in the net cage to catch falling pellets, a technique borrowed from shrimp net cage culture. Additionally, spiny lobsters and rabbitfish *(Siganus canaliculatus*) can graze on algae growing on the net cage sides, which helps control bio-fouling and provides a portion of their diet.

The source of seed for cultivation, typically fry or fingerlings, can be either wild-caught or hatchery-bred. Wild-caught seeds are often more robust and hardy due to natural pre-selection but come with the challenge of being seasonal and unpredictable. Hatchery-bred seeds offer a more reliable and scheduled supply, depending on whether the parent stocks were wild-caught or farm-raised.

Although many species are cultured globally, species such as *Lates calcarifer*, *Epinephelus* spp., *Trachinotus* sp., *Rachycentron* sp., *Lutjanus* spp., and *Acanthopagrus* spp. have proven particularly suitable for cage farming in India and are currently being successfully farmed in various coastal states.

The success of grow-out culture in cages largely depends on the quality of fish seed. To prevent escapes, it is crucial to stock seeds of uniform size that are compatible with the mesh size of the fish net cage. This practice not only facilitates the selection of appropriate feed sizes but also minimizes feed wastage and reduces cannibalism. It is vital that the seeds chosen are healthy and free from diseases and deformities.

In India, the main challenge to expanding sea cage farming is the scarcity of fish seeds. Currently, only a few hatcheries produce seeds for Cobia, Pompano, Seabass, and Groupers. In addition to these species, seeds from wild-caught fishes like Mullets, Snappers, and Milkfish can also be used for cage farming. To meet the growing demand from farmers, there must be an immediate focus on either increasing commercial hatchery production or exploring seed importation options until self-sufficiency in seed production is achieved. Culture details of some cultivable species done by CMFRI

Species	Stocking Size (Length/ Weight)	Stocking Density (Nos./ m 3)	Production per Cage (kg)
Cobia	15 cm/ 35 g	8-10	2400 kg/ 7 months
Pompano	10 cm/ 35 g 3	0-40	1800 kg/ 8 months
Seabass	10 cm/ 30 g	30-40	2000 kg/ 8 months
Grouper	15 cm/ 40 g	15-20	2000 kg/ 7 months

Fish Nutrition

The fundamental principles of any feed material are based on five main constituents: (i) Protein, (ii) Carbohydrate, (iii) Fat, (iv) Minerals, and (v) Vitamins. Proteins are essential for the growth of animals, and a deficiency in protein can lead to growth retardation. Marine fishes, in particular, require a higher protein content in their feed, ranging from 35% to 40%, for optimal growth. It is also important to adjust the feed pellet size as the fish grow. Initially, the standard feeding rate for juvenile fish is 10% of their body weight, which should be gradually reduced to 3% as they mature. A feed with a Feed Conversion Ratio (FCR) of 1:2 is recommended for efficient growth. To avoid wastage and environmental pollution, it is essential to adhere to the recommended feeding ration, as overfeeding can be harmful. In aquaculture, it is common to feed carnivorous fish with low-value trash fish, but this practice is both economically inefficient and environmentally unsustainable, as it contributes to pollution. Under normal farming conditions, the Feed Conversion Ratios (TFCR) for marine carnivorous fish typically range from 2:1 to 4:1.

Feeding

Feeding rates and frequencies are crucial for fish growth. Small larval fish and fry require frequent feeding with a high-protein diet, often in excess. However, as the fish grow, the feeding rates and frequencies need to be reduced. Given that feeding is a labor-intensive task, the feeding schedule must also be economically viable. Generally, increasing feeding frequencies leads to better growth and feed conversion.

The timing of fish feedings is affected by several factors, including the time of day, season, water temperature, dissolved oxygen levels, and other water quality variables. These factors must be considered when creating a feeding regimen to balance fish health, growth, and economic efficiency.

Feeds can deteriorate during storage, which decreases their nutritive value, palatability, and appearance. To maintain optimal quality, feeds should be kept in dry, ventilated warehouses away from direct sunlight and at a stable temperature. Feeds should ideally be used within two months of manufacture and inspected regularly. Extended storage can lead to problems like fungal growth, vitamin degradation, and fat rancidity. Additionally, minimizing handling is important to avoid damaging feed bags and turning pellets into powder, which fish tend to avoid. Effective pest control measures are also necessary to prevent contamination from rats and cockroaches. While proper feed storage is relatively simple, maintaining high quality remains essential.

Cage Management

In Sea Cage management, optimizing production at the lowest possible cost is essential. The farm operator's skill and efficiency are vital for effective management, which includes tasks such as adjusting feeding rates, managing stocking densities, minimizing losses from diseases and predators, monitoring environmental conditions, and ensuring overall technical efficiency. Regular inspections of the cage frame and mooring are necessary, with any required maintenance and repairs being performed promptly. Bio-fouling, which obstructs the net cage mesh and diminishes water exchange, can cause low oxygen levels and waste buildup, ultimately leading to fish mortality. Therefore, it is crucial to brush the net cage mesh on a regular basis.

Harvesting

To achieve the highest returns, harvesting should be aligned with market demand. Adopting a partial harvesting approach, where larger fish are collected first, helps to prevent market gluts and subsequent declines in sale prices. Accurate and detailed site-specific harvest records must be maintained. Large-scale sea cage farming requires a well-conceived postharvest and marketing strategy. Essential facilities for production centers include proper harvesting gear, equipment for icing, holding, and storing fish, live-fish transport capabilities, and links to post-harvest processing centers and market distribution networks.

Carrying capacity

When selecting a site for fish farming, one of the most critical factors to evaluate is the site's carrying capacity, which denotes the maximum production level it can sustain. In intensive cage fish farming, the waste generated can alter the characteristics of the water body, affecting both abiotic and biotic factors. On the other hand, less intensive methods might cause excessive algae growth, which can reduce overall productivity and impact the venture's profitability and viability. Thus, it is essential to conduct a precise assessment of sustainable production levels for the site before beginning fish culture. Carrying capacity is assessed through two main factors: loading, which refers to the weight of fish per unit of water flow, and density, which is the weight of fish per unit area of the water body. Understanding and managing these factors are crucial for ensuring responsible and sustainable practices in cage fish farming.

Environmental impact

One of the negative aspects of the cage culture system is the release of waste, including uneaten feed, feces, and other debris, into the aquatic environment. This waste can accumulate beneath the cages, potentially reducing dissolved oxygen levels, and is particularly likely to settle on the sea bed in sheltered inshore sites. To address this problem, it is recommended to avoid continuous farming at the same sheltered site for extended periods and to switch sites after several crops. Alternatively, semi-exposed or exposed sites with effective tidal flushing should be chosen to prevent waste accumulation at the cage bottom. Adequate spacing between cages and farms is also important for controlling diseases. The misuse of antibiotics, which may be released into the environment, can lead to the emergence of antibiotic-resistant bacteria. Furthermore, cage culture can pose risks such as disease introduction, parasite transmission, and changes in aquatic flora and fauna. Thus, considering the environmental carrying capacity based on site characteristics is crucial for successful sea cage farming.

Redefining Lives: Inspiring Case Studies of Self-Help Groups and Gender Empowerment

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Development signifies the upliftment of the most marginalized sections of society, enhancing their standard of living. In the context of India's fisheries sector, true development and empowerment of weaker sections can be significantly realized through poverty alleviation initiatives driven by transparent mechanisms like Self-Help Groups (SHGs). These groups hold immense potential to play a pivotal role in advancing the fisheries sector. A critical aspect of this transformation is ensuring the active participation of fisherfolk, particularly women, in the planning and execution of various coastal development programs. Their involvement is key to creating sustainable and inclusive growth within the sector.

The open-access nature of marine fishery resource harvesting in India necessitates a dual focus on technological innovation and management strategies that balance livelihood needs with resource conservation. As India's premier Marine Fisheries Research Institute, the Central Marine Fisheries Research Institute (CMFRI), with over six decades of dedicated service, has been at the forefront of proposing sustainable strategies for harnessing the potential of capture and culture fisheries while ensuring their optimal utilization.

Technological advancements thrive best in collaborative ecosystems. The success or failure of any innovation hinges on the strength of the partnership between researchers and the end-user community. Rational utilization of common property resources for sustainable development, without jeopardizing environmental health, becomes achievable through active community participation.

One promising avenue is bivalve farming, particularly mussel and oyster cultivation, which holds significant potential for boosting food and livelihood security in coastal agro-climatic regions. Mussel farming, in particular, has emerged as a profitable supplementary income source for coastal fisherfolk, as demonstrated by CMFRI's experimental trials, which confirmed its techno-economic viability (Vipinkumar V.P. et al., 2001; Vipinkumar V.P. and Asokan, P.K., 2008).

This narrative delves into three case studies from Kasargod and Kollam districts of Kerala, and Karwar in Karnataka, highlighting the dynamics of Self-Help Groups (SHGs) of fisherfolk engaged in mussel farming. These case studies provide valuable insights into how SHGs, combined with innovative aquaculture practices, can serve as catalysts for sustainable development in coastal regions.

A Self-Help Group (SHG) is composed of individuals united by a common bond, such as caste, sub-caste, community, place of origin, or a shared activity. The concept of Group Dynamics within these SHGs refers to the interactions and forces at play between members, shaping the group's internal structure and processes. It explores how these groups are formed, their organizational structure, how they function, and how they impact individual members and the overall group (Lewin et al., 1960).

In their in-depth study of Group Dynamics, Pfeiffer and Jones (1972) identified key factors that influence a group's success, including how the group is organized, the leadership style, the training received by members and leaders, the tasks assigned to the group, and the group's history of success or failure. Further, in a comprehensive study, Hersey and Blanchard (1995) emphasized the roles individuals play within groups—both helpful and hindering. These roles include establishing, persuading, manipulating, committing, being dependent, attending, and avoiding.

This section presents a couple of case studies that explore the dynamics of Self-Help Groups engaged in bivalve farming, shedding light on how these forces come together to influence the success and sustainability of such initiatives.

1. Case Study: Empowering Women through Mussel Farming in Kasargod District

Kasargod, located in the northernmost region of Kerala, has emerged as a notable hub for mussel farming, a success story largely driven by women's Self-Help Groups (SHGs). These groups have been thriving in mussel farming for several years, thanks to financial assistance provided under the Swarnajayanthi Gramaswa Rosgar Yojana (SGSY), a state government initiative focused on the economic empowerment of marginalized communities (Vipinkumar et al., 2001). This scheme offers subsidies, bank loans, and other financial support, emphasizing poverty alleviation through organized SHGs. The program targets comprehensive empowerment, offering training, credit, marketing, technical expertise, and essential facilities to uplift the poor. Its ultimate goal is to help participants earn a minimum of Rs 2,000 per month and rise above the poverty line within three years.

Kasargod, with an area of 1,992 km² and a population of 1,071,508, has a population density of 538 per km² and an impressive literacy rate of 82.51%. The district's economy is largely driven by agriculture, fishing, coir retting, toddy tapping, and other local industries. The coastal belts of Kasargod have significant potential for aquaculture diversification, offering opportunities for finfish culture, prawn, and crab farming (Asokan et al., 2001). Mussel farming, in particular, has proven to be a profitable and sustainable livelihood for many coastal women.

This case study delves into the impact of mussel farming on the economic empowerment of women in Kasargod, examining the adoption dynamics, cost-effectiveness, and broader implications for poverty alleviation in the region. Through the efforts of SHGs, these women have not only contributed to the local economy but have also demonstrated how organized collective action can lead to meaningful change.

Methodology

This study was conducted in two prominent panchayats—Cheruvathur and Padanna—within the Kasargod district, both of which are ideal for mussel farming due to their brackish water estuary systems. Cheruvathur panchayat spans 18.37 km² and has a population of 24,504, with 18,631 individuals being literate. The majority of the population depends on agriculture, while approximately 150 families rely on fishing as their primary occupation, with an additional 300 families engaged in fishing as a subsidiary livelihood. Similarly, Padanna panchayat covers 13.08 km², with a population of 17,961 and 12,746 literate individuals. Around 200 families in Padanna depend on fishing as their primary occupation, while 400 families participate in fishing on a part-time basis.

In both panchayats, six women's Self-Help Groups (SHGs)—three from each—were mobilized under the DWCRA scheme, with ongoing support and technological assistance from the Central Marine Fisheries Research Institute (CMFRI). These groups were selected as the sample for the study, and data was collected through exploratory case studies involving personal interviews with the respondents.

To assess the Group Dynamics within these SHGs, the study introduced the Group Dynamics Effectiveness Index (GDEI). This index was designed to measure the overall effectiveness of group dynamics based on key sub-dimensions, such as participation, influence and styles of influence, decision-making procedures, task functions, maintenance functions, group atmosphere, membership, feelings, norms, empathy, interpersonal trust, and the achievements of the SHGs (Vipinkumar and Baldeo Singh, 1998). This approach provided valuable insights into how the internal dynamics of the SHGs influenced their success in mussel farming and the broader impact on the community.

To calculate the Group Dynamics Effectiveness Index (GDEI), the scores for each of the sub-dimensions were first standardized, then multiplied by the corresponding weightage assigned by expert judges. These weighted scores were summed to determine the GDEI score for each respondent. It was ensured that all sub-dimensions, identified as key components of Group Dynamics Effectiveness (GDE), held high significance, as confirmed by the coefficient of agreement in judges' ratings and statistical evidence from the pilot study. The content validity of the measurement device used for GDE was thoroughly assessed.

Measurement of Sub-Dimensions

A. Participation:

Participation was defined as the extent to which a member engages in group meetings, discussions, and activities within the Self-Help Group (SHG).

B. Influence & Style of Influence:

Influence was defined as the ability of a member to impact other SHG members in a positive manner.

Style of influence referred to the method a member uses to influence others, which was categorized into four styles: autocratic, peacemaker, laissez-faire, and democratic.

C. Decision-Making Procedures:

This sub-dimension measured the degree to which a member contributes to decisions by involving others, avoids topic drifting, supports consensus, values the majority opinion, encourages participation, and feels recognized for their input in the decision-making process.

D. Task Functions:

Task functions were defined by the extent to which a member actively suggests solutions to group problems, summarizes discussions, provides feedback, offers ideas, and ensures the group stays focused on its objectives.

E. Maintenance Functions:

Maintenance functions measured how well a member assists others in group activities, fosters cooperative behavior, helps clarify ideas, and maintains the group's focus on both task and interpersonal harmony.

F. Group Atmosphere:

This sub-dimension assessed the degree to which a member values a friendly and supportive environment, works to resolve conflicts, encourages involvement, and is satisfied with the work climate within the SHG.

G. Membership:

Membership was defined as how accepted or included a member feels within the SHG, including whether they feel part of sub-groups or outside the main group.

H. Feelings:
Feelings were measured by the extent to which a member experiences emotions such as anger, frustration, warmth, affection, excitement, boredom, or competitiveness during group activities.

I. Norms:
Norms referred to the perceived standards, ground rules, and regulations that govern the behavior of members, ensuring the smooth operation of the SHG.

J. Empathy:
Empathy was defined as the ability of a member to understand and relate to the feelings of others within the group.

K. Interpersonal Trust:
This sub-dimension measured the level of trust a member has in others and the degree of trust other members place in them.

L. Achievements of SHG:
Achievements were assessed by how well the SHG performs as a collective, as well as the individual contributions and accomplishments of each member within the group.

Each of these sub-dimensions was measured using an inventory of relevant questions, rated on a three-point scale: *always*, *sometimes*, and *never*, with scores of 2, 1, and 0 for positive questions (and vice versa for negative questions). This structured approach allowed for an in-depth analysis of the dynamics within the Self-Help Groups and their effectiveness.

The cost estimates for all the selected Self-Help Groups (SHGs) were also calculated, focusing on major expenditures essential for mussel farming. These included costs for materials such as bamboo, nylon rope, coir, cloth, and seed, as well as labor costs covering construction, seeding, harvesting, and other critical activities. Additionally, the Net Operating Profit and Benefit-Cost (B:C) ratio were computed for each SHG, providing valuable insights and enabling the drawing of meaningful conclusions from the financial data.

Results and discussion

Table 1 presents the basic data related to the fisheries sector of Kasargod district. The study focused on Group Dynamics Effectiveness (GDE) as a characteristic of Self-Help Groups, shaped by the collective influence of individual members. This influence is drawn from their skills and life experiences, which naturally vary from person to person, place to place, time to time, and situation to situation. As a result, the degree of GDEI observed among the respondents differs, reflecting these diverse factors and circumstances.

Table 1 : General profile of fisheries sector in Kasargod district

Sl.No	Parameter	Kasargod
1	Length of the Coast line	70 km
2	No. of Marine Fishing villages	16
3	No. of Inland Fishing villages	2
4	Marine Fisherfolk population 2004-2005	45989
5	Active marine fishermen	10566
6	Inland Fisherfolk population 2004-2005	1004
7	Active inland fishermen	435
8	No. of Fisheries co-operatives	27
9	No. of domestic fish markets	164
10	Annual Marine Fish Production 2004-2005	8292 tonnes
11	Annual Inland Fish Production 2004-2005	1612 tonnes

Profile of Cost Estimates of Mussel Farming

The primary expenditures for mussel farming include materials such as bamboo, nylon rope, coir, cloth, and seed, along with labor costs for construction, seeding, and harvesting. Women's Self-Help Groups (SHGs) under the DWCRA scheme began mussel farming as early as 1996-97, with each member receiving a loan of Rs 8,800, accompanied by a subsidy of Rs 4,400. The loan has a 5-year term and an interest rate of 12.5% per annum. In addition, a revolving fund of Rs 5,000 was provided interest-free. As these SHGs become economically empowered through loan facilities, the returns from mussel farming allow them to gradually repay the loans.

The loans were disbursed through the Farmers' Service Cooperative Banks and North Malabar Gramin Banks in the Cheruvathur and Padanna panchayats of Kasargod district. The majority of SHGs showed remarkable progress in repaying the loans, indicating the profitability of mussel farming. The expenditure details for the selected SHGs during the initial year of mussel cultivation are presented in Table 2.

The Net Operating Profit across all six SHGs was found to be significantly positive, confirming the profitability of mussel farming even in its early stages. Furthermore, as material costs like bamboo, rope, cloth, and labor costs for construction decrease in subsequent years, it ensures a steady and reasonable profit. This, in turn, highlights the economic empowerment of rural women through the organized efforts of Self-Help Groups and the adoption of mussel farming as a sustainable enterprise.

Table 2 : Cost estimates of the SHG's in mussel farming in Kasargod district.

	SHG1	SHG 2	SHG 3	SHG 4	SHG 5	SHG 6
No. of ropes	**500**	**800**	**600**	**750**	**900**	**725**
Items						
Bamboo	6400	9600	7980	9000	11437	7800
Nylon rope	9954	17500	12000	15000	18000	14500
Coir rope	1100	1500	1200	1587	2000	1450
Cloth	3000	3250	1700	3338	3600	2250
Seed	6500	10000	8700	9000	10800	9770
Labour						
Construction	1600	2400	2170	2250	2700	2200
Seeding	1500	2565	1500	1875	2500	1800
Harvesting	1300	2000	1500	2000	2750	1875
Miscellaneous	1000	1600	1200	1500	1800	1450
Total Cost	**32,354**	**50,415**	**37,950**	**45,550**	**55,587**	**43,095**
Returns	**40,000**	**64,000**	**48,000**	**60,000**	**72,000**	**58,000**
Net Operating Profit	**7,646**	**13,585**	**10,050**	**14,450**	**16,413**	**14,905**
B: C Ratio	**1.236**	**1.269**	**1.265**	**1.317**	**1.295**	**1.346**
GDE Index	**52.78**	**54.33**	**53.91**	**57.32**	**55.68**	**59.14**

Experiences and observations have shown that developing a Self-Help Group (SHG) requires a minimum of 36 months and is a demanding process. The group progresses through various phases: the Formation phase, Stabilization phase, and Self-Helping phase. These phases cultivate a cooperative and participative culture among members, fostering the empowerment culture during the Self-Helping phase. The successful sanctioning and utilization of loans, diligent maintenance of accounts, and timely repayment are all meticulously managed by the group members, ensuring the proper documentation of records. This adherence to norms and standards confirms the group's success and leads to the economic empowerment of its members. A clear proportional relationship between the Benefit-Cost (B:C) ratio and the Group Dynamics Effectiveness (GDE) index is observed, as shown in Table 2.

2. Case Study: Mussel Farming Self-Help Groups in Karwar, Karnataka

Self-Help Groups (SHGs) of fisherfolk were mobilized by CMFRI in the coastal belts of Karwar and Bhatkal, Karnataka. A total of six SHGs, with 15 members each (45 members per site), were formed across two key locations: Majali (Open Sea) and Sunkeri (Kali Estuary) in the Uttar Kannada district. Training and demonstration programs on mussel farming were conducted in these regions. Two distinct training sessions were held: one focusing on raft culture in the open sea at Majali, and the other on rack culture in the Sunkeri estuary.

In Majali, a 5x5 meter raft was constructed for mussel farming in the open sea, while at Sunkeri, a 5x5 meter rack was set up for mussel culture in the Kali estuary. Additionally, in the Bhatkal estuary, four Self-Help Groups of women fisherfolk, under the NGO 'Snehakunja', comprising 60 participants, were trained on mussel farming. They initiated a trial using a 5x6 meter rack culture by the long-line method.

The study involved gathering data through personal interviews with members of these 10 SHGs. Group Dynamics within these SHGs was assessed using the Group Dynamics Effectiveness Index (GDEI). Growth parameters were monitored weekly across all sites, and mussel yield details were recorded during the harvesting phase for each SHG.

For further reference, the sample design for the study, including the number of trained SHGs, beneficiaries, and the method of culture used, is provided in Table 3.

Table 3: Mussel culture interventions in Karwar of Karnataka state

Site	No. of SHGs Trained	No. of beneficiaries	Method of culture	Size of the rack / raft
Sunkeri of Kali estuary	3	45	Rack culture	5 x 5 m
Majali of Dhandebag	3	45	Raft culture	5 x 5 m
Bhatkal of Mundalli estuary	4	60	Raft culture	5 x 6 m

Results & Discussion

The primary expenses involved in mussel farming include materials such as bamboo, nylon rope, coir, cloth, and seed, as well as labor costs for construction, seeding, and harvesting. The Self-Help Groups (SHGs) in Majali and Sunkeri were mobilized by the CMFRI project team, while the SHGs in Bhatkal were supported by the NGO Snehakunja. The first two trials and demonstrations were funded by CMFRI, while CMFRI only provided technical assistance during the training and demonstration for the third trial. The yield in all ten SHGs was found to be significantly good, confirming the profitability of mussel farming. Over time, as material costs such as bamboo, rope, cloth, and labor for construction decrease, reasonable profits emerge, making mussel farming a viable enterprise that contributes to the economic empowerment of rural women through organized SHGs.

However, the open-sea mussel culture encountered a setback due to sabotage of the seeded mussels by miscreants. Although reseeding was done, the yield did not match the success of the estuarine trials. Despite this, the yield per meter length of rope in all SHGs showed a positive relationship with the Group Dynamics Effectiveness Index (GDEI). A significant correlation (r = 0.958139) was observed, with a ‘t’ value of 9.465624 at a 1% level of significance (Table 4).

Previous experiences have shown that the development of an SHG requires at least three years, passing through distinct phases: Formation, Stabilization, and Self-Helping. These phases foster a cooperative and participative culture, contributing to the empowerment of group members during the Self-Helping phase. Fund utilization, account maintenance, and proper documentation are all meticulously handled by group members, ensuring compliance with SHG norms and standards. This adherence leads to the economic empowerment of the members.

As seen in this case, a positive correlation between yield and GDEI is evident. One of the key dimensions of GDEI is the achievement of the SHG, which directly correlates with yield and economic success from the SHG's micro-enterprise. Thus, it is natural to observe a positive relationship between yield, the B:C ratio, and GDEI.

Table 4 : Relationship of Yield and GDEI of selected SHGs in Karwar

SHG	Yield in Kg / m	GDEI score	Correlation Coefficient (r)	't' value
SHG 1	9.2	53.71	0.958139	**9.4656248****
SHG 2	9.1	52.31		
SHG 3	8.9	51.91		
SHG 4	12.6	57.32		
SHG 5	12.7	56.68		
SHG 6	12.5	57.14		
SHG 7	13.6	60.01		
SHG 8	13.1	59.98		
SHG 9	13.8	61.29		
SHG 10	13.2	60.02		

3. Case Study on Mussel Farming Technologies in a Gender Perspective in Kollam District, Kerala

This study aims to assess the adoption of mussel farming technologies in Kollam, Southern Kerala, with a focus on gender dynamics. Specifically, it examines how mussel farming serves as a supplemental income source for rural fisherfolk, particularly through women's Self Help Groups (SHGs). The experimental trials conducted by CMFRI have demonstrated the techno-economic feasibility of brown mussel farming in the region. Kollam, renowned for brown mussel farming, has seen the active participation of women's SHGs organized through Kudumbashree Ayalkoottams. Analyzing the outcomes and cost dynamics of mussel farming within these groups is crucial to understanding its impact on women's economic empowerment.

Geographical Overview of Kollam District

Kollam, an ancient seaport town on the Arabian coast, is strategically located with approximately 30% of the district covered by the Ashtamudi Lake, making it the gateway to Kerala's scenic backwaters. Kollam is a microcosm of Kerala's natural beauty, offering a mix of coastal areas, lakes, plains, mountains, rivers, and streams. It has a land area of 2,491 km² and a population of 2.58 million, with an impressive literacy rate of 91.49%.

Agriculture plays a vital role in the economy of Kollam, with a total cultivated area of 218,267 hectares. The principal crops include paddy, tapioca, coconut, rubber, pepper, banana, mango, and cashew. Approximately 70% of the workforce is engaged in agriculture. The district is also known for its extensive coconut gardens, which span 75,454 hectares. Notably, small and marginal farmers represent over 95% of the farming community, with an average per-family landholding of 0.21 hectares.

Fisheries Sector in Kollam

Kollam is a key maritime district in Kerala, with a coastline of 37.3 km. The fishing industry is integral to the district's economy, with key fishing villages such as Neendakara and Sakthikulangara thriving on fishing and allied activities. Around 22,000 individuals are involved in the fishing sector. The district has 26 significant fishing villages, including Cheriazheekkal, Alappad, Pandarathuruthu, Puthenthura, Neendakara, Thangasseri, Eravipuram, Paravoor, and Thekkumbhagam, alongside 24 inland fishing villages.

The Government has taken steps to further enhance the fisheries sector by initiating the development of a fishing harbor at Neendakara, which is expected to increase fish production by 15%. Kollam contributes one-third of Kerala's total fish catch, with an annual average fish landing of 85,275 tonnes. The district also boasts 93 producer cooperatives, two credit cooperatives, and one marketing cooperative in the fisheries sector. Additionally, 38 Fishermen Development Welfare Cooperative Societies (FDWCS) are active in the region. Over 3,000 mechanized boats operate from the Neendakara fishing harbor.

With the support of agencies like FFDA and VFFDA, Kollam is also a hub for freshwater fish culture and prawn farming. The district produces approximately 60% of Kerala's prawn production, further solidifying its prominence in the state's fisheries industry.

Table 5 : General profile of fisheries sector in Kollam district

Sl. No	Parameter	Kollam
1	Length of the Coast line	37 km
2	No. of Marine Fishing villages	27
3	No. of Inland Fishing villages	26
4	Marine Fisherfolk population 2004-2005	96703
5	Active marine fishermen	21368
6	Inland Fisherfolk population 2004-2005	36653
7	Active inland fishermen	6255
8	No. of Fisheries co-operatives	99
9	No. of domestic fish markets	324
10	Annual Marine Fish Production 2004-2005	143138 tonnes
11	Annual Inland Fish Production 2004-2005	10778 tonnes

This comprehensive picture of Kollam highlights its rich natural resources and the robust role of fisheries in the local economy, setting the stage for understanding the broader impact of mussel farming, particularly for women's empowerment through organized Self Help Groups.

Methodology

This study was conducted in the Kaunagappally Thaluk, located 27 kilometers north of Kollam, well-connected by both rail and road. The villages selected for data collection were from the Thekkumbhagam and Neendakara Panchayats within this Thaluk. Specifically, Dhalavapuram and Malibagam villages from Thekkumbhagam, and Pannakkal Thuruthu and Puthan Thuruthu from Neendakara were chosen. A total of 200 mussel farming households, mobilized into Self Help Groups (SHGs), were surveyed in these villages to represent the southern part of Kerala. Trained enumerators conducted separate interviews with both men and women of each household, using a pre-tested and structured interview schedule to assess gender needs and roles in mussel farming.

Additionally, four women's Self Help Groups from each Panchayath were selected for detailed case studies. Personal interviews were conducted with the members of these groups to gather in-depth insights (Table 6). A Benefit-Cost (B:C) ratio analysis was performed for each group, and the associated cost dynamics were calculated. The study also identified and documented the problems and constraints faced by the women involved in mussel farming.

Table 6. Details of the basic information gathered & SHGs identified in Kollam district.

Name of the panchayat	Village	Samples selected (Self Help Groups)	No. of members
1. Thekkumbhagam	Dhalavapuram	Mahatmaji Kudumbasree Group	19 members
	Malibhagam	St.Maries Kudumbasree Group	16 members
2. Neendakara	Puthan thuruthu	Ashtajalarani Group	18 members
	Pannakkal thuruthu	Chavara south Group	15 members

Results and Discussion

Gender Roles and Needs in Mussel Farming

In Kollam district, the study examined the gender roles in various mussel farming activities, gender-specific needs, decision-making, and access to resources. Overall, both men and women shared similar perspectives, with no significant differences in their views. However, notable gender-based variations were observed between the villages. One significant finding was that accounting and financial transactions were primarily managed by women. Both men and women identified the timely availability of spat as the most critical requirement for successful mussel farming. In terms of participation and needs, both genders expressed similar opinions on the matter. These findings align with Sahoo et al. (2009), who noted that gender roles in mussel farming are largely collaborative. Furthermore, the study analyzed the socio-economic, technological, and export support necessary for gender mainstreaming in the industry.

Yield Aspects and Group Dynamics in Mussel Farming

The major costs involved in mussel farming are materials such as bamboo, nylon rope, coir, cloth, seed, and labor for tasks like construction, seeding, and harvesting. The relationship between yield and Group Dynamics Effectiveness Index (GDEI) for the selected SHGs is illustrated in Table 7. The yield, measured in kilograms per meter of rope, showed a strong positive correlation with GDEI scores, with a correlation coefficient of (r = 0.92025).
Case studies of women-led Self Help Groups in Kollam further highlighted that it takes at least 36 months for a group to fully develop into a successful and self-sustaining SHG. After the third year, most of the groups in the study areas entered the Self Helping phase, where they fostered a cooperative, participative, and empowerment-driven culture. These groups demonstrated excellent management in loan sanctioning, fund utilization, account maintenance, and timely repayment, all while meticulously keeping records. This effective organization and discipline played a crucial role in the economic empowerment of the members, ensuring the sustainability and growth of mussel farming through SHGs.

Table 7. Relationship of Yield and GDEI of selected SHGs in Kollam district.

SHG	Yield in Kg / m	GDEI score	Correlation Coefficient (r)
SHG 1	14.6	60.08	0.92025
SHG 2	12.1	57.78	
SHG 3	13.9	59.16	
SHG 4	15.1	62.17	

Problems and Constraints in Mussel Farming from a Gender Perspective

Mussel farming faces various challenges, including water salinity, seed availability, site selection, climatic conditions, and proper monitoring. The key problems and constraints faced by women in mussel farming, ranked in order of significance, include unpredictable seed availability, difficulties with meat shucking, marketing challenges, seed mortality during transportation, reduced growth in certain years, and, to a lesser extent, social constraints like caste divisions and conflicts.

All group members are in unanimous agreement that improved marketing facilities, particularly those supported by government agencies, are crucial, as marketing is considered one of the biggest obstacles. The introduction of low-interest loans and freezer facilities for storing harvested mussels could significantly boost this sector.

The adoption of mussel farming through organized women's Self Help Groups (SHGs) in North Malabar and South Quilon areas of Kerala has proven to be highly profitable. Mussel farming has the potential to become a fully developed, women-driven enterprise in Kerala. Gender considerations play a critical role in site selection and the various operations of mussel culture, and an assessment of gender roles and needs is essential for the success of these farming initiatives.

Further research is needed on the drudgery involved in mussel farming, the impact of coir retting zones on seed growth and attachment, and the broader effects of these zones on mussel development. Additionally, laboratory experiments should be expanded to study these factors. The export potential of mussels can be enhanced through value-added processes like depuration in filtered seawater. Organized fishermen's cooperatives can play a key role in various stages of mussel farming, from seeding to marketing, with a particular focus on export opportunities. This study underscores the importance of gender roles and needs in mussel farming, ultimately advocating for economic empowerment and poverty alleviation through Self Help Groups (SHGs).

Conclusion

This study assesses the socio-economic impact of mussel farming through Self Help Groups (SHGs) in the coastal areas of Kasargod and Kollam in Kerala, and Karwar in Karnataka. Mussel farming has gained significant traction due to its profitability, but attention must be given to the selection of suitable sites that meet the essential parameters for successful mussel culture trials. Research on the impact of coir retting zones on seed growth and attachment should be expanded, as current observations indicate that these zones may not always be suitable.

The adoption of mussel farming by women's Self Help Groups in the North Malabar and South Quilon areas has proven especially profitable. To further promote mussel farming, the export potential can be enhanced through value addition processes such as depuration in filtered seawater. Organized fishermen's cooperatives will be crucial in improving various stages of mussel farming, including seeding, harvesting, sorting, grading, packing, and marketing for export.

As seed availability remains a major constraint, efforts should be directed toward scaling up mussel seed production technologies developed by CMFRI. The study revealed the profound impact of group dynamics within SHGs, shaped by participation, decision-making procedures, task functions, group atmosphere, interpersonal trust, and achievements. This reinforces the importance of organized SHGs in empowering rural women and alleviating poverty through mussel farming. The correlation analysis further supports the positive relationship between Group Dynamics Effectiveness and Average Yield, demonstrating the substantial profitability and economic empowerment resulting from mussel farming in organized Self Help Groups.

4. Dynamics of Women's Self Help Groups in the Malabar Fisheries Sector

(A Case Study of Women in Fisheries-Based Micro-Enterprises)

Case Study Overview:

Women have made significant contributions to the fisheries sector, especially in subsidiary activities related to capture fisheries, such as processing, value addition, sorting, grading, peeling, trading, and aquaculture practices like breeding and rearing fish, as well as marketing. In coastal fishing communities, families are heavily dependent on sea resources for their livelihood. The roles of Self Help Groups (SHGs) of women fisherfolk in the marine fisheries sector, which are mobilized through appropriate micro-enterprises in fisheries and diversified sectors, are pivotal in sustaining and enhancing the economic well-being of their families.

This case study, conducted in the Malabar region of Kerala, aimed to assess the Group Dynamics of women's SHGs to identify key factors contributing to their effectiveness and to uncover the challenges these women face in order to develop strategies for mobilizing more effective SHGs. From each of the four districts of Malabar—Kasargod, Kannur, Kozhikode, and Malappuram—three SHGs were randomly selected. The Group Dynamics of each SHG was evaluated using the Group Dynamics Effectiveness Index (GDEI), which included 12 dimensions: participation, influence and styles of influence, decision-making processes, task functions, maintenance functions, group atmosphere, membership, feelings, norms, empathy, interpersonal trust, and achievements of the SHG. The findings revealed significant variations in Group Dynamics, with the key dimensions influencing GDEI being the achievements of the SHG, participation, and group atmosphere. Personal and socio-psychological characteristics, such as education, income, socio-economic status, extension orientation, scientific orientation, participation in mass media and social activities, cosmopolitanism, knowledge, attitude towards the SHG, and information use patterns, all had a positive and significant impact on GDEI. Empowerment programs were designed based on the ranking of preferred micro-enterprises in fisheries and allied sectors. Success stories showcasing the economic empowerment of women's SHGs were also highlighted. The constraints faced by these women were identified and ranked, and a strategy for mobilizing effective SHGs in the fisheries sector was developed.

Women's Self Help Groups in the Malabar Fisheries Sector

Women play a crucial role in the fisheries sector, particularly in subsidiary activities such as processing, value addition, sorting, grading, peeling, trading, and aquaculture practices, including breeding and rearing fish, and marketing. Coastal fishing communities depend almost entirely on marine resources for their livelihood, and the contribution of SHGs of women fisherfolk in establishing micro-enterprises within the fisheries and diversified sectors is central to the economic prosperity and sustainability of their families. Women in these communities are often the most vulnerable, experiencing deprivation and destitution. Thus, poverty alleviation programs should focus on improving the living conditions of women by creating sustainable livelihood opportunities.

In recent years, micro-credit-based poverty alleviation schemes have been implemented across many developing countries, including India, to address these issues. These schemes have been reinforced by state actions and institutional formations to streamline and successfully implement poverty alleviation programs (Yaron, 1992; Yunus, 1999).

In Kerala, the role of SHGs organized by women fisherfolk is critical in the fisheries sector, particularly in maritime states along India's coastal belts. Despite the economic and socio-cultural importance of fishing in the state, women fisherfolk often remain marginalized, excluded from the benefits of the fishing industry (Kurien, 1994). The Malabar region, which makes up about half of Kerala's coastline, has lagged behind the rest of the state in terms of development (MCITRA, 2003). Fisherwomen in this region rarely benefit from the booming fish production, as fisheries development has often been separated from the advancement of fishing communities.

It is therefore important to examine the group dynamics of existing SHGs mobilized by development agencies to empower women in the Malabar fisheries sector. The sustainability of these SHGs—whether they are temporary initiatives or will continue in the long term—needs to be critically analyzed (Fernandez, 1995). Addressing the constraints these women face and adopting viable micro-enterprises in fisheries and related sectors will be essential to strengthen SHGs and empower women within the fishing community.

Focus of the Study

This case study in the Malabar region primarily aimed to achieve the following objectives:

- **Assessing Group Dynamics**: Evaluating the Group Dynamics of Self Help Groups (SHGs) formed by women fisherfolk, identifying the key dimensions that contribute to their effectiveness, and understanding the influence of personal and socio-psychological factors on these dynamics.
- **Empowering Women's SHGs**: Supporting the empowerment of women's SHGs through targeted training and the adoption of economically viable micro-enterprises in the fisheries and diversified sectors, while highlighting success stories of SHGs.
- **Identifying Constraints and Developing Strategies**: Identifying the challenges faced by women fisherfolk and formulating strategies to mobilize and strengthen effective SHGs, thereby addressing these constraints and enhancing their impact.

Quantification of Group Dynamics of Self Help Groups
Group Dynamics refers to the interactions and forces at play among members within a social group. It encompasses how groups are formed, their structures, processes, and how they function, influencing individual members, other groups, and the organization as a whole (Hersey & Blanchard, 1995). This study was conducted across four districts in the Malabar region of Kerala: Kasargod, Kannur, Kozhikkode, and Malappuram. In each district, three Self Help Groups (SHGs) of women fisherfolk were randomly selected, making a total of 12 SHGs. From each SHG, 15 women were interviewed using a pre-tested interview schedule.

To quantify the Group Dynamics of each SHG, an index called the Group Dynamics Effectiveness Index (GDEI) was developed. This index comprises 12 dimensions, as identified by Vipinkumar (1998) and Vipinkumar & Baldeo Singh (2001), including: Participation, Influence & Styles of Influence, Decision-Making Procedures, Task Functions, Maintenance Functions, Group Atmosphere, Membership, Feelings, Norms, Empathy, Interpersonal Trust, and Achievements of SHG. In this study, the GDEI was defined as the total of these forces acting among SHG members, based on these key dimensions.

Measurement of Group Dynamics Effectiveness
The 12 dimensions measured for the Group Dynamics Effectiveness Index are as follows:

Participation: The extent to which members are involved in group meetings and activities.
Influence & Styles of Influence: The nature of leadership and how influence is exerted within the group.
Decision-Making Procedures: The group's ability to make effective decisions.
Task Functions: The capacity of members to tackle problems and address challenges.

Maintenance Functions: The extent to which members maintain essential tasks within the group.
Group Atmosphere: The overall climate of the group, including its congeniality and supportiveness.
Membership: The level of inclusion and belonging within the group.
Feelings: The emotional engagement and expression within the group.
Norms: The rules and regulations that govern group behavior.
Empathy: The ability to understand and respond to the feelings of others.
Interpersonal Trust: The mutual trust and faith between group members.
Achievements of SHG: The overall performance of the SHG, including economic success and progress.
Each of these dimensions was measured through a set of inventories containing relevant questions (Pfeiffer & Jones, 1972). The total GDEI score for each individual was calculated by summing the individual scores across all components.

Location of Selected SHGs, Micro Enterprises, and GDEI Score

Table 1 presents the details of the 12 selected Self Help Groups (SHGs), their locations across four districts in the Malabar region, the corresponding micro enterprises, and their Group Dynamics Effectiveness Index (GDEI) scores. Based on the GDEI scores, steps were taken to empower the SHGs with the lowest scores, while success stories of women's empowerment from the SHGs with the highest GDEI scores in each district were highlighted.

Group Dynamics and Variability in GDEI Scores

The results, as shown in Table 2, indicated a significant variation in the GDEI scores across different SHG members and groups, as evidenced by the high variance ratio (F=18.21). Group Dynamics is a multifaceted phenomenon, shaped by a range of interacting factors. These factors vary in strength depending on individual skills, orientations, and past life experiences. Consequently, Group

Dynamics can differ from person to person, from group to group, and across different times, places, and situations. This variability helps explain the differential GDEI scores observed among the respondents.

Table 1: Selected SHGs', location, micro enterprise and GDEI

District	Name of SHG	Location	Micro enterprise	GDEI Score
Kasargod	Kavunchira Kairali	Cheruvathur	Bivalve farming	61.7
	Ori unit	Padanna	Bivalve farming	**79.1**
	Vedavyasa	Kottikkulam	Fish drying & value addition	57.2
Kannur	Seafood unit	Thayyil	Fish drying & value addition	**68.8**
	Krishnamadham	Mattul	Fish drying & value addition	59.6
	Chaithanya	Ayikkara	Fish Processing & value addition	52.8
Kozhikkode	Kasthurba	Chombal	Fish processing & value addition	**67.1**
	Samudra	Virunnukandy	Fish processing & value addition	47.2
	Snehatheeram	Beypore	Fish drying & value addition	57.4
Malappuram	Yuvasakthi	Puthupponnani	Bivalve farming	**67.0**
	Arafa	Ponnani	Fish drying & value addition	65.8
	Soorya	Marakkadavu	Fish Processing & value addition	56.8

Table 2 Analysis of variance in Group Dynamics Effectiveness of SHGs

Source of Variation	**Degrees of freedom**	**Sum of squares**	**Mean sum of squares**	**Variance ratio 'F'**
Between groups	11	14368.06	1306.19	18.21**
Error	168	12064.26	71.81	
	179			

** Significant at 1% level of significance.

Influence of dimensions of Group Dynamics Effectiveness

The relationship of dimensions of Group Dynamics Effectiveness with GDEI was established in this study first by simple correlation analysis to identify the most important dimensions (Table 3).

Table 3. Simple correlation analysis of dimensions of Group Dynamics Effectiveness (n=180)

Variable No.	Characteristic	Correlation coefficient (r)
1.	Participation	**0.947****
2.	Influence and Styles of influence	0.938**
3.	Decision making procedures	0.919**
4.	Task functions	0.907**
5.	Maintenance functions	0.913**
6.	Group atmosphere	**0.945****
7.	Membership	0.874**
8.	Feelings	0.879**
9.	Norms	0.884**
10.	Empathy	0.869**
11.	Interpersonal trust	0.918**
12.	Achievements of SHG	**0.949****

** Significant at 1% level of significance

A perusal of the Table 3 indicated that, out of 12 dimensions, the degree of relationship with GDEI was maximum in the case of Achievements of SHG, followed by Participation and Group atmosphere.

Influence of Personal and Socio-Psychological Characteristics

Among the 17 personal and socio-psychological characteristics examined, Table 4 reveals that 14 variables—namely education, annual income, farm household size, socio-economic status, extension orientation, scientific orientation, mass media participation, social participation, cosmopolitanism, knowledge, attitude towards SHGs, attitude towards the intervening agency, attitude towards fellow farmers, and information source use pattern—were positively and significantly correlated with the dependent variable, "Group Dynamics," at the 1% significance level. However, three variables—age, occupation, and fishing experience—were found to have no significant relationship with Group Dynamics.

Table 4. Relationship of personal and socio-psychological characteristics with GDEI (n=180)

Variable No.	Characteristic	Correlation coefficient
1	Age	0.087
2	Education	0.310**
3	Occupation	0.058
4	Annual income	0.503**
5	Farm household size	0.508**
6	Fishing experience	0.147
7	Socio-economic status	0.871**
8	Extension orientation	0.840**
9	Scientific orientation	0.813**
10	Mass media participation	0.479**
11	Social participation	0.687**
12	Cosmopoliteness	0.678**
13	Knowledge	0.767**
14	Attitude towards SHG	0.820**
15	Attitude towards intervening agency	0.791**
16	Attitude towards other members	0.782**
17	Information source use pattern	0.847**

** Significant at 1% level of significance

Micro Enterprises in Fisheries and Diversified Sectors

Empowerment programs were implemented in each district for the SHGs with the lowest GDEI scores, focusing on suitable micro enterprises in fisheries and allied sectors. These programs were based on the preference ranking of the SHGs. The preference ranking of micro enterprises, tailored to the location-specific needs in fisheries and allied sectors across all four districts, was conducted. The identified and appropriate micro enterprises for each district are presented in Tables 5 and 6.

Table 5. Ranking for priorities of fisherfolk for fishery based micro enterprises

No	Fishery based micro enterprise	Preference Rank of respondents			
		Kasargod	Kannur	Kozhikkod	Malappuram
1.	Preparation of Value Added products	III	V	I	I
2.	Preparation of Dry Fish products	IV	I	III	V
3.	Fish Processing Unit	V	II	II	IV
4.	Ready to eat fish products	VI	VI	V	VI
5.	Ready to cook fish products	VII	VII	VI	VII
6.	Ornamental Fish culture enterprise	VIII	IX	VII	VIII
7.	Mussel culture	I	III	IV	II
8.	Clam collection	XI	IV	IX	IX
9.	Edible oyster culture	II	VIII	VIII	III
10.	Pearl culture	X	XI	XI	X
11.	Mud Crab culture	IX	X	X	XI
12.	Cage culture	XII	XII	XII	XII

Table 6. Ranking for priorities of fisherfolk for diversified micro enterprises

No	Agri - based micro enterprise	Preference Rank of respondents			
		Kasargod	Kannur	Kozhikkod	Malappuram
1.	Vegetable farming	I	II	I	I
2.	Ornamental Gardening enterprise	III	I	III	III
3.	Floriculture	IV	V	II	IV
4.	Kitchen garden	VI	VI	V	VI
5.	Orchards	VII	VII	VI	VII
6.	Fruit products	VIII	IX	VII	VIII
7.	Fruit Processing	V	III	IV	II
8.	Snacks bar	XI	IV	IX	IX
9.	Catering Unit	II	VIII	VIII	V
10.	Bakery Unit	X	XI	X	X
11.	Cereal Pulverizing Unit	IX	X	XI	XI
12.	Sericulture Unit	XIII	XIII	XII	XIII
13.	Planting mangroves & acacia trees	XII	XII	XIII	XII
14.	Coconut processing/oil extraction unit	XIV	XIV	XIV	XIV
15.	Vanilla nursery	XV	XV	XV	XV
	Allied sector based micro enterprise				
16.	Grocery repacking	II	I	I	I
17.	Garment unit	I	II	II	II
18.	Soap unit	VII	IV	III	IV
19.	Wood – Stone carpentry	VIII	IX	X	XII
20.	Computer centre	IX	X	IV	VIII
21.	Cattle unit	XIII	XII	XIII	IX
22.	Poultry unit	XII	XI	XI	X
23.	Hand weaving	V	III	XII	XI
24.	Candle unit	III	VII	V	VII
25.	Chalk Unit	IV	VI	VII	VI
26.	Umbrella Unit	VI	V	VI	V
27.	Foam Bed Unit	X	VIII	VIII	III
28.	Bamboo based handicrafts	XIV	XIV	IX	XIV
29	Firewood	XI	XIII	XIV	XIII
30.	Beauty parlour	XV	XV	XV	XV

A review of Table 5 highlights the promising potential of bivalve farming, particularly mussel culture, in the Malabar fisheries sector, as well as other activities such as processing, drying, and value addition, which are all highly viable fishery-based micro enterprises (Vipinkumar et al, 2001). Table 6 reveals a strong preference for agricultural-based enterprises in Malabar, including vegetable farming, ornamental gardening, and floriculture.

Additionally, allied sector micro enterprises such as glossary repacking and garment manufacturing show tremendous potential. A micro enterprise is defined as an activity requiring minimal capital, manpower, local raw materials, and a local market. These enterprises can be individual ventures, either known or unknown (Vedachalam, 1998).

Preference rankings for 12 fishery-based micro enterprises, 15 agricultural micro enterprises, and 15 allied sector micro enterprises based on their suitability in the northern coastal belts of Kerala are detailed in Tables 5 and 6. In the fisheries sector, successful micro enterprises developed through the availability of local resources and experiences include value-added fish units, dry fish units, fish processing units, ready-to-eat fish products, ready-to-cook fish products, ornamental fish culture, mussel culture, edible oyster culture, clam collection, and cage farming. In the agricultural sector, women's Self Help Groups have successfully ventured into vegetable cultivation, ornamental gardening, floriculture, kitchen gardens, orchards, fruit products, fruit processing, sericulture, mushroom cultivation, medicinal plants, vermi-composting, snack production, catering, bakery units, and cereal pulverizing units.

In allied sectors, micro enterprises undertaken by SHGs across Kerala include woodwork units, stonework units, soap production, garment units, computer centers, poultry farming, cattle rearing, piggery units, beekeeping, stitching units, hand weaving, candle production, chalk manufacturing, umbrella units, foam bed units, bamboo handicrafts, paper covers, scrap selling, vegetable seed production, marriage bureaus, medicine collection, patient services, real estate, medicine processing, direct marketing, coir brushes, plastic weaving, second-hand sales, meat masala production, pickle and spice powders, consumer service centers, home delivery services, repacking businesses, cleaning products, soap production, kids' garments, toffee and sweets, photocopying, emery powder, domestic animals, nursery plants, notebook production, bookbinding, rubber slipper manufacturing, pillow cushions, incense stick production, cloth whiteners, eucalyptus oil, dolls, hand shampoos, soap shampoos, detergent shampoos, jackfruit jam, chips, catering services, grape wine, pineapple wine, soft drinks, chicken farming, dried mango wafers, gooseberry wine, ginger wine, papads, tomato sauce, day care centers, coconut water vinegar, syrups, artificial vinegar, mixed fruit jams, milk chocolate, tomato squash, gum production, cleaning lotions, soft drink shops, reading rooms, private tuition, counseling services, rent sales, and repair centers. These opportunities are contingent upon the suitability of local situations and the availability of resources.

The suitability of micro-enterprises varies based on the context. Key features for the success of viable micro-enterprises include the availability of sufficient local raw materials, ease of learning or familiarity with the enterprise, low production costs, high-quality products, and a readily available market for the products. Several financial organizations support SHGs by providing funding, including the Khadi and Village Industries Board, Department of Commerce & Industry, Jawahar Rosgar Yojana, Women Industrial Cooperative Societies, Kerala State Social Welfare Advisory Board, Kerala Financial Corporation, National Bank for Agriculture and Rural Development (NABARD), District Rural Development Agency (DRDA), and various Non-Governmental Organizations (NGOs), along with Kudumbashree Ayalkoottam groups.

The constraints faced by women fisherfolk in Malabar, both in general and as members of Self Help Groups (SHGs), are outlined in Table 7. While common challenges like poor living conditions, illiteracy, and unemployment are acknowledged, the focus of this study is on the specific constraints faced by SHGs. Among these, the marketing aspect was identified as the most significant barrier, overshadowing procedural challenges related to preparing minutes, reports, meetings, and banking. These priorities and constraints clearly indicate the urgent need for diversifying micro-enterprises within SHGs, in addition to those centered around fisheries, for their long-term sustainability. Many women-led SHGs in Malabar have already begun exploring and diversifying into other viable enterprises within the fisheries sector.

Table 7. Ranking of constraints of women fisherfolk in Malabar

No	General Constraints	Rank assigned by respondents (n = 180)			
		Kasargod	Kannur	Kozhikkod	Malappuram
1.	Poor living conditions & livelihood security	I	I	I	I
2.	Educational Illiteracy	II	II	II	II
3.	Lack of proper employment	IV	III	III	IV
4.	Socially unorganized set up	III	IV	V	III
5.	Gender inequality	VI	VI	IV	V
6.	Alcoholism of men fisherfolk & exploitation	V	V	VI	VI
7.	Health problems	VIII	VII	VII	VII
8.	Scientifically less advanced	VII	VIII	VIII	IX
9.	Cultural bonding, customs, traditions, conservatism	IX	IX	IX	VIII
	Constraints of SHG	**Rank assigned by respondents (n = 180)**			
10.	Marketing is a tough task	I	I	I	I
11.	Choosing Diversification difficult	III	IV	III	II
12.	Sustenance difficult	IV	II	II	III
13.	Hectic procedures in preparing minutes, reports, meetings, banking etc.	II	III	IV	IV
14.	SHG became an additional burden	V	V	V	V

Strategy for Mobilizing and Strengthening Effective SHGs of Women Fisherfolk

Based on the findings of the study, a comprehensive strategy for mobilizing and strengthening effective Self-Help Groups (SHGs) of women fisherfolk was developed through consultations with 6 social mobilization experts, 12 leader members from selected SHGs, and 12 officials from intervening agencies. This strategy is organized into three key phases of group development: **Group Formation**, **Stabilization**, and **Self-Helping**. Each phase outlines critical features, including norms and bylaws, to ensure the SHG's success. Below is a brief outline of the developed strategy:

1. Group Formation Phase (0 to 4 Months)

The initial phase involves laying the groundwork for the SHG. Key steps include:

- Conducting initial visits to the location, building rapport, and creating awareness among the women fisherfolk.
- Organizing introductory meetings to identify potential members and discuss the group's goals.
- Developing an action plan and documenting all deliberations.
- Mobilizing genuine members and holding follow-up meetings to address challenges and provide solutions.
- Organizing training on fishery-based and diversified micro-enterprises, with a focus on sourcing raw materials, gathering marketing information, and selecting 'Leader Fisherwomen' for roles in production, credit, and marketing.
- Conducting the first basic field training, followed by need assessments for future training programs focused on production technology and management.

2. Building Up / Stabilization Phase (4 to 15 Months)

In this phase, the focus is on strengthening the group's structure and functionality. Key steps include:

- Holding regular, need-based meetings to maintain momentum and address emerging issues.
- Training women leaders in production, credit management, and marketing, ensuring they are equipped to implement the action plan.
- Procuring necessary inputs based on the production plan aligned with market demands, and ensuring synchronized production planning.
- Providing intensive training on production, credit, and marketing aspects, with leaders teaching other members.
- Rotating the leadership within the SHG every year to provide new members with opportunities for leadership, while maintaining the role of intervening agencies as enablers.

3. Self-Helping Phase (15 to 36 Months)

The final phase focuses on ensuring the sustainability and autonomy of the SHG. Key steps include:

- Developing a fortnightly action plan for the group to continue refining, improving, and solving problems.
- Reducing the intervention of external extension personnel, allowing the SHG members to manage their own affairs independently.
- Rotating leadership every two years to ensure fresh leadership and maintain engagement within the SHG.
- Encouraging inter-SHG communication and fostering a competitive spirit through activities such as contests to recognize the best member or SHG.
- Establishing norms for defaulters and ensuring active participation in all activities for the SHG's continued success.
- Promoting a positive group atmosphere, empathy, and interpersonal trust to achieve significant outcomes and maintain the group's cohesion.

By following this strategy, SHGs of women fisherfolk will be better equipped to manage their micro-enterprises and continue making a positive impact on their communities.

Practical Utility

This study offers a glimpse into poverty eradication efforts within the Malabar Fisheries sector, focusing on the dynamics of women’s Self-Help Groups (SHGs). The **Group Dynamics Effectiveness Index (GDEI)**, which encompasses 12 key dimensions, serves as a valuable tool for future research on community-based groups in fisheries and allied sectors. This framework can be applied to various groups, such as youth, laborers, and extension personnel, to assess and enhance their group dynamics.

The insights gleaned from the identified gaps in the GDEI provide essential feedback for improving the functioning of SHGs. Addressing these gaps can directly enhance the effectiveness of

SHGs. The successful case studies highlighted in this research can serve as model templates for mobilizing SHGs in other sectors, including **Agriculture**, **Forestry**, **Floriculture**, **Agro-based industries**, and **Watershed development**.

The strategy developed for mobilizing SHGs can be utilized as a practical manual for organizing and managing SHGs in any sector, ensuring their sustainability over time. Furthermore, the constraints identified within the SHGs, along with the preference ranking of micro-enterprises, offer valuable insights into the suitability of location-specific ventures in both **fisheries** and **diversified sectors**, fostering the economic empowerment of women fisherfolk.

The interrelationships among the identified variables act as catalytic points for promoting group empowerment. These insights can guide the strengthening of SHG functions, enhancing their ability to address challenges effectively. Ultimately, it is through mobilizing women to tackle their problems independently via SHGs that poverty eradication becomes a tangible reality.

5. Institution-Village-Linkage-Programme (IVLP) for Technology Assessment and Refinement (TAR) in the Coastal Agro-Ecosystem of Ernakulam, Kerala

A significant initiative aimed at empowering fisherfolk was undertaken through the **NATP-funded IVLP project**, with the primary objectives of assessing local needs, understanding the coastal agro-ecology, and refining production systems using advanced scientific management practices. The program aimed to enhance productivity, ensure sustainability, and improve farm systems, making them more equitable, stable, and profitable.

The IVLP was implemented in **Elamkunnapuzha Village**, located in **Vypeen Island, Ernakulam District, Kerala**, over the past three years. The project engaged **687 farm families**, representing a population of **3,435 stakeholders**. In this collaborative effort, **31 techno-interventions** were introduced, including **13 in fisheries**, **13**

in agri-horticulture, and **5 in livestock**. Additionally, **15 training programs** were organized, benefiting **576 farmers**. The strong linkages established during the program helped stakeholders sustain their efforts, leading to a lasting impact. This initiative has earned widespread acclaim and is now celebrated as the **"Elamkunnapuzha Model of Development."**

Key Techno-Interventions for Expansion

During the final phase, refined technologies were prioritized for horizontal expansion across Kerala. The six selected interventions included:

1. **Monoculture of Grey Mullet**
2. **Monoculture of Milkfish**
3. **Polyculture of Finfish**
4. **Integrated Nutrient Management (INM) in Coconut Plantations**
5. **Dairy Farming with Paragrass**
6. **Poultry Farming with the 'Gramalakshmi' Breed**

Projected Economic Impact

At just **25% adoption** across Kerala, the projected economic benefits from these six interventions are staggering:

- **₹420 crore** from an additional **60,000 tons of fish production**.
- **₹220 crore** from a surplus **1,000 tons of milk yield per day**.
- **₹12 crore** from enhanced poultry farming revenue.
- **₹190 crore** from increased productivity in coconut plantations in coastal districts.

Sustained Development and Market Support

Several IVLP interventions were sustained through the **ATIC of CMFRI**, which acted as a sales outlet for products from IVLP units. This platform provided a vital connection between the production units and the market, ensuring the long-term viability of the technologies introduced.

The **Institution-Village-Linkage-Programme** at Elamkunnapuzha stands as a beacon of sustainable development, illustrating how targeted interventions, scientific practices, and stakeholder collaboration can transform local economies and empower communities. This model now serves as an inspiration for scaling similar initiatives across other regions.

6. **Empowering Weaker Sections: Success Case Studies of Individual Achievements**

The empowerment of weaker sections, particularly fisherfolk, is vividly exemplified through success stories of individuals who achieved remarkable professional milestones, enhanced their earnings, and generated employment opportunities. These inspiring case studies highlight the transformative impact of strategic interventions and the resilience of individuals in overcoming challenges.

Self Help Groups (SHGs) mobilized around various micro-enterprises, with significant inspiration and support from **ATIC**, were also studied to uncover additional success stories. The role of ATIC in guiding and facilitating these SHGs was pivotal in turning small initiatives into thriving ventures.

Methodology for Livelihood Analysis

Data collection for the livelihood analysis involved a combination of methods, including:

- Existing information: Utilizing documented resources and records.
- People's perceptions and opinions: Gaining insights through interactive discussions.
- Direct observations: Studying real-time practices and outcomes.
- Personal interviews: Engaging with individuals to capture their lived experiences.

This comprehensive approach to livelihood analysis sought to uncover the strategies and assets individuals and households use to sustain their livelihoods. The analysis followed frameworks and methodologies from leading references in the field, such as: Aujimangkul et al. (2000), DFID (2001), Graham and Tanyang (2001), CBCRM Resource Center (2003), Arciaga et al. (2002), Ashby (2003) etc. These studies emphasize that a livelihood encompasses not just financial earnings but also the resources, strategies, and networks individuals and households deploy to build resilience and achieve sustainable development.

A Model for Inspiration

The success cases serve as a guiding light, demonstrating the transformative potential of strategic interventions, knowledge sharing, and community mobilization in improving the lives of marginalized communities. These stories are not just about economic gains but about restoring dignity, confidence, and hope for a better future.

(6.a) Dry Fish Processing: A Success Story of the 'Janani' Women's Self-Help Group at Elamkunnapuzha

The **'Janani' Self-Help Group** (SHG), based in Puthuvyppu Post, Elamkunnapuzha, Vypeen Island, has become a shining example of empowerment through sustainable fish drying practices, facilitated by the **CMFRI** intervention. This group, comprising 15 determined women, revolutionized their traditional fish drying methods into a commercially successful venture.

Drying fish was not new to these women. For years, they had been individually drying fish on a small scale, relying on traditional methods. However, the lack of hygiene in their processes led to significant wastage, yielding minimal profits. Most of the dried fish was used for household consumption, with the surplus sold locally, often door-to-door.

A Journey of Transformation

The President of the group, **Mrs. Chandramathi Appukuttan**, reflects on this transformation with pride. Having settled in Elamkunnapuzha after her marriage 20 years ago, she became part of a 13-member women's group in 1997. At the time, they relied on market surpluses during bumper fish catches for their drying activities. Though operational costs were low, the lack of hygienic practices resulted in poor product quality and low profits.

Everything changed when their group was selected by **ATIC of CMFRI** for targeted interventions under the **IVLP** program. Through this initiative, the group began processing high-quality fish on a commercial scale. The transition was accompanied by a host of improvements:

1. **Training and Awareness**

   Scientists from CMFRI provided hands-on training, introducing the group to hygienic fish-drying techniques, such as dip treatment using calcium powder. This knowledge dramatically improved the quality and shelf life of their products.

2. **Upgraded Infrastructure**

   The group received **special drying racks**, which minimized fish wastage during processing and maintained product quality. This improvement replaced the traditional methods of drying fish on open surfaces, reducing contamination and spoilage.

3. **Enhanced Packaging and Marketing**

   The group transitioned from using paper packing to high-quality, attractive packaging, making their products more marketable. New marketing outlets suggested by CMFRI further expanded their reach.

A Growing Impact

Mrs. Chandramathi remarks, "It feels like luck smiled upon us when ATIC of CMFRI chose our group for this program. With their inputs and support, we've learned hygienic processing methods and found better markets for our products. Today, our dried fish is in demand, and more women are inspired to take up similar ventures."

This success story highlights how scientific interventions and community support can empower marginalized groups, transforming traditional practices into scalable, sustainable businesses. The achievements of **'Janani' SHG** serve as an inspiring model for women across coastal communities to venture into profitable, hygienic, and sustainable fish-drying enterprises.

Conservation of Marine Resources: The Inspiring Story of Theeram Turtle Protection Group at Kolavi Palam, Payyoli

The picturesque **Kolavi Palam Beach**, near Payyoli in northern Kerala, is renowned for its seasonal gatherings of marine turtles during nesting periods. Inspired by the beauty and vulnerability of these creatures, a group of passionate young nature enthusiasts formed the **Theeram Nature Conservation Society** to safeguard this vital marine resource. Their commitment soon caught the public eye, with newspapers highlighting their dynamic efforts in marine conservation.

The remarkable work of Theeram quickly gained widespread recognition, prompting interventions from key stakeholders like the **Kerala Forest Department**, the **Kerala Forestry Project**, the **Malabar Coastal Institute for Training, Research and Action (MCITRA)**, and leading research institutions such as **CMFRI** and **IISR**. These collaborations focused on educating the public about the importance of sea turtle conservation and marine resource management.

From Awareness to Action

In 1992, the group launched awareness programs that resonated with the community, culminating in formal assistance from the Kerala Forest Department in 1998. Support included the establishment of two turtle hatcheries and sheds, along with the provision of lanterns, torches, and wages for six dedicated members. With this support, Theeram gained legal registration and began operating systematically.

The group transformed Kolavi Palam into a vital turtle breeding ground while also championing broader marine resource conservation. They connected with the **ATIC of CMFRI** to learn the principles of **Responsible Fisheries Management**, mangrove conservation, and ecosystem sustainability. ATIC provided essential materials such as bulletins on sustainable fisheries management, FAO's Code of Conduct for Responsible Fisheries, and national conference proceedings on marine turtles. Interactive meetings facilitated by CMFRI scientists at Kolavi Beach fostered knowledge-sharing with fisherfolk, reinforcing the group's efforts.

Overcoming Challenges

Despite facing significant hurdles such as severe sea erosion—which reduced the shoreline to just 350 meters—and the loss of several hatcheries, Theeram's dedication has not wavered. Over the years, the group has successfully released more than **40,000 turtle hatchlings** into the sea. They remain hopeful for a large arribada (mass nesting) in the near future.

Expanding Conservation Efforts

Theeram's impact extends beyond turtle conservation. The group has planted mangrove seedlings, nurturing them with unwavering commitment to restore natural habitats. They have also established a **nursery of forest trees** comprising 35 different species, raising approximately **30,000 seedlings** with assistance from the Forest Department. This initiative aims to create a permanent green infrastructure for the region.

Educating and Inspiring

The group organizes awareness camps, projects films, and conducts slide shows to educate the community on the importance of nature protection and mangrove conservation. They continue to maintain strong ties with ATIC, with frequent interactive discussions held both at Kolavi Palam and at ATIC, under the leadership of their President, **Sri Surendrababu**, and Secretary, **Sri Sureshbabu**.

The efforts of Theeram Nature Conservation Society stand as a testament to the power of grassroots action in conserving marine resources. Their unwavering commitment serves as an inspiration to many, showcasing the profound impact of collective effort in protecting our natural world. But as the time progressed, the present stage of Theeram is not at all conspicuous because of sea erosion and lack of government support.

(6.c) infish Culture: A Farmer's Success Story at Puthuvyppu

Mr. Karthikeyan, a 48-year-old resident of Thirunilathu, Puthuvyppu, Elamkunnapuzha, with a primary level education, has become a shining example of success in finfish culture. In 1996, he ventured into fish farming on his own 42 cents of land, initially facing several challenges. The land, overgrown with dense bushes, blocked the inflow and outflow of saline water, leading to silt accumulation and an increase in weed growth. Determined to turn his fortunes around, he cleared the bushes, deepened the area, and constructed temporary sluices at the eastern corner of the pond to facilitate water exchange.

Without hiring additional labor, Mr. Karthikeyan relied entirely on his family, particularly his wife, **Mrs. Isha**, who actively participated in all farm operations. Initially, he allowed the natural entry of species such as **gray mullets, pearl spot, and milkfish**, occasionally supplementing them with selective stocking of **Mugil cephalus**. However, the absence of a specific stocking rate and irregular feeding patterns resulted in low yields and minimal economic returns, barely sufficient to sustain the family.

The Turning Point

Mr. Karthikeyan approached **ATIC** and enrolled in the **IVLP program** of CMFRI. He received hands-on training on critical aspects of finfish farming, including the importance of maintaining functional sluice gates for effective water exchange, systematic stocking, and feeding protocols. Armed with newfound knowledge and guidance from scientists, he implemented these best practices in his farm operations.

Reflecting on his journey, he shares:
"*The training I received completely transformed my approach to fish farming. By following the stocking and feeding methods suggested by the experts, my income from fish culture increased from Rs. 32,000 to nearly Rs. 55,000. This additional income allowed me to provide quality education for my daughters. Without a doubt, I owe this success to the IVLP program and the support from ATIC of CMFRI.*"

A Remarkable Transformation

Today, Mr. Karthikeyan’s farm stands as a model for aspiring fish farmers in the region. His journey underscores the potential of adopting scientific methods and leveraging institutional support to achieve both personal and professional growth.

(6.d) Crab Culture & Crab Fattening: A Farmer’s Success Story at Malippuram

Sylvi Figerado, a dynamic farmer from Pathissery, Malippuram, Elamkunnapuzha, has achieved remarkable success in **crab monoculture** using CMFRI technology. A matriculate by education, Figerado initially leased a 6-acre pond for shrimp farming after an unsuccessful stint as a boat owner during the 1980s. His fishing business suffered significant losses, leaving him in financial distress. At the time, his two young sons were unable to contribute to the family income, prompting him to explore other avenues.

The Transition to Crab Culture

With guidance from the **IVLP team of CMFRI** and regular farm advisory support from **ATIC**, Figerado decided to try crab farming. Initially skeptical, his doubts and reluctance toward crab culture were dispelled through consultations and hands-on advice on critical aspects like water exchange, stocking quality seeds, uniform seed size selection, farm management, and feeding techniques. His wife, **Juliet**, also 53, played a vital role, providing unwavering support in all farming operations.

Financial Success

In 2002, the couple earned an impressive profit of ₹47,000 from a single harvest, and their earnings crossed ₹50,000 in the next cycle. This upward trend has continued, and Sylvi and Juliet now confidently rely on crab farming as a consistent source of income. They proudly state:

"*Whenever we need money, we just sell crabs and get the required amount instantly. Crab farming is undoubtedly the best technology for generating high profits with minimal risk.*"

Diversification and Sustainability

Sylvi and Juliet have further diversified their farming activities by integrating **duck farming** and **homestead vegetable cultivation**, including bitter gourd and cowpea. The ducks' excreta serve as organic manure for their homestead garden, enhancing soil fertility and sustainability.

Their journey exemplifies how adopting innovative technologies and sustainable practices can transform lives, making Sylvi and Juliet role models for aspiring farmers in the region.

Other projects for Self Help Groups

Under **SCSP scheme**, the DST funded project on 'Empowerment of SC fisherfolk through Entrepreneurial Capacity Building of SHGs in marine sector' an amount of 7 lakhs and under the project on Science Technology and Innovation Hub in Fisheries Sector, Kochi Corporation, Ernakulam district, Kerala State' Rs. 86 lakhs have been utilised for the following number of startups mobilised for 91 SHGs representing 576 beneficiaries. The training on the technologies to the SHGs was essentially undertaken with the assistance of KVK, Ernakulam.

1. Cage farming-16
2. Pearlspot seed production-7
3. Fish culture-10
4. Fish fertiliser production-3
5. Value added fish production-13
6. Mussel culture-5
7. Oyster-5
8. Clam units -5
9. Integrated fish farming- 8
10. Ornamental fish culture-10
11. Dry fish unit-3
12. Fish vending units- 6

Under the project on Science Technology and Innovation Hub in Fisheries Sector, Kochi Corporation, Ernakulam district, Kerala State' an interactive kiosk on fishery-based interventions, entrepreneurial consultancy cell, entrepreneurial data documentation cell with smart class set up and digital training hall and a mobile training unit embedded with a lab facility with all digital devices for imparting filed training to farmers have been mobilised. The adoption of innovative farming technologies, including cage culture, mussel and oyster farming, marine ornamental fish cultivation, scientific fish farming, and advanced seed production techniques, has been actively promoted to empower Self-Help Groups and enhance sustainable livelihoods.

Amble research on the fish farming technologies with practical application such as Cage culture, Mussel & Oyster culture, Seaweed farming, Marine ornamental fish culture has been done and these technologies have been brought out for enhancing the income of farming communities.

Under the Government Scheme, the Department of Science and Technology (DST) granted 2 funded projects to offer technological and scientific aid to farmers as the following:

1. 'Empowerment of SC fisherfolk through Entrepreneurial Capacity Building of SHGs in marine sector' with a financial outlay of Rs 26 lakhs (2019-22)
2. 'Science Technology and Innovation Hub in Fisheries Sector, Kochi Corporation, Ernakulam district, Kerala State' with a financial outlay of Rs 3.2 Crores (2022-25)

A project proposal focusing on fishery-based entrepreneurial technologies for the Scheduled Tribe community in Lakshadweep Islands and Kerala has been meticulously prepared and is ready for submission to the Department of Science and Technology (DST), New Delhi for external funding.

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- Kato, M. P., & Kratzer, J. (2013). Empowering Women through Microfinance: Evidence from Tanzania. ACRN Journal of Entrepreneurship Perspectives, 2(1), 31-59.

Under the umbrella of "Redefining Lives," a collection of inspiring case studies highlights the transformative power of Self-Help Groups (SHGs) and their role in economic and gender empowerment. (Kumar and Corbridge (2002), Holvoet (2005), Sanyal (2009), Swain and Wallentin (2009), Deininger and Liu (2013), Kato and Kratzer (2013), Desai and Joshi (2014), Brody et al. (2015), Datta (2015), and Odede (2023).) These case studies, drawn from the researcher's dedicated projects undertaken throughout the coastal belt of the country, exemplify how community-driven initiatives can uplift marginalized sections of society, particularly women in fisheries and allied sectors.

These narratives emphasize the interplay of collective effort, scientific intervention, and grassroots innovation, revealing how SHGs serve as catalysts for holistic empowerment. Beyond economic gains, they foster self-reliance, gender equity, and environmental stewardship, offering replicable models for broader community development. Together, these stories reflect the profound potential of empowering lives through purpose-driven collaboration and resource optimization, painting a compelling picture of transformation and hope.

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Phytotoxicity test: Proof of Compost Maturity and Quality

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Composting, a natural and eco-friendly biochemical process, is a standout method for sustainable organic waste management. It turns organic waste into compost that can enrich soil, support plant growth, and reduce the need for chemical fertilizers. Composting is widely used in sanitizing and recycling bio-wastes such as animal wastes, carcasses, crop straws, agro-industrial residues, municipal organic solid wastes, *etc*. Since all the potential applications of compost need close contact of the compost with plants, phytotoxicity is one of the critical criteria to assess its quality and suitability for agricultural purposes, landscaping and environmental restoration, and it is particularly relevant for the compost used in high-value horticulture applications. A delay in seed germination, inhibition of plant growth, or any other unfavourable consequences brought by certain compounds is referred to as phytotoxicity. Phytotoxicity tests should be simple, rapid, and reproducible. Prolonged field experiments are not recommended for phytotoxicity evaluation as the plants may adapt to the toxic compounds during long-term exposure. Determination of *in vitro* seed germination and plant growth are the most common techniques to assess the phytotoxicity of compost (Barral and Paradelo 2011).

Applications of Seed Germination Test

1. **Quality assessment of compost**: The seed germination test evaluates the impact of the compost on seedling growth and development. By observing how well seeds germinate and

grow in compost, researchers can infer the quality and safety of the compost for agricultural use. It can evaluate how well compost supports seed germination, indirectly indicating nutrient availability.

2. **Toxicity evaluation of compost**: A phytotoxicity test helps identify the toxic effects of the compost material that might inhibit seed germination or seedling growth. The phytotoxic effects of compost are caused mainly by ammonia, ethylene oxide, organic acids, *viz.* acetic acid, propionic acid, butyric acid and isobutyric acid, phenols, salts, and heavy metals. Even though different analytical methods can identify several toxic components, they are usually expensive. Moreover, it can miss the unexpected contaminants present in the compost. Further, no analytical procedures can measure the effects of synergy and antagonism of toxic compounds. In these circumstances, the seed germination test is the most realistic and thorough way to assess the compatibility of composted materials with plants.
3. **Standardization of composting protocol**: Phytotoxicity assessment is a valuable way to assess whether the stable stage of the composting process (maturity) has been achieved. Since composting can remove most of the phytotoxic substances found in fresh waste and the toxic compounds produced during the initial stages of composting, the test can be crucial for determining the minimal time required for the composting process to obtain mature/ stable compost.

Seed species: The choice of plant species susceptible to the toxic components under evaluation is an essential element of the biotests. The result of the seed germination test is a seed species-dependent parameter, and cress seed (*Lepidium sativum* L.) is the most adopted species in the published papers. However, Chinese cabbage seed was recommended as the model species for compost evaluation in a review by Luo et al. (2017) due to its merits, *viz*. response to toxic substances (sensitivity), the germination cycle (<48 h) and the medium seed size. A lot of other plant seed species have been used by several authors, viz. tomato, carrot, cucumber, cabbage, radish, lettuce, beans, cereals such as barley, rice, wheat, rye, soya or corn, sunflower, petunia, amaranth, *etc*. The ISO protocol (ISO11269-2:2005) recommends using at least one monocotyledonous and one dicotyledonous species in seed germination tests.

Methodology: The typical seed germination test involves three steps:

1. Preparation of aqueous extract: In this step, the compost sample is mixed with distilled water in a 1:10 proportion, stirred well and allowed to sit for 24 h.
2. Incubation: After 24 hours, the compost-water mixture is filtered to obtain the compost extract. The seeds are then incubated with the prepared extract in a warm, light environment suitable for germination.
3. Plant the seeds: The seeds are then planted and placed in a suitable environment with adequate light and temperature. Water the plants with distilled water as needed. After 5-7

days, the number of germinated seeds in each dish is counted. The length of the roots and shoots is measured.

4. Calculation and interpretation: Measure and calculate various indicators, including the seed germination (SG), the relative seed germination (RSG), the relative radicle growth (RRG) and the seed germination index (GI) (Luo et al. 2017).
   - SG%: The percentage of seeds that successfully germinate. (Number of germinated seeds/ Number of total seeds) *100
   - RSG%: The percentage of germinated seeds in the extract compared to a control. (Number of germinated seeds in the sample/ Number of germinated seeds in the control) *100
   - RRG%: The growth of the radicle (root) in the test sample compared to the control (Total radicle length of germinated seeds in the sample/ Total radicle length of germinated seeds in the control) * 100
   - Seed Germination Index (GI)%: A composite index that combines germination percentage and radicle growth to provide a holistic view of seed performance (RSG*RRG*100)

Interpretation of results

The germination index (GI) is the most sensitive indicator for assessing the phytotoxicity of compost. Some authors recommend using relative root elongation for the phytotoxicity of compost, as the root elongation is more sensitive to toxins than seed germination. GI is an integrated parameter which combines relative germination and relative root elongation. The general interpretation guidelines for the GI values include that below 50% are highly phytotoxic, between 50% and 80% are moderately phytotoxic, and above 80% are non-phytotoxic. When the index exceeds 100%, the compost is a phytonutrient or phytostimulant.

Conclusion

The phytotoxicity test is a valuable tool in compost quality and maturity assessment since phytotoxic substances can impede seed germination and early plant growth, thereby potentially reducing crop yields and reducing soil health. The seed germination test is the most commonly used technique for phytotoxicity evaluation, but the procedure variability and variations in seed species currently restrict the test's efficacy. By addressing these challenges, we can improve the development and application of compost, supporting more sustainable farming practices. Standardizing the testing methods and seeds is a promising avenue for improving the accuracy and reliability of these tests. Seed germination testing using a variety of plant species can provide insights into the suitability of compost for a diverse agricultural application. In conclusion, phytotoxicity testing remains a vital component of sustainable compost management, ensuring that the compost we produce is beneficial for plant growth and safe for the environment. By prioritizing such evaluations, we can foster healthier agricultural ecosystems and support the principles of sustainable farming.

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Harnessing the Power of Microbial Consortia for Sustainable Fish Waste Treatment

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Introduction

The global population is expected to reach 9.8 billion in 2050 and 11.2 billion in 2100 (UN report 2017), significantly increasing the demand for food. Further, the increasing economic growth and growing awareness of balanced nutrition shift the nutrition demand of people towards higher consumption of animal-based products and diverse food items. Among different food production sectors, the fisheries sector is critically important in providing food safety and employment for the growing global population. Currently, fish provides > 4.5 billion people with a minimum of 15% of their average per capita animal protein intake (FAO 2016). Fisheries and aquaculture have been the world's fastest-growing food industries for the last 40 years and this trend is predicted to continue (Bene et al. 2015). The global fisheries and aquaculture production has reached 223.2 million tonnes in 2022 with a 4.4% increase from 2020 (FAO 2024). As a result, there has been a sharp increase in fish waste worldwide. It is estimated that ~10% of the global fish catch (>90 million tonnes) is currently discarded, and fish processing wastes including heads, bones, scales, viscera, gills, and skin account for up to 70% of the whole fish weight (Boronat et al. 2023).

Impacts of fish waste

Fish waste is a menacing issue and a major source of environmental pollution, necessitating creative solutions to implement sustainable waste management methods. As fish wastes are rich in nutrients (58% and 19% of dry matter is protein and fat, respectively), unless efficiently managed, they will be dumped in the environment causing pollution from organic matter, nutrients, and chemicals used in fish processing (Selvi et al., 2014). Improper fish waste disposal can disrupt aquatic ecosystems. The accumulated waste overloads the water with nitrogen, phosphorus, and ammonia, causing a pH shift and increased water turbidity. Fish waste produces harmful hydrogen sulphide, ammonia, and greenhouse gases like carbon dioxide and methane exacerbating climate change if not managed sustainably. Release of toxic gases, oxygen depletion, and pH change produce harmful algal blooms and negative impacts on aquatic and marine life. It leads to increased scavenger gatherings at discharge locations and noxious conditions brought on by bacteria, odours, and waste decomposition (U.S. Environmental Protection Agency Report, 2010). Improper management of fish waste will detrimentally affect human health, by contaminating water supplies, increasing the prevalence and spread of infectious diseases, and degrading local water supplies and groundwater.

Valuables resources from fish waste

Addressing the burden of fish waste management requires a comprehensive approach that includes improving waste treatment technologies, promoting sustainable fishing and processing practices, enhancing regulatory frameworks, and encouraging the utilization of fish waste in value-added products. Fish waste management techniques and utilization/ further processing of fish waste in each place are dependent on the local conditions and the structure of the industry. The most common value-added products from the fish waste include organic fertilizers, animal feeds, silage, and feed supplements (fish oil, fishmeal, fish silage, calcium supplements), biogas and bioenergy, protein hydrolysates (can be used as a milk replacer and food flavouring agents), antioxidants and bioactive peptides that have applications in nutraceuticals, pharmaceuticals, and functional foods, natural pigments, chitin (applications in the production of biodegradable plastics, water treatment, and as a feed additive), industrial enzymes (proteases, alkaline phosphatase, hyaluronidase, acetyl glucosaminidase and chitinase), fortified foods, cosmetics, pharmaceutical products such as collagen, chitosan, gelatin, fish bone extracts, amino acids, and polyunsaturated fatty acids. The synthesis of surgical sutures from fish gut, the use of fish scales as natural adsorbents and in ornamental applications, the production of short-chain organic fatty acids, use as substrates for microbial culture media, the creation of attractants for commercially significant flies, and the production of fish glue from fish skin and heads are additional value-added options for fish waste.

Benefits of fish waste as an organic fertilizer

The six macronutrients for plants are nitrogen, phosphorous, potassium, calcium, magnesium, and sulphur. Even though fertile soils can deliver a significant share of these nutrients, most soils require a regular input of fertilizers containing these six macronutrients and preferably thirteen micronutrients for successful growth. Fish waste usually contains significant amounts of nitrogen, phosphorous, calcium, and sulphur, even though they are less well-balanced concerning potassium and magnesium. The average nitrogen content in fish waste is ~12–13% of dry matter. The composition of nutrients in fish waste varies between different fish species, size and with the inclusion/exclusion of tissues like head, bones, and viscera. The average nitrogen content in the powder from trimmings was ~14% compared to 5–7% of DM from the powder from frames and gills. The fish bones contain ~60 to 70% minerals, mainly in the form of calcium and phosphorus as hydroxyapatite. The average phosphorus and calcium content in the fish bones was 170 and 221 g per kg dry matter, respectively. Fish scales are very rich in nitrogen (5 to 11% of dry matter), phosphorus and calcium. Generally, the average values of N-P-K for inland captured and marine captured fish were 120:11:13 and 130:16:11, respectively. However, the potassium content was low in fish waste, ranging from 0.003 to 1.7 g per kg dry matter. The major difference between shellfish waste and finfish waste is that shellfish waste contains a large amount of chitin due to shell residues. Altogether, different studies showed that fish waste possesses substantial amounts of nitrogen and minerals, and thus can play an important role in meeting the nutritional requirements of crop plants (Ahuja et al. 2020).

Composting fish waste for organic fertilizer

Composting is an old practice and simple technique for controlling environmental pollution. Composting is the biological alteration of waste materials, under controlled conditions, into a hygienic, humus-rich, relatively stable bioproduct

that conditions soils and nourishes plants (Mathur, 1991). It is an aerobic biological decomposition of organic matter by microorganisms. It is essentially similar to the natural decomposition process except that it is accelerated by mixing organic waste with other ingredients to optimize microbial growth. The resulting product termed 'compost' enhances the physical properties of soil like total porosity, available water content,

saturated hydraulic conductivity, and organic matter. Fish remains are a preferred substrate for fertilizer due to their high nutritional value. Composting initiatives using fish waste have been done worldwide as a viable technique for converting fish waste into useful agricultural products (López-Mosquera et al. 2011). Composting can effectively reduce the volume of fish waste and demolish disease-causing organisms and larvae of flies from waste. The composting of fish waste for producing organic fertilizers has received attention in recent years to increase the economic and ecological sustainability of the fish industry, however, the technique is not well-popularised in India (Jayvardhan and Arvind 2020). As fish waste is rich in protein, the compost merely based on fish waste tends to have a low C/N ratio. Hence, "bulking agents" are required for an adequate composting process. Adding bulking agents also facilitates aeration through the pile and provides carbon sources for microorganisms. The rapid release of ammonia from protein degradation of fish wastes and calcium from fish bones tends to shift the pH of the compost mixture towards the alkaline range, where adding bulking agents with acidic characteristics contributes to a decrease in pH. Further, the water-absorbing character of the bulk agent helps to control the moisture components of the fish wastes. Different bulking agents include sawdust, rice hulls, coconut pith, wood chips, bark, crop residues, leaves, crushed grass, wheat bran, agricultural wastes, peat, seaweeds, poultry litter, and straw.
Fish composting has been evaluated from very simple to complex composting techniques such as in-vessel composting bays, compost-pits and bin systems including three-bin systems, wooden crates, reactors, ceramic pots, and passively aerated windrow method. The maturation of the fish waste compost with peat moss in a passively aerated windrow method took 8 to 10 weeks.

Operative constraints in the composting process

1. ***Aeration***: Many aerobic microbes involved in the bioconversion process require oxygen for their growth and other metabolic processes. Anaerobic degradation will be

adopted in the absence of sufficient oxygen, which will eventually cause the emission of malodorous gases. Aeration also aids in regulating the moisture content and temperature by dissipating the heat produced during the composting reactions. Conversely, over-aeration dries out the mixture and produces low temperatures that are inappropriate for the composting process. If the composting time is four months, it is advised to turn the pile once every two weeks for the first two months and once every fifteen days for the final two months.

2. ***Carbon to nitrogen ratio (C: N)***: The available carbon to nitrogen ratio needs to be maintained at the right levels to support an active microbial population during the composting process. Higher ratios will cause the composting process to take longer, while lower ratios will cause nitrogenous compound losses. The optimal C: N ratio of the total substrate in compost should be between 20 to 30 (Busato et al., 2018)
3. ***Moisture level***: Water provides a medium for the bioconversion activities in the compost mixture and is necessary for the survival of microbial populations. Low moisture content will slow down the decomposition of compost, but flooding the compost site will prevent the gas exchange that is necessary for aerobic processes. The optimum moisture range for composting operations is 40-60%.
4. ***Temperature***: In the composting process, temperature affects the microbial population and bioconversion rates. Temperatures in the range of 32°C to 60°C indicate the rapid progression of the decomposition process in the compost. Reduced temperatures indicate the slow progression of the composting process. However, high temperatures >65°C result in a reduction in the activity of the majority of microorganisms. The compost pile must maintain the composting materials at a temperature between 131 °F (55°C) and 170 °F (76°C) for a minimum of three days to destroy

weed seeds, pathogenic microorganisms, eggs of parasites and fruit flies.

5. ***pH***: A good composting performance is indicated by the pH of the final compost as 6-8.5. Release of carbon dioxide and ammonia during the degradation of protein-rich wastes such as fish waste will impart acidic and alkaline characteristics respectively, which tend to neutralize the pH value of compost without the need for external modification
6. ***Site for composting***: The composting should be done at least 100 m from surface waterways and far enough away from residential areas to protect from odours (EPA, 1996). The compost area needs to be set up on an impermeable base like concrete that is graded so that runoff and leachate drain into a pit or collection tank. The tank should be big enough to keep things from overflowing. A shade is also required to avoid the dryness of the pit/ compost pile.
7. ***Minimization of odour***: The primary cause of odour development in fish waste composting is the generation of anaerobic conditions within the compost piles. Odorless carbon dioxide is the primary gas produced by composting under aerobic conditions. On the other hand, volatile fatty acids, ammonia, methane, and hydrogen sulfide are produced under anaerobiosis. By adding fish wastes to the composting process on the same day as their generation, odours can be minimized. To effectively control odours, aerobic conditions must be maintained through frequent compost pile turnover or ventilation systems. Preserving compost at the proper carbon-to-nitrogen ratio will also reduce odour even further.
8. ***Minimization of dust formation***: Dust can be effectively managed by mild water spraying. While the high-water content of compost makes dust generation unlikely, its existence can be interpreted as a warning of insufficient moisture in the compost.

Assembly of compost windrows/piles: A source of carbon (bulking material) and a source of nitrogen (fish waste) are the only two basic requirements for composting fish waste. Three or two parts carbons to one part nitrogen is a basic formula. Accordingly, fish waste is mixed with the selected bulking agent during the composting process. The size of the compost pile might vary depending on the available space; nevertheless, a minimum of 10 cubic feet, or 3 feet × 3 × 3 feet, is advised for productive degradation. For minor volumes of waste, an ordinary compost bin can be used for composting. The compost bins vary from small plastic backyard bins holding about 9 cubic feet of material to larger mechanically rotated bins holding several cubic yards of materials. In commercial or municipal composting facilities, materials are usually placed on the ground in long narrow piles, called windrows. Composting is carried out on enormous concrete pads in certain plants. Windrow turners or mechanical aeration may be applied for turning the piles. A 200 mm thick base layer of bulking material is laid at the bottom to build the compost windrow's base. On top of this substrate, layers of bulking materials and fish waste are put alternately at 1: 2 to 3 proportions. The width and height of these windrows may reach up to 3 m. The windrow may be extended lengthwise when it reaches its tallest point. The compost pile can be covered with a thick layer (~150 mm) of mature compost or bulking material to keep away flies, birds, and odours. Approximately 2 tonnes of fish waste will create a compost windrow measuring 3 m wide by 10 m long containing four layers of waste materials. Seasonal effects can influence the proportional quantities of the required fish wastes and bulking agents. In rainy periods, the extra bulking agents should be added to increase absorbency while slightly less bulking agent may be necessary during dry periods. Depending on the structure of the pile and the type of materials used, unturned compost will sufficiently mature in about one year. Turning the compost windrow three to four times will help maintain an even temperature throughout and will hasten the decomposition process. To reduce the spread of odours downwind from the composting site, avoid turning windrows on windy days. The compost is sieved using a 20-mm mesh screen after it is deemed mature.

Role of microbes in the composting process

The biological phase of the composting process encompasses microbes and hydrolytic enzymes present in plant materials and animal tissues. The biological phase regulates the outcome of the whole composting process. Fish viscera contain several degrading enzymes, however, these enzymes can function at the start of the composting process because as the composting progresses, the enzymes will become damaged. As a result, microbes continue to be the primary component of the composting process. Since only 5–10% of the total microbial population represents the actual degraders during the natural composting process, it is advantageous to use different beneficial microorganisms in the composting process. As a result, traditional composting without the aid of an effective microbial consortium is exceedingly labour-intensive, and inefficient, and may produce a less valuable soil amendment. An easier mode to achieve beneficial microbes is through adding a small amount of immature compost from a different composting process. The increasing mandate for valuable composts has exaggerated the exploration of beneficial microorganisms for improved composting processes.

Microbes for turning fish waste into fertilizer

Creating an effective microbial consortium for fish waste composting involves selecting a diverse group of microorganisms that can work synergistically to break down various components of fish waste efficiently. An ideal consortium for enhancing fish waste composting should include:

1. Ammonia oxidizing bacteria
2. Nitrite oxidizing bacteria
3. Sulphur oxidizing bacteria

4. Proteolytic bacteria
5. Chitinolytic bacteria
6. Lipolytic bacteria
7. Phosphate solubilizing bacteria

Since fish waste includes large amounts of ammonia, which is harmful to plants, ammonia-oxidizing bacteria that convert ammonia to nitrite is an essential component in the fish waste-degrading consortium. Further oxidation of nitrite to nitrate, the form of nitrogen mainly assimilated by plants through nitrite-oxidizing bacteria is another important process. As ammonia oxidation is often the rate-limiting step during the composting process, adding ammonia and nitrite-oxidizing bacteria can improve the quality of the final compost. The action of sulphur oxidizing bacteria in compost results in the formation of sulphate, which can be used by plants, while the acidity produced by oxidation helps to solubilize plant nutrients and improves alkali soils. Similarly, the phosphate-solubilizing bacteria can increase plant growth by solubilizing the sparingly soluble inorganic and organic phosphates. The effective conversion of fish waste into a beneficial fertilizer also requires bacteria that can break down the organic components of fish waste, specifically the protein, lipid, chitin, and cellulose of bulking materials. Combining these microbes into a consortium ensures a comprehensive breakdown of fish waste, resulting in high-quality compost. Proper conditions such as moisture, temperature, and aeration should be maintained to support the activity of these microbes.

In this context, it is worth mentioning that ICAR-CMFRI has developed an indigenous microbial consortium that can degrade the fish and shellfish waste and a novel composting technology applying the consortium that can efficiently convert various marine fish waste into valuable organic fertilizer.

Salient details

- The raw materials included marine fish trash comprising both finfish and shellfish, a carbon source, and an indigenously developed consortium. The developed consortia had two components with part I containing thermotolerant microbes (to be applied at the initial stage of composting) and part II containing mesophilic microbes (to be applied after the thermophilic stage of composting).

- On the first day, all the raw materials are mixed in the proper ratio with the required volume of water, followed by building the compost pile and covering it with a garden mesh net to keep out the flies. The mixing is repeated on the fifth day with the required volume of water. The mesophilic microbial consortium (part II) is added on the eighth day of composting with proper mixing. Mixing is repeated on the 10th and 15th day to maintain aeration. At every turning time, the necessary amount of water is added to balance the moisture level.
- The compost became fully matured and stable by 20-25 days of composting as per the results of seed germination assay, temperature and pH dynamics, ammonia & nitrate concentrations, and C: N ratio.
- There was a 3-4 times reduction in the weight by 20-25 days of composting

Role of FPOs in Agriculture and Fishing Sector

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Introduction:

FPO (Farmer Producer Organizations) is an organization where the members are farmers. They provide end-to-end support to small farmers, covering technical services, marketing, processing, and other aspects of agriculture inputs. The government, NBFCs, civil societies, and other financial institutions have invested in FPOs, looking at their significant role in the future of rural development. FPOs have the potential to act as a motivation for change in the economic system of our nation.

In India, the necessity for an FPO arose as a result of farmers' struggles to get their goods into major markets. FPO helps small farmers improve the quality of their food by giving them quality seeds, teaching farmers how to manage soil, use less fertilizer, manure, irrigation, and livestock. Along with assisting in the selling of goods to larger and better markets, it also updates and aids farmers in implementing cutting-edge farming equipment and upgrades in technology.

FPOs have emerged as crucial mechanisms to address the challenges faced by the agriculture sector in India, such as fragmented land holdings, limited access to markets, and inadequate infrastructure. FPOs are collective enterprises formed by farmers to enhance their income, improve livelihoods, and ensure sustainable agricultural development. They facilitate collective bargaining, market access, input procurement and distribution, capacity building and training, technology adoption, financial services, value addition and processing, policy advocacy, risk mitigation, and social welfare activities. The benefits of FPOs include economies of scale, input procurement and cost reduction, income enhancement, and empowering farmers. However, FPOs also face challenges related to limited access to finance, capacity and skill development, infrastructure and technology, market linkages and price realization, policy and regulatory support, social inclusion and gender equity, and sustainability and governance. Overall, FPOs have emerged as key drivers of rural development and the growth of agribusiness in India, contributing to the welfare of farmers and the sustainable development of the agricultural sector.

Fish Farmers Producer Organisation:

Fish farming is a rapidly growing industry across the world, with an increasing demand for fish and seafood products. In recent years, the concept of Fish Farmer Producer Organizations (FFPOs) has emerged as a popular model for promoting sustainable fish farming practices and improving the socio-economic conditions of small-scale fish farmers. FFPOs are collective organizations of fish farmers who come together to achieve common goals related to production, marketing, and value addition of their fish and seafood products. These organizations aim to provide small-scale fish farmers with a platform to access technical, financial, and marketing support, which they would otherwise find difficult to access individually.

Presently, there are several FFPOs operating across the world, which have been successful in improving the livelihoods of small-scale fish farmers. In India, for example, the National Fisheries Development Board has been promoting the establishment of FFPOs as a means to improve the socio-economic conditions of small scale fish farmers. The PMMSY, to be implemented over a period of five years from FY 2020-21 to FY 2024-25, seeks to ensure the socio-economic development of fishers, fish farmers, and fish workers with the goal of doubling their incomes. The scheme includes the establishment of

500 Fish Farmers Producer Organizations/ Companies (FFPOs/Cs) to empower fishers and fish farmers and enhance their bargaining power. Among these, 300 FFPOs will be set up under PMMSY, while the remaining 200 will be established through convergence with the Department of Agriculture, Cooperation, and Farmers Welfare's ongoing FPO Scheme. Additionally, the Department aims to establish a total of 720 FFPOs through convergence with other schemes and programs of the central and state governments, in collaboration with the Department of Agriculture, Cooperation, and Farmers Welfare, Ministry of Agriculture and Farmers Welfare.

The key features of an FPO are mentioned below for a better understanding of how FPO works.

- The FPOs are voluntary organizations controlled by members who are farmers actively participating in making decisions and setting policies.
- They are open to people who accept the responsibilities of membership without any sort of discrimination.
- Their farmer-members, managers, elected representatives, and employees are provided with training and education to efficiently contribute to the FPOs' growth.
- 'One District One Product' promote the FPOs to encourage better branding and specialization, processing, marketing, and exports.

The Need for FPOs and their Role in Business development

Taken together, small and marginal holdings (below 2 hectares) constitute 85 percent of the farming community in India. Small farmers face various farm- and household-specific transaction costs, limiting their ability to participate in input and product markets. As food preferences change toward a diversified, higher-quality diet due to income and population growth, small-farm commercialization is crucial to meet this rising demand.

Aggregation models are potential institutional interventions that help redress the constraints of small farms, wherein groups of producers jointly manage resources or access credit, inputs, information, and product markets to reduce transaction costs. Successful aggregation models have shown increasing economies of scale, decreased transaction and coordination costs, improved access to markets, and investment in yield-stabilizing technologies like irrigation and improved crop varieties to be the main benefits of organizing farmers.

In the past, cooperatives were the most common form of aggregation model in rural India. With the exceptions of dairy and sugar, cooperatives in India have been mostly ineffective due to issues involving incompetent management, political interference, financial irregularities, and corruption within the organizations. Poor management also made many cooperatives dependent on government funds for working capital. Cooperatives mandated government representation on their governing boards, allowing political interference in their functioning which further hindered growth.

What is the Need of an FPO for Farmers?

Farmers/ fishers in India face tremendous hardships which include the following –

- Small Size of landholdings. Nearly 86% of farmers are small and marginal with average land holdings in the country being less than 1.1 hectares.
- Good quality inputs are out of reach of small and marginal farmers mainly because of exorbitant prices of better seeds.
- Less or no accessibility to large scale mechanisation.
- Challenges in marketing their products due to lack of economic strength. In the absence of sound marketing facilities, the farmers have to depend upon local traders and middlemen for selling their farm produce which is disposed of at an extremely low price.

- FPOs help in the collectivization of such small, marginal and landless farmers/fishers in order to give them the collective strength to deal with such issues.

Aim of Farmer Producers Organisation

The main aim of FPO is to ensure better income for the producers through an organization of their own. Small producers do not have the volume individually (both inputs and produce) to get the benefit of economies of scale. Besides, in agricultural and fish marketing, there is a long chain of intermediaries who very often work non-transparently leading to the situation where the producer receives only a small part of the value that the ultimate consumer pays. This will be eliminated.

Through aggregation, the primary producers can avail the benefit of economies of scale. Farmers Producers will also have better bargaining power in the form of the bulk buyers of produce and bulk suppliers of inputs.

Difference Between cooperative societies and Producer Companies

Table No. 01 Key differences between Cooperative Societies and Producer Companies

Features	**Co-operatives Producer Company**	**Producer companies**
Registration	under Co-operative societies Act	Companies act
Membership	Open to any individual or co-operative	Only to producer members and their agencies
Professionals on Board	Not provided	Can be co-opted
Area of operation	Restricted	Throughout India
Relation with other entities	Only transactional based	Can form joint ventures and alliances

Shares	Tradable within membership only	Not tradable Tradable within membership only
Member stakes	No linkage with no. of shares held	Articles of association can provide for linking shares and delivery rights
Voting rights	One person one vote, but RoC and government have veto power	One member one vote
Reserves	Can be created if made profit	Mandatory to create reserves
Profit sharing	Limited dividend on capital	Based on patronage but reserves must and limit on dividend
Role of government	Significant	Minimal
Disclosure and audit requirements	Annual report to regulator	Very strict as per the Companies Act
Administrative control	Excessive	None
Borrowing power	Restricted	Many options
Dispute settlement	Through co-op system	Through arbitration

PMMSY AND FPOs

The Pradhan Mantri Matsya Sampada Yojana (PMMSY) represents a significant investment in the fisheries sector, focusing on the socio-economic development of stakeholders and the establishment of FFPOs to support fishers and fish farmers. By enhancing their bargaining power and economic empowerment, the scheme aims to bring about positive transformation and sustainable growth in the fisheries sector in India. In addition to providing a platform for accessing technical, financial, and marketing support, FFPOs also promote sustainable fish farming practices. They encourage the adoption of eco-friendly farming practices that reduce the impact of fish farming on the environment. FFPOs also promote the use of high-quality fish feed and the adoption of good aquaculture practices to improve the health and productivity of fish farms.

Current status on FPOs in India:

There are over 33711 FPOs across India with 28.2 lakh stakeholders with over Rs 4000 crore revenue in 2022-23 (Source: - FPO Platform for India, Tata Cornell Institute). Government of India has launched Formation & Promotion of 10,000 FPOs Scheme with a clear strategy and committed resources in order to form and promote 10,000 new FPOs across India. Rs 6866 crore have been allocated for this scheme. (Source: -Formation and Promotion of 10,000 Farmer Producer Organizations (FPOs), Operational guideline)

Fish farmer Produce organisation as envisaged under PMMSY

Fish Farmers Producer Organization (FFPO) is a generic name, which means an association or group of fishers or fish farmers or of fisheries stakeholders, with the primary objective of carrying out sustainable fisheries value chain business by whatever name called,
(i) registered under any law for the time being in force; or
(ii) promoted under a scheme or programme supported by the Central or State Government

In alignment with the larger mandate of PMMSY, the primary objectives of developing Fish Farmer Producer Organisations have been envisioned to:

(i) Economically empower the fishers and fish farmers and enhance their bargaining power by achieving economies of scale.
(ii) Enhance productivity through efficient, cost-effective and sustainable resource use.
(iii) Realize higher returns for fishers and fish farmers through better liquidity and remunerative market linkages for their produce.
(iv) Build capacities of fishers and fish farmers to develop entrepreneurial skills for making the FFPOs economically viable and self-sustaining.
(v) Develop vibrant and sustainable income-oriented fisheries value chains.

Broad Services and Activities to be undertaken by FFPOs

The FFPOs may provide and undertake following major services and activities across the fisheries value chain:

Production and Productivity:

- Supply of quality inputs like seed, fingerlings, brood stock, fish feed, fishing nets and such other inputs for production at reasonable rates.
- Undertake Pond Culture, Pen Culture, Cage culture, RAS, Raceways, Bio-floc etc. related fish culture activities for both inland and marine regions.
- Dissemination of Technology, Quality control and other fisheries related activities and innovations.
- Undertake aggregation of smaller lots of farmer-members produce.

Post-Harvest Management and Infrastructure:

- Make available need-based production and post-production machinery and equipment like storage – Ice flakes, ice boxes, and transportation/logistic support – reefer vans, insulated cargo and such other machinery and equipment on custom hiring basis for members to reduce the per unit production cost.

- Make available services offering value addition like cleaning, assaying. sorting, grading, packing and also fish farm level processing facilities at user charge basis at a reasonably cheaper rate.
- Undertake high value addition / processing units for better price realization and exports.
- Traceability related interventions can also be proposed by FFPOs.
- Undertake higher income generating activities like cold chain development, seed/brood stock production, ornamental fisheries, seaweed cultivation, cold water fisheries, fish kiosks, aquarium manufacturing etc.
- Undertake any activity (including but not limited to microfinance, e-market, technical support, repairs and maintenance services for boats, motors, cold chain, reefer transport etc.) associated with fisheries supply chain as door-step support

Marketing and Branding:

- Branding, packaging, lebelling, standardization of products.
- Market the aggregated produce with better negotiation strength in marketing channels offering better and remunerative prices.
- Facilitate market information about the produce for educated decision-making in production and marketing.
- FFPOs may also undertake operation of fish vending kiosks at various urban centers. Development of fish and fisheries related products / by-products and tie ups for domestic and export sales

Composition of FFPO: The FFPOs may comprise of

- Fishers
- Fish Farmers
- Fish Workers and Fish Vendors
- Fisheries entrepreneurs

Or any other person(s) associated with fisheries sector as decided by Dept of Fisheries, Government of India.

Conclusion

FPOs have emerged as crucial mechanisms to address the challenges faced by the agriculture sector in India, such as fragmented land holdings, limited access to markets, and inadequate infrastructure. FPOs increase the income for the producers through an organization of their own since a small farmer does not have the volume to take advantage of economies of scale. The non-transparent workings of a chain of mediators and intermediaries in agricultural marketing usually lead to a situation where the farmer receives only a tiny & unfair part of the value. FPOs help in eliminating the chain of intermediaries in agricultural marketing to provide producers their fair share. Overall, FPOs have emerged as key drivers of rural development and the growth of agribusiness in India, contributing to the welfare of farmers and the sustainable development of the agricultural and fishing sectors.

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Perspective on Fish Feed Production Technologies

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Feed is defined as the mixture or compound of various ingredients that accomplish the nutritional requirements of any organism. The intensification of aquaculture has necessitated a more substantial supply of food from external sources. In this context, artificial feeding is the only option available to satisfy the nutritional requirements of cultured aquatic species. As the fish become more dependent on prepared feeds, the need for nutritionally complete feeds becomes more critical. In cultured organisms, proper nutrition is one of the most critical factors affecting their ability to reach their genetic potential for growth, reproduction, maintenance, and longevity. Better feed management is essential to ensure the better performance of cultured organisms. Overall, feeds and their management are essential parts of any mariculture method, and there are different types of feeds are available for fish farming.

Feed is a crucial component of aquaculture production, and there has been a growing demand for high-quality feeds over the years. Ensuring the availability of affordable, species-specific formulated feeds is vital for the success of aquaculture operations. Presently, fish feed accounts for 40-60% of the total operational costs of a fish farm, making aquaculture a costly venture. Imported feeds are available in Indian markets, but their exorbitant prices make them unaffordable for small and medium-scale farmers.

Feed manufacturing techniques Fish feed manufacturing technology will differ based on the types of feeds produced. Aquafeed manufacturing is often a challenging task that involves the production of feed with good water stability, manufacturing difficulties due to high-fat content, good keeping quality due to high unsaturated fatty acids and protein content and protecting the water-soluble vitamins and minerals from leaching. Though several kinds of feeds are available in the market basically two methods are employed to produce most of the commercial feeds. They are steam pelleting and extrusion pelleting techniques. For both of the techniques, most of the preparatory procedures and equipment are common except the pelletizer and extruder, respectively in steam pelleting and extrusion pelleting. Equipment/ Machinery in a fish feed mill. The major essential equipment/ machinery required for a feed mill and their purpose are listed in the following Table:

Si no.	Equipment	Purpose
1.	Pulverizer/ hammer mill	To grind the ingredients and to reduce particle size
2.	Weighing balance	To weigh the ingredients and feeds
3.	Homogenizer/ bowl mixer	Uniform mixing of ingredients in a feed mix
4.	Extruder and/or pelletizer	To produce feed pellets. Different dies (1, 1.5, 2, 3 mm etc.) are used for producing pellets of desirable sizes. Extruder can produce floating pellets, while pelletizer produces sinking pellets
5.	Hot air oven	To dry the feeds and ingredients by blowing hot air
6.	Sieve assembly/ shaker	To sort the feed pellets of desirable particle sizes
7.	Packaging system-impulse sealer	For air tight packing of feed pouches
8.	Fat coater	To coat oil on feed pellets
9.	Spheronizer	For preparation of spherical feeds for larvae

10.	Steam Conditioner	For conditioning/ maturing of feed mix/ dough prior to extrusion. To adjust the moisture and temperature for cooking during extrusion
11.	Spray drier	To produce dry powder from liquid slurry by rapid drying, preferably in the case of thermally sensitive materials

Steps in feed manufacturing

The basic steps in feed manufacturing are:

1. Selection of ingredients; 2. Grinding/ particle size reduction; 3. Feed formulation; 4. Mixing/ homogenizing; 5. Pre-processing or preconditioning; 6. Pelleting; 7. Drying, cooling and sieving; 7. Packing; 8. Bagging and storage

Selection of ingredients: The first operation in the feed processing plant involves the selection of raw materials. The quality of feed ingredients both dry and liquid form has an important impact on the quality of final feed. It should be fresh and free from contaminants like sand, stones, and others earthen materials. The ingredients should be examined for quality check and also for nutrient analysis.
Grinding: Grinding or particle size reduction is a major step in feed manufacture. Prior to use, ingredients must be powdered, in order to get uniform particle size. The grinding of ingredients generally improves feed digestibility, acceptability, mixing properties, pelletability, and increases the bulk density of some ingredients. It is accomplished by many types of manual and mechanical operations involving impact, attrition, and cutting. The most commonly used grinding machines are hammer mill, pulverizers, flour mill etc. The powdered ingredients are then passed through a standard mesh sieve to obtain a uniform particle size. Sieving the ingredients helps in preparing feed pellets with uniform and attractive physical appearance.

Feed formulation: In this process appropriate dietary ingredients are selected on the basis of availability, chemical composition, nutritional value and, cost. The ingredients are selected in appropriate amount and blended to produce a compounded feed which is nutritionally balanced, palatable, pelletable, and easy for storage. The important points to be considered for feed formulation are:

- Nutritional requirements of the species to be cultivated
- Feeding habits of the species
- Expected feed consumption
- Type of feed processing required

Mixing: Feed mixing may include all possible combinations of solids and liquids. Sieved ingredients were weighed and mixed in desired proportion according to the formulation. Generally dried ingredients are mixed first followed by liquid materials. Liquid materials such as fish oil may be added at the end and further homogenized. Water is also added for increasing the moisture level may also be added. For proper mixing of different feed ingredients into a homogenous mass, the mixing may be 20 to 30 minutes. Mixing can be done in batches or in continuous mixers. Batch mixing can be done on an open flat surface with shovels or in any containers. Continuous mixers are such that the material moves through the mixers as it is being mixed. The types of mixers used are horizontal ribbon mixers, vertical mixers, and turbine mixers.

Pelleting: It is the process of compacting of feeds by extruding individual ingredients or mixtures of ingredients. Pelleting converts the homogenous mixture into a quality feed, having physical characteristics that make them suitable for feeding. Pelletisation is mainly done using two types of machines namely extruder pelleting and compressed pelleting.

(i) Extruder pelleting technology

Fish feed extrusion process refers to cook the mixture of feed ingredients under high temperature, pressure, and moisture by the means of an extruder within a short time. The basic components in an extruder are, a barrel fitted with a die plate and a screw shaft conveyor connected to a high speed motor. The most important operating parameters are the temperature, pressure, diameter of the die apertures and shear rate.

(ii) Compressed Pelleting technology

The pelletizer works on the principle that the finely ground feed mixture is pelleted by compression process. Compressed pelleting then involves exposing the mixture to steam for 5-20 seconds obtaining 85o C and 16% moisture followed by forcing the mix through holes in metal die by the action of a roller located inside the die. This process is also known as steam pelleting, due to the use of steam to precondition the mix prior to compression. The combination of heat, moisture, and pressure in which gelatinization of the starch occurs. As the pellets emerge to outside surface of the die, they are cut off by a stationary adjustable knife to the desired length. Pellet quality is influenced by the fat level, moisture, and humidity.

The fat level of the mixture should be not less than 2-3% to lubricate the holes in the die and to reduce the dustiness and not higher than 8-10% to avoid excessive lubrication causing insufficient compression of the feed mixture. The moisture level is also critical as the excessive moisture results in soft pellets and insufficient moisture results in crumbly pellets.

Drying: Immediately after pelleting the feed should be dried to reduce the moisture content below 10%. This is essential for good shelf life of the feed. Different type of dryers are used for drying feed pellets, like horizontal conveyer type, vertical hopper type, hot air oven and fluid bed dryers. The ambient temperature used for drying feed is at 65-75oC. Higher temperature is not desirable.

Packing: The dried feed is cooled before packing. Good quality packing covers are used to prevent damage to the feed quality on transportation and storage.

Storage of aquafeeds

Appropriate storage of ingredients and feeds is an important aspect in feed manufacturing process. Good storage is essential because the value of the feed presented to fish depends on it. Feed spoils during storage and the extend of deterioration depends very largely on the storage conditions. Since fish feeds usually contain relatively high amounts of fish meal and/or fish oil, they are very much susceptible to rancidity. In addition, loss of certain nutrients occurs during prolonged periods of storage. For these reasons, fish feeds should not be stored for longer periods (not more than 3 months). Ingredients and feeds should be stored in a cool, dry place away from direct sunlight.

Classification of feeds based on moisture content

Feeds are broadly classified into 3 categories based on the moisture content as follows:

Wet / Moist feed: The feed contains 35-75 % moisture and is made by mixing well-ground dry ingredients with well-ground wet materials and then extruding/pelletizing the mixture through a food processor equipped with the optimum size holes. Many fish species find soft diets more palatable than dry, dense diets. In preparation of farm-made wet feeds, heating and drying are avoided, which may prevent nutrient loss. Feeding fresh or preserving wet feed against microbial spoilage is necessary. The cost of frozen or refrigerated wet diets is very high.

Semi-moist feed: This type of feed contains 12 – 35 % moisture level. The wet and dry ingredients should be combined in the correct proportions to achieve the desired moisture level and consistency. A semi-moist formulated feed uses natural/ wet ingredients as its main ingredient and other additives with graded lipid levels that can be accepted by culturing organisms like crabs and broodstock fish. For long-term storage, the feed can be refrigerated.

Dry feed: The moisture level in this type of feed is 6-12 %. A mix of more dry ingredients and wet ingredients is used for the preparation of feed and to achieve the desired moisture and nutrient levels. Dry pellets do not require refrigeration, and room-temperature storage is sufficient for at least 90 days with adequate preservatives, after manufacture.

Types of Dry feed

Dry feeds are further classified into different types such as:

(i) Pellet feed: Feeds that are compressed into a defined shape, generally by mechanical means. Pelleting can be defined as the agglomeration of small particles into a larger solid with a given shape and texture. This is done using a mechanical process in combination with moisture, heat and pressure. Pellets can be classified into compressed pellets, expanded pellets and extruded pellets.

(ii) Compressed pellets: Steam pelleting is used to produce this kind of feed, which produces a dense pellet that sinks quite rapidly. The compressed pellets are called sinking pellet feeds. The amount of lipid included in the pellet mix does not exceed 10%. Additional lipid can be sprayed onto the feed after pelleting, and lipid levels of 16-20% can be obtained. The bulk density of compressed pellet feed will be 0.45 - 0.6 g/cc.

(iii) Expanded pellets: The feed is manufactured based on high pressure conditioning of feed mixtures within an angular expander and it will be slow sinking in nature. It is possible to increase the lipid content of expanded pellets up to 20-22 % via top dressing (coating) with oil. The amount of starch gelatinization obtained by expansion exceeds 60% and the microbial content of the mixture can be reduced significantly. In addition, it is possible to add additives such as oils and molasses. The bulk density of expanded pellet feed will be 0.3-0.4 g/cc.

(iv) Extruded pellets: Fish feeds may be pelleted by the "extrusion" process, thereby expanding rather than compressing the various ingredients. The extruded feed will be floating in nature. Due to the porosity of the extruded pellet there is the possibility of increasing lipid incorporation by top – dressing with oil up to 30%. The bulk density of extruded pellet feed will be 0.25 - 0.35 g/cc.

(v) Flake feeds: Flake feeds are the most common type of feed fed to aquarium fish. The most common method of manufacturing flake feed is the double-drum drier. The ingredients are ground to an extremely fine particle size with an attrition mill. They are blended with water to form a slurry that is spread over the surface of a heated rotating drum to turn into a thin dry sheet. The dried sheet is continuously scraped off the rotating drum and crumbled into flakes. By adjusting the distance between the drums, the thickness of the flake can be adjusted. Drying conditions may influence the nutritional value of the product.

(vi) Microencapsulated feeds: The process of microencapsulating involves surrounding and coating another substance (the payload) with a material (the wall). The process involves coating a small particle or granular feed with a thin layer of compound that will reduce dissolving and leaching of nutrients. Nylon (N-N bonds) cross–linked proteins, calcium alginate, and lipids have been used as encapsulation materials. As a larval feed technology, this technology has been developed and adapted.

(vii) Microbound feeds: In microbound diets, nutrients (both particulate and dissolved) are bound within a matrix containing binding material such as agar, gelatine, alginate or carrageenan. Dietary ingredients are mixed with the binder to form a slurry, which is then dried, ground and sieved to produce food particles of the desired size. There is no barrier between dietary ingredients and culture water so there is a chance for nutrient leaching and they are susceptible to direct bacterial attack.

(viii) Micro-coated diet: A micro-coated diet refers to the miniature feed surrounding the microcoherent feed within a capsule. To improve its quality and water stability, these feeds are prepared by coating microbound diet with zein, cholesterol, and lecithin.

Fish feeds and technologies developed by ICAR-CMFRI

The Central Marine Fisheries Research Institute (CMFRI) is committed to research and development in marine fisheries and mariculture. In recent decades, focused efforts have been made to enhance the nutrition of marine ornamentals, lobsters, and food fishes.

(i) Cadalmin™ Varna- Marine ornamental fish feed

Scientifically evaluated, marine ornamental fish feed with 38% protein, 9% fat, 7% minerals and 39% carbohydrates. The slow sinking pellets are produced through twin screw extrusion technology which is the state of art in aquatic feed production. Capable of maintaining growth, health, colour and vigour of the fishes. Available in different pellet sizes (250, & 750 microns, and 1.0 mm), and coded as CMFRI OFF 25538, CMFRI OFF 7538, and CMFRI OFF 138.

(ii) Cadalmin™ Varsha- Freshwater ornamental fish feed

Scientifically developed Fresh Water Ornamental Fish Feed. Central Marine Fisheries Research Institute's Freshwater Ornamental Fish Feed (CMFRI FWOFF) with protein contents 25, 30, 35, 40 and 45% as 1mm & 2mm slow sinking feed pellets coded as CMFRI FWOFF 134, 234, 139, 239, 144, 244

(iii) Cadalmin™ Broodmax

Scientifically developed feed for brood fish. Contains protein- min. 42%, and fat- 8%. Adequately rich in essential nutrients to ensure high fecundity, good larval quality and survival. Enhances the health and condition of broodstock.

(iv) Cadalmin™ Silvergrow

Specially formulated, feed for silver pompano to ensure higher growth with a better feed conversion ratio. Contains protein- min. 38%, and fat- 8%. Adequately rich in essential nutrients, suitable for pompano grow- out in sea cages and pond culture.

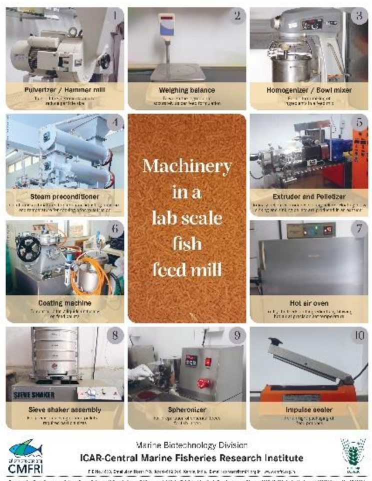
(v) Cadalmin™ Microfin

A cost-effective indigenous micro-feed for marine fish larvae (suitable for cobia, Rachycentron canadum and silver pompano, Trachinotus blochii) for sustainable mariculture. Prepared through extrusion, spheronization, fluidized bed processing (drying and spray coating), and precision sieving which delivers the highest quality feed for fish larvae. Tested and evaluated in the marine fish hatcheries of ICARCMFRI. Ensures better growth, survival and condition of larvae. Available in particle sizes of 100 to 700 microns according to life-stage/ mouth size of larvae.

(vi) Cadalmin™ BSF FFF

A fish meal free feed was developed using Black soldier fly larvae meal (BSFLM) for the juveniles of Indian pompano (Trachinotus mookalee) and Silver pompano (Trachinotus blochii). Feeding trials and evaluation using the standardized feed (having not less than 38%
protein & 6% fat) have proven that BSFLM can be used as a total replacer for fish meal in the diets of pompano juveniles without any adverse effects on the growth and condition.

CMFRI publications in fish feed technology



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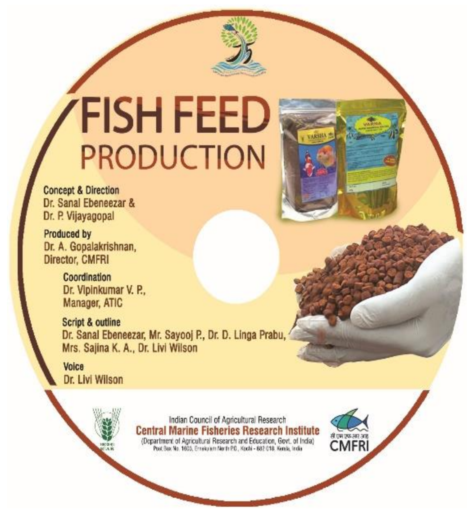

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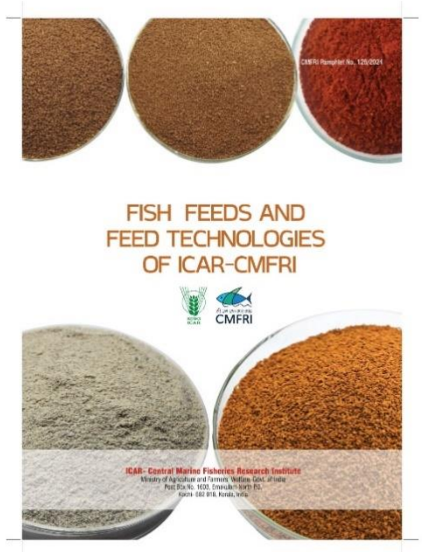
Grow out feed for Silver Pompano
Premium Quality & Cost Effective Pompano Feed from ICAR-CMFRI
Contains 38% CP and 8% fat (min.)


FISH FEEDS AND
FEED TECHNOLOGIES
OF ICAR-CMFRI
CMFRI
ICAR- Central Marine Fisheries Research Institute

Data Collection Tools and Methods for Social Science

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Any scientific study involves a systematic process to investigate natural phenomena, solve problems, or answer questions. The different stages in a scientific study are structured to ensure the research is logical, reproducible, and objective. These stages form a cyclical process, as the outcomes of one study often inform the development of new hypotheses and research, advancing the body of scientific knowledge. The stages of scientific study include;

1. **Defining the research problems and question**: The process begins with observing a phenomenon and identifying a question or problem that needs to be addressed. Observations may come from previous research, everyday experiences, or gaps in existing knowledge. A clear, focused, and testable research question is formulated at this stage.
2. **Background research**: Once a question is identified, background research is conducted to understand the context and gather existing information. This step helps refine the question, identify knowledge gaps, and formulate hypotheses. It involves reviewing scientific literature, consulting experts, and analyzing previous studies.
3. **Hypothesis development**: Based on observations and background research, a hypothesis is proposed. A hypothesis is a testable prediction or explanation for the phenomenon being studied. It is typically stated in an "if-then" format and establishes a relationship between variables.

4. **Research design**: Research design is a structured framework that guides the planning, execution, and analysis of a study to ensure that the research objectives are effectively addressed. It serves as a blueprint for the collection, measurement, and interpretation of data, helping researchers maintain consistency, reliability, and validity throughout the process. The research design includes decisions about the research approach (qualitative, quantitative, or mixed methods), sampling strategy, data collection methods (e.g., surveys, experiments, or interviews), and data analysis techniques. It is tailored to the specific research question and goals, ensuring that the chosen methods align with the study's objectives. A well-crafted research design minimizes bias, maximizes the accuracy of findings, and provides a clear roadmap for conducting the study, making it a critical component of any scientific investigation.
5. **Data collection: It** is the process of gathering information systematically to address a research question or test a hypothesis. It involves selecting appropriate methods, such as surveys, interviews, observations, or experiments, based on the nature of the study and its objectives. Ensuring accuracy, reliability, and validity during data collection is essential to obtain meaningful and unbiased results. The process also includes defining the data sources, and tools for measurement. Effective data collection lays the foundation for robust analysis and contributes significantly to the credibility and success of the research.
6. **Data analysis and processing: It** involve organizing, transforming, and interpreting raw data to extract meaningful insights and address the research objectives. This process begins with data cleaning, where errors, inconsistencies, or missing values are addressed to ensure accuracy. Once processed, statistical, computational, or qualitative methods are applied to

analyze the data and identify patterns, trends, or relationships. The results are then interpreted in the context of the research question, enabling informed conclusions and decision-making. Effective data analysis and processing ensure the reliability and relevance of the study's findings.

7. **Conclusion**: Based on the analysis, conclusions are drawn about the validity of the hypothesis. If the hypothesis is supported, it may contribute to the existing body of knowledge. If not, it provides insights for further refinement or alternative approaches.
8. **Replication and further Study**: Scientific studies often lead to new questions and further investigation. Replicating experiments validates findings and ensures their consistency under different conditions or with larger samples.

Importance of the data collection stage and its methods & tools

Purpose of data collection

The purpose of data collection is multifaceted. First and foremost, data collection serves to ***obtain information*** that is critical to understanding a particular phenomenon or answering specific research questions. This information forms the basis for analysis, interpretation, and drawing conclusions. Secondly, data collection is crucial to ***keep records*** of relevant data over time, allowing researchers, policymakers, or organizations to track changes, monitor trends, and reference past findings when needed. Moreover, collected data plays a pivotal role in helping to ***make informed decisions*** about important issues, whether in scientific research, business strategies, public policy, or other domains, ensuring that choices are based on evidence rather than assumptions. Lastly, data collection allows researchers to ***pass information on to others***, whether through reports, publications, or presentations, contributing to the broader knowledge base and enabling others to build upon or apply the findings in different contexts. Ultimately, data collection is a vital tool for both advancing knowledge and supporting effective decision-making across various sectors. While all stages of research are integral to achieving meaningful conclusions, the data collection phase stands out as the most critical, as it forms the foundation for all subsequent processes. The accuracy and reliability of collected data are paramount to addressing research objectives; any errors or biases introduced at this stage can significantly compromise the study's validity and credibility. Unlike later stages, such as analysis or interpretation, which rely on the quality of the collected data, this phase directly determines the integrity of the entire research effort. A meticulously executed data collection process ensures that the information obtained is relevant, complete, and unbiased, facilitating robust analysis and sound conclusions. Conversely, inadequacies in data collection can lead to erroneous findings and diminish the study's overall contribution, underscoring its pivotal role in the research process. Hence reliable and valid data collection tools and methods lie in their role as the foundation for obtaining accurate, reliable, and valid data, which is essential for meaningful research outcomes. Carefully chosen tools and methods ensure that the data collected aligns with the research objectives, minimizes bias, and captures the required information effectively. Appropriate tools, such as surveys, interviews, or observational checklists, combined with suitable methods like quantitative, qualitative, or mixed approaches, enhance the precision and relevance of data collection. They also ensure consistency, standardization, and replicability, which are crucial for the credibility of the research. Without well-designed tools and methods, the collected data may lack reliability and validity, leading to flawed interpretations and undermining the study's overall value.

Types of data

1. **Based on the source of data:** In social research, the two main sources of data are 'people' and 'paper.' 'People' refers to primary data obtained through direct interaction with individuals or groups, often through interviews, surveys, focus groups, or observations. This type of data is invaluable for understanding human behavior, attitudes, experiences, and social dynamics. On the other hand, 'paper' refers to secondary data, which includes documents, records, reports, and other written materials that provide insights into historical, social, or institutional contexts. Both sources complement each other in social research, with 'people' providing real-time, subjective data, and 'paper' offering objective, often historical or institutional perspectives that can help to triangulate findings and build a more comprehensive understanding of the research subject.
2. **Based on the nature of data:** Qualitative and quantitative data are two distinct types of data used in research, each serving different purposes and providing unique insights. Qualitative data is descriptive and non-numerical, focusing on understanding the characteristics, experiences, and meanings behind a phenomenon. It is often collected through interviews, focus groups, or observations and is analyzed thematically to uncover patterns, themes, and narratives. This type of data is particularly useful for exploring complex social issues, behaviours, and emotions. In contrast, quantitative data is numerical and measurable, often gathered through surveys, experiments, or secondary datasets. It involves statistical analysis to quantify variables and identify relationships or trends. Quantitative data is valuable for testing hypotheses, making predictions, and establishing generalizable findings. While qualitative data provides depth and context, quantitative data offers precision and objectivity, and researchers often use both in combination to gain a more comprehensive understanding of a research problem.

Data collection methods and tools: their difference

Data collection tools and data collection methods are two distinct but complementary components of the data collection process, each serving a specific role in gathering data. Data collection tools refer to the instruments or devices used to collect data. These tools are designed to facilitate the collection of information in a structured, organized manner. Examples of data collection tools include open or closed surveys, questionnaires, interview guides, checklists, and measurement instruments. Each tool is tailored to the type of data being collected, ensuring that the process is efficient and aligned with the research objectives. The choice of tool depends on the nature of the data—whether qualitative or quantitative—and the specific research question. On the other hand, data collection methods refer to the overall approaches or strategies employed to gather data. These methods outline how the data collection process is carried out, including the techniques for data gathering, and managing the information. Common data collection methods include surveys, experiments, case studies, observations, and interviews. The method determines how and where the tools are applied, such as conducting a survey online, through face-to-face interviews, or using a laboratory experiment. The method dictates the scope, scale, and design of the study, ensuring the data collected is appropriate for analysis and supports the research objectives. The key difference between tools and methods lies in their roles within the research process. Tools are the specific instruments used to gather data, while methods define the broader framework within which these tools are applied. A well-chosen method will employ suitable tools that align with the research goals, ensuring both are complementary and contribute to the overall success of the study.

Forms of data collection methods

In social science research, various data collection methods are employed to gather information, each suited to different types of research questions and objectives. Some of the key methods include:

1. **Observation (Participant and Non-participant)**: In the observational research method, the researcher watches and records the behaviour or events as they occur naturally. This method can be either participant or non-participant. In *participant observation*, the researcher becomes actively involved in the group or setting they are studying, gaining an insider's perspective while observing the phenomena. This method provides rich, detailed data but can introduce bias due to the researcher's active participation. In *non-participant observation*, the researcher remains detached and does not engage with the group, which helps maintain objectivity but may limit access to deeper insights. It is used to study social interactions, rituals, or cultural practices and is widely used in ethnographic research, anthropology, and sociology in real-world settings.
2. **Experiments (Lab and Field)**: *Lab experiments* are controlled studies conducted in a scientific setting where researchers manipulate variables to observe their effects on the subjects/participants. The controlled environment allows for high precision and reliable results, making it ideal for testing hypotheses. However, the artificial setting may not always reflect real-world conditions. *Field experiments,* in contrast, are conducted in natural settings where the researcher still manipulates variables but in a more organic environment. Field experiments offer greater ecological validity, as they observe behaviours of the people in real-life contexts, but they may be less controlled and susceptible to external variables.

3. **Surveys (Personal Interview, Telephonic, and Electronic Means – Sampling/Census)**: Surveys are a widely used method of data collection that involves asking respondents questions to gather quantitative or qualitative information. *Personal interviews* allow for in-depth responses and clarification of questions but are time-consuming and resource-intensive. *Telephonic surveys* are more cost-effective and convenient, though they may limit the depth of responses and accessibility to certain groups. *Electronic surveys* (e.g., via email or online platforms) are efficient, scalable, and convenient for large samples, but they may suffer from lower response rates or sample bias. Surveys can be conducted using sampling (where a subset of a population is studied) or census (where the entire population is surveyed) depending on the scope and resources available.
4. **Case Studies**: Case studies involve an in-depth, detailed examination of a single case or a small number of cases, such as an individual, organization, or event. This qualitative research method allows for a thorough understanding of complex issues within their real-life context. Case studies provide rich insights into specific phenomena but may not offer generalizable findings. They are often used in disciplines like psychology, business, and social sciences to explore new theories or test existing ones in specific situations.
5. **Simulation**: Simulation is a data method that uses models or virtual environments to replicate real-world scenarios and observe how variables interact. It is especially useful for studying complex systems or phenomena that are difficult to observe in real life. For example, social scientists may use simulations to model behaviours in economic markets, traffic systems, or social networks. Simulations allow researchers to manipulate variables and test outcomes without the ethical or

logistical challenges of conducting real-world experiments, but they rely heavily on accurate models and assumptions to produce valid results.

Each of these methods has its strengths and limitations, and the choice of data collection method depends on the research questions, objectives, and resources available. Researchers can use a combination of these methods to provide a more comprehensive understanding of the social phenomena under study.

Forms of data collection tools

Data collection tools refer to the devices/instruments used to collect data such as;

1. **Paper questionnaire**: A paper questionnaire is a widely used and traditional data collection tool that involves respondents answering a set of questions on paper. It is commonly employed in surveys to gather both qualitative and quantitative data from a target population. The questionnaire can consist of a combination of closed-ended questions (which provide predefined options for respondents to choose from, such as multiple-choice or Likert scale questions) and open-ended questions (which allow respondents to provide their own answers in a free-text format). This mixed approach enables researchers to collect both objective, quantifiable data and subjective insights into the respondents' attitudes, experiences, and opinions. The main advantage of paper questionnaires is their cost-effectiveness and simplicity. They do not require special equipment, software, or internet access, making them an accessible option for a wide range of research projects. Additionally, paper questionnaires are particularly useful in settings where electronic devices are not feasible, such as in rural areas or for populations without regular access to technology. However, there are some limitations associated with paper questionnaires. One of the main challenges is the time-

consuming process of data entry and data processing. After the questionnaires are collected, the responses must be manually entered into a digital system for analysis, which can be prone to human error and requires considerable time and resources. Moreover, the return rate of paper questionnaires can be low, especially if respondents are required to return the completed form by mail or in person. There's also the challenge of missing or incomplete responses, as respondents may skip questions or misinterpret instructions.

2. **Computer assisted interviewing system**: A Computer-Assisted Interviewing (CAI) system is an advanced data collection tool that uses computers and software to facilitate and streamline the process of conducting interviews. In a CAI system, interviewers are guided by a software application that displays the questions on a screen, ensuring that they follow a predefined sequence and script. As the interviewer asks questions, the system records the responses in real time, either by typing the answers directly into the computer or using voice recognition software, depending on the setup. The responses are immediately stored in a digital database, significantly improving the accuracy and speed of data collection. One of the primary advantages of CAI is its ability to increase efficiency in data collection. Unlike traditional paper-based methods, where responses must be transcribed later, CAI systems eliminate the need for manual data entry and minimize the potential for human error. Data is captured directly in electronic form, reducing the risk of inaccuracies or discrepancies caused by manual transcription. This leads to faster data processing and analysis, which is particularly useful in large-scale surveys or studies that involve large volumes of data. Furthermore, CAI systems can handle complex survey designs more effectively. They allow for dynamic question flow based on respondents' previous answers, meaning the software can skip irrelevant questions or ask follow-up questions based on specific responses (referred to as branching or skip logic). This flexibility enables researchers to design more intricate

surveys with tailored questions, ensuring that the interview process is more relevant to each respondent. Additionally, CAI systems can incorporate multimedia elements such as images, audio, or videos, which can enhance the clarity of questions and improve participant engagement. Another key benefit of CAI is its ability to reduce data entry errors. Since responses are automatically recorded by the system, there is less chance of data being incorrectly transcribed, especially for large datasets or responses with complex formatting (e.g., numerical data, dates, or coded answers). Additionally, built-in validation checks can ensure that responses are logical and within expected parameters (e.g., checking for inconsistent answers or missing data), which helps to improve the quality of the collected data. However, while CAI systems offer many advantages, they also require access to computers or mobile devices, and participants need to be familiar with the technology, which may limit their applicability in certain populations or settings. In some cases, ensuring that the system works smoothly in diverse environments, such as remote areas with limited internet access, can present challenges.

3. **PRA Tools (Participatory Rural Appraisal):** Participatory Rural Appraisal (PRA) tools are a set of qualitative research methods designed to engage local communities actively in the process of data collection, analysis, and decision-making. The primary aim of PRA is to empower local people by involving them directly in identifying, analyzing, and prioritizing the issues that matter most to them. These tools encourage the use of local knowledge and community participation, making the research process more inclusive and grounded in the community’s lived experiences. PRA tools, such as checklists, mapping, and other participatory techniques, are used to collect data in community-based research. ***1) Checklists:*** Checklists are structured lists of questions or criteria used to guide the systematic collection of information. These checklists help researchers gather essential data on various aspects of community life, such as local

resources, social conditions, or environmental issues. They serve as a tool for ensuring that key topics are covered during community meetings or interviews. Checklists can be tailored to address specific issues within the community, such as health, education, or agriculture, and are especially useful in gathering comparable data from multiple participants or across different locations. By using checklists, PRA facilitates consistent and comprehensive data collection while allowing community members to reflect on and share their knowledge on specific topics. ***2) Mapping:*** Community mapping is another core PRA tool that involves creating visual representations of local resources, spaces, social networks, and challenges. Community members participate in drawing maps of their village, neighbourhood, or broader landscape, helping them visualize and identify key features such as roads, water sources, agricultural land, schools, markets, and other critical infrastructure. Mapping can also be used to represent social dynamics, such as the distribution of wealth, gender roles, or power structures within the community. This process not only serves as a tool for data collection but also sparks discussions among community members, encouraging them to share their perspectives and identify issues that might otherwise go unnoticed. By highlighting local resources, challenges, and opportunities, mapping provides deeper insights into community dynamics and can help guide development initiatives and interventions. *3)* ***Other Participatory Techniques***: Beyond checklists and mapping, PRA incorporates various other participatory tools to collect and analyze data. These can include techniques such as **transect walks**, where researchers and community members walk through the landscape to identify resources and problems; **seasonal calendars**, which track changes in farming patterns or weather-related events throughout the year; and **social mapping**, which focuses on the relationships, networks, and power dynamics within the community. PRA also uses **voting exercises** (e.g., ranking problems by importance) to prioritize issues and help determine the community's collective needs. The strength of PRA tools lies in their ability to engage local people in the research process, allowing them to shape the agenda, share their experiences, and contribute to the analysis. By emphasizing local knowledge and active participation, PRA helps researchers gain a deeper, more understanding of community life, which may not be captured through traditional top-down research tools. Additionally, because PRA emphasizes community ownership of the process, it fosters a sense of empowerment and collaborative action, which can be instrumental in implementing sustainable development solutions based on the data collected.

4. **Interviews:** These are a fundamental data collection tool in qualitative research, where researchers engage directly with individuals or groups to gather detailed information on specific topics. This method allows researchers to explore a participant's experiences, beliefs, attitudes, perceptions, and personal narratives in a way that other data collection tools, such as surveys or questionnaires, might not fully capture. Interviews provide an in-depth understanding of the social, psychological, or cultural aspects of the research subject, making them particularly valuable for exploring complex issues or sensitive topics. Interviews can be categorized into three main types based on their level of structure: **1) Structured Interviews**: In structured interviews, the researcher follows a strict script with a set of predetermined, closed-ended questions. The questions are asked in a specific order, and the responses are typically standardized for easier comparison across participants. This format ensures consistency and helps reduce interviewer bias. Structured interviews are often used when the goal is to collect specific, comparable data, such as in large-scale surveys or quantitative research. However, their rigidity limits the opportunity for exploring deeper or unanticipated aspects of the topic. **2) Semi-structured Interviews:** Semi-structured interviews provide more flexibility, combining a set of

predetermined questions with the opportunity for the interviewer to probe deeper or ask follow-up questions based on participants' responses. This format allows the researcher to maintain a clear focus on the main topics of interest while also exploring unexpected insights. Semi-structured interviews are widely used in qualitative research, as they balance structure and flexibility, allowing for detailed and rich data while maintaining some consistency across interviews. This format is particularly useful for exploring complex topics where a degree of spontaneity is needed. **3) Unstructured Interviews**: Unstructured interviews are the most flexible and informal type. In this approach, the researcher has a general topic or theme in mind but allows the conversation to flow naturally without a fixed set of questions. The goal is to create an open environment where participants feel comfortable sharing their experiences and thoughts in their own words. Unstructured interviews are especially useful for exploring new or poorly understood topics, as they allow for the discovery of unexpected themes or insights. However, this flexibility can also make the analysis of unstructured interviews more challenging, as it requires careful interpretation and identification of patterns within the conversation. One of the key advantages of interviews is their ability to provide rich, qualitative data. Since interviews often involve open-ended questions, participants have the freedom to express themselves fully, providing insights into their thoughts, emotions, and personal experiences that would be difficult to capture through structured surveys or tests. Interviews also offer the opportunity for follow-up questions, allowing researchers to seek clarification or probe deeper into a response, ensuring a more thorough understanding of the participant's perspective. Furthermore, interviews foster a personal connection between the researcher and the participant, which can enhance the depth of the information collected. The researcher can observe non-verbal cues, such as body language or facial expressions, which may provide additional context to the responses. This dynamic interaction helps build rapport and trust, which is especially important in sensitive research topics, such as health, trauma, or social inequality. Despite their advantages, interviews can be time-consuming, both in terms of data collection and analysis. The process of conducting interviews, transcribing responses, and interpreting the data can require significant resources. Additionally, the interviewer's bias or subjective interpretation can influence the outcomes, making it important for researchers to employ strategies to ensure objectivity and consistency, such as using interview guides and maintaining ethical standards in data handling.

5. **Scales:** Scales are measurement/data collection tools widely used in social research to quantify abstract or subjective concepts in a standardized manner. They enable researchers to assess variables such as attitudes, opinions, perceptions, behaviours, and subjective experiences, making these complex and qualitative constructs measurable and comparable. Scales provide a structured way to quantify these variables, transforming them into numerical data that can be analyzed statistically, facilitating clearer interpretation and more robust conclusions. There are several common types of scales used in social science research, each designed for different purposes: 1) **Likert Scales**: The Likert scale is one of the most widely used tools in social research for measuring attitudes, opinions, or perceptions. It typically consists of a series of statements related to the topic of interest, and respondents are asked to rate their level of agreement or disagreement on a predefined scale, usually ranging from 1 (strongly disagree) to 5 or 7 (strongly agree). Likert scales are highly effective for measuring the intensity of respondents' feelings towards a subject, allowing researchers to gauge the overall sentiment of a population. The scale is often used in surveys measuring attitudes towards social issues, political opinions, customer satisfaction, and organizational behaviour. 2)n **Semantic Differential Scales**: The **semantic differential scale** measures respondents' perceptions

of a concept by asking them to rate it on a scale between two opposite adjectives. For example, a respondent might be asked to rate a product on a scale from "good" to "bad," or a political candidate from "trustworthy" to "untrustworthy." The scale typically uses a 7-point or 5-point format, allowing participants to select a position on a bipolar scale that reflects their subjective assessment. This type of scale is particularly useful for measuring **attitudes** towards concepts that have strong emotional or evaluative components, such as branding, political candidates, or public policies. 3) **Visual Analogue Scales (VAS)**: **Visual analogue scales** are often used to measure subjective experiences or feelings, such as pain, mood, or satisfaction. This scale consists of a continuous line, usually 10 cm long, with two endpoints representing extremes (e.g., "no pain" and "worst pain imaginable"). Participants are asked to mark a point on the line that best represents their experience. The VAS is particularly useful in health research and psychology, as it allows individuals to express their subjective feelings or sensations along a continuous range. It provides a more granular measure of experience compared to categorical or discrete scales. 4) **Other Types of Scales**: Beyond these well-known examples, there are other specialized scales used in social research, such as the **Guttman scale** (a cumulative scale that arranges items in increasing order of intensity) and the **Thurstone scale** (a method for measuring attitudes based on agreement with pre-defined statements). These scales are used for more specific research needs, such as measuring hierarchical patterns of attitudes or scaling responses to sensitive or complex issues. The main strength of using scales is their ability to quantify abstract concepts, allowing researchers to transform subjective opinions, emotions, or perceptions into objective, analyzable data. By assigning numerical values to responses, scales facilitate statistical analysis, which can reveal patterns, correlations, and differences between groups. This transformation of qualitative data into quantitative formats makes it easier to compare responses across different populations, track changes over time, and conduct large-scale surveys. However, scales also have limitations. The precision of the data depends on the validity and reliability of the scale itself. For instance, a poorly designed Likert scale may fail to accurately capture the true intensity of respondents' feelings or may introduce bias if the statements are leading. Furthermore, scales that rely on self-reporting can be influenced by respondents' tendencies to give socially desirable answers or their inability to accurately express their true feelings. Researchers must therefore be mindful when choosing or designing scales to ensure they are valid, reliable, and appropriate for the specific context of the study.

Quality of data collection tools:

The quality of data collection tools is crucial for ensuring that research findings are accurate and trustworthy, and it can be assessed in terms of validity and reliability. Validity refers to the extent to which a tool measures what it is intended to measure. For example, a questionnaire designed to assess attitudes toward climate change must accurately capture the respondents' beliefs and perceptions about climate change, not their knowledge of scientific facts. Validity can be further classified into different types, such as content validity (ensuring the tool covers all relevant aspects of the concept), construct validity (confirming the tool measures the theoretical construct it is intended to measure), and criterion-related validity (testing how well the tool correlates with other established measures of the same construct). On the other hand, reliability refers to the consistency and stability of the tool's measurements over time and across different conditions. A reliable tool will yield the same results when used repeatedly under similar circumstances. Common methods to assess reliability include test-retest reliability (measuring consistency over time), inter-rater reliability (ensuring consistency between different researchers or raters), and internal consistency (assessing whether items within a tool are measuring the same construct). Both validity and reliability are critical for ensuring the quality of a data collection tool. If a tool is not valid, it may collect data that is irrelevant or inaccurate, leading to flawed conclusions. Similarly, if a tool is unreliable, it may produce inconsistent results, undermining the robustness of the research. Ensuring that a tool is both valid and reliable strengthens the research process and helps ensure that findings are credible and trustworthy. Researchers must carefully design and test their data collection tools, conducting pilot studies and applying statistical methods to evaluate both validity and reliability before fully implementing them in a study. This rigorous process ensures that the data collected is accurate, meaningful, and contributes to a sound understanding of the topic being researched.

Further Reading

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STI Hub in Fisheries: Pioneering Innovation for a Sustainable Future

Vipinkumar V.P., Reshma Gills, Ramachandran C, Boby Ignatius, Aswathy N., Anuja A.R., Rajesh N., Jayasankar J., Swathilekshmi P.S., Vidya R., Sanal Ebeneezar, Saju George, Jenni B., Athira P.V., Sary P.S., Binitha K.V., Smitha R.X., and Ambrose T.V.
ICAR – CMFRI

The 'Science, Technology, and Innovation (STI) Hub in the Fisheries Sector' at Kochi Corporation, Ernakulam district, Kerala, is an externally funded project awarded to the ICAR-Central Marine Fisheries Research Institute (CMFRI) by the Department of Science & Technology (DST), New Delhi, for the period 2022–2025, with a budget of ₹3.18 crores. This initiative aims to enhance the institute's infrastructure while implementing fisheries-based interventions to benefit Scheduled Caste communities.

Strategic Goals:

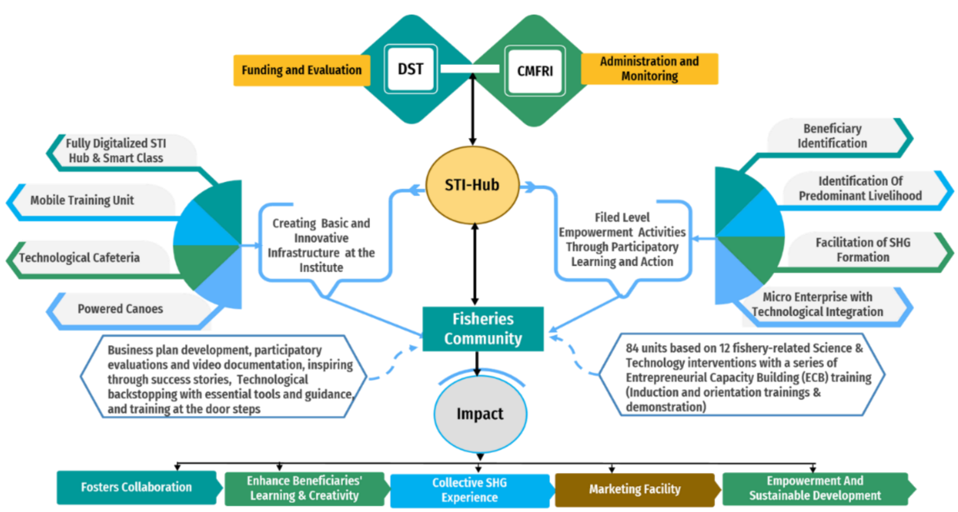
The project aims to empower Scheduled Caste (SC) fisherfolk by mobilizing and strengthening Self-Help Groups (SHGs) and individual enterprises in the marine fisheries sector of central Kerala. A key focus of this initiative is to identify location-specific, fishery-based micro-enterprises that cater to the needs of SC stakeholders while promoting Entrepreneurial Capacity Building (ECB). This is achieved through targeted training programs and the adoption of economically viable and sustainable micro-enterprises. Additionally, the project seeks to elucidate and document successful ECB cases among SHGs and individual SC entrepreneurs, leveraging **Information and Communication Technology (ICT) interventions** to contribute to the STI Hub. A crucial component of this initiative is facilitating linkages between SHGs/entrepreneurs and technical, institutional, and financial organizations, ensuring long-term empowerment and sustainability in the sector.

Execution Framework

The Science, Technology, and Innovation (STI) Hub in the Fisheries Sector aims to empower Scheduled Caste (SC) fisherfolk by mobilizing and strengthening Self-Help Groups (SHGs) and individual enterprises in the marine fisheries sector of central Kerala. A key focus of this initiative is to identify location-specific, fishery-based micro-enterprises that cater to the needs of SC stakeholders while promoting Entrepreneurial Capacity Building (ECB). This is achieved through targeted training programs and the adoption of economically viable and sustainable micro-enterprises. Additionally, the project seeks to elucidate and document successful ECB cases among SHGs and individual SC entrepreneurs, leveraging Information and Communication Technology (ICT) interventions to contribute to the STI Hub. A crucial component of this initiative is facilitating linkages between SHGs/entrepreneurs and technical, institutional, and financial organizations, ensuring long-term empowerment and sustainability in the sector.

Conceptual Model of STI Hub

The Science, Technology, and Innovation (STI) Hub Project is designed to facilitate Self-Help Groups (SHGs) and individual entrepreneurs in establishing and strengthening linkages with government and financial institutions. This will enable them to access financial credit and livelihood entitlements, ensuring effective resource mobilization through appropriate Human Resource Development (HRD) intervention programs. A key aspect of this initiative is fostering self-sustainability, where the experiential knowledge gained by SHGs will empower them to continue operating income-sustaining enterprises independently. The STI Hub at CMFRI operates under a unified collaboration with various institutional entities, including the Agricultural Technology Information Centre (ATIC), Fishery Resource Assessment, Economics and Extension Division, Programme Monitoring and Evaluation Cell, and Krishi Vigyan Kendra (KVK) of CMFRI. Additionally, the initiative ensures market sustainability by leveraging the ATIC sales counter as a practical sales outlet for SHG products, thereby providing a dedicated platform for marketing and long-term economic viability of the interventions.



Geographical Scope and Beneficiary Outreach of the STI Hub Project

The STI Hub Project is strategically implemented in the central zone of Kerala, with a primary focus on Ernakulam district, aiming to establish a robust Science, Technology, and Innovation (STI) ecosystem in the fisheries sector. The project specifically targets coastal areas with a high concentration of Scheduled Caste (SC) households, including Vypin, Narakkal, Elamkunnappuzha, Cherai, Vallarpadam, Chellanam, and Paravoor. Additionally, the initiative may extend its impact to selected border regions of Thrissur, Alappuzha, and Kottayam districts to ensure broader outreach and inclusivity. A total of 500 SC fisherfolk, comprising men, women, and transgender individuals, will be engaged as direct beneficiaries, representing 500 households. Through this structured intervention, the project is expected to generate a cascading effect, benefiting an estimated 2,500 indirect beneficiaries, significantly enhancing livelihood opportunities, economic stability, and social empowerment within the SC fisherfolk communities.

Practical Implementations of the STI Hub: Empowering SC Fisherfolk through Entrepreneurial Capacity Building

The STI Hub is dedicated to fostering Entrepreneurial Capacity Building (ECB) among Self-Help Groups (SHGs) of Scheduled Caste (SC) beneficiaries and individual entrepreneurs by imparting hands-on training in cutting-edge fisheries-based technologies. Key focus areas include cage culture, pearl spot seed production, fish vending, fish fertilizer production, value addition, integrated fish farming, fish culture, mussel culture, oyster culture, clam collection, fish drying, and advanced fish value addition techniques.

Training will be systematically conducted in three phases: awareness programs, orientation training, and practical demonstration sessions. To ensure long-term impact, all data, success stories, and scientific advancements in fisheries technology will be meticulously digitized and documented in the state-of-the-art Data Documentation Centre at the STI Hub of CMFRI. This centre will be equipped with an Entrepreneur Consultancy Cell, an Entrepreneur Technology Park, and a Digital Training Hall, serving as a knowledge repository and practical reference for sustaining and scaling fisheries-based entrepreneurial ventures.

To extend its reach across potential locations, the STI Hub's field initiatives will be executed through a Mobile Training Unit equipped with essential laboratory instruments, canoes with safety gear, and cutting-edge digital tools such as high-resolution cameras and drones for real-time documentation and impact assessment of interventions. This dynamic approach ensures effective dissemination of technology-driven fisheries innovations, fostering self-reliance and economic empowerment among SC fisherfolk communities.

Progress and Impact: Advancing Fisheries-Based Microenterprises under the STI Hub

The STI Hub Project has made significant strides in promoting fisheries-based microenterprises across eight districts of Kerala, including Ernakulam, Thrissur, Kottayam, Alappuzha, Kozhikode, Kannur, Pathanamthitta, and Kollam. A total of 71 microenterprises have been successfully initiated, building on the 57 enterprises established during the first and second years of the project. Additionally, 13 new interventions have been implemented in various parts of the state, further expanding the project's reach and impact.

These microenterprises cover a diverse range of fisheries-related activities, including cage culture, pearl spot seed production, fish vending, fish culture, ornamental fish culture, integrated fish farming, fish fertilizer production, value-added fish products, mussel culture, oyster culture, clam processing, and dry fish production units.

To date, the initiative has directly benefited 400 individuals, comprising 197 men, 197 women, and 6 transgender beneficiaries, empowering them with sustainable livelihood opportunities and enhancing their economic resilience through technology-driven fisheries entrepreneurship.

Transforming Livelihoods: The Impact of the STI Hub on SC Fisherfolk Communities

The Science, Technology, and Innovation (STI) Hub Project is a groundbreaking initiative aimed at enhancing the livelihoods of Scheduled Caste (SC) fisherfolk through the implementation of 12 distinct fisheries-based microenterprises, replicated across 84 targeted interventions.

Among these interventions, cage culture has emerged as a promising livelihood and nutritional security solution, with significant potential to expand employment opportunities, improve the socioeconomic status of fisherfolk, and boost aquaculture production at a global scale. The pearl spot seed production venture addresses the persistent challenges of seed scarcity, poor survival rates, and inferior quality stock, ensuring a consistent supply of superior fish seed for sustainable fish farming.

The establishment of value-added fish product units has facilitated year-round production and supply of processed fish products, enhancing economic viability. Fish vending units, equipped with transparent display cases, allow consumers to select fresh fish while extending shelf life by 4 to 5 days, increasing profitability for vendors. Fish drying, predominantly carried out by fisherwomen in coastal regions, has been revolutionized through the adoption of modern drying technologies, improving hygiene standards, ensuring food safety, preserving fishery resources, and boosting income generation.

Fish culture, a critical sector for income generation and job creation, particularly for local youth, offers an accessible and low-risk aquaculture model that strengthens food security and protein availability for marginalized communities. The cultivation of mussels and oysters, which require minimal investment and no supplementary feed, provides a highly nutritious and sustainable source of protein, fat, and carbohydrates for indigenous communities while generating steady income within just six months.

Clam collection and processing not only create employment opportunities but also contribute to nutritional well-being, as clams are rich in vitamins, proteins, iron, and essential nutrients that support heart and thyroid health.

The implementation of integrated fish farming technology has transformed waste management practices by repurposing by-products from different subsystems to enhance productivity and reduce production costs. This model promotes economic efficiency, diversification of aquaculture activities, and the integration of allied enterprises, ensuring higher profitability. Similarly, fish fertilizer production effectively addresses waste disposal challenges by converting fish market and processing industry waste into biofertilizers, serving as a sustainable plant growth promoter. Given its low capital requirement, this sector is highly accessible to marginalized communities, promoting income generation and environmental responsibility.

The ornamental fish culture industry, another key intervention, leverages the growing domestic market for marine and freshwater aquaria, stimulating the expansion of subsidiary industries and providing a stable livelihood for economically disadvantaged populations.

Unlike conventional fisheries projects, the STI Hub is unique in its practical implementation of diverse, location-specific, technologically feasible, economically viable, and environmentally sustainable interventions. It is specifically designed to uplift SC fisherfolk, who face numerous socio-economic challenges, including marginalization due to mechanization, unemployment, financial distress, high investment demands from motorization, inter-sectoral conflicts, shifting job opportunities, out-migration, and the erosion of traditional skills.

The STI Hub facilitates the development of linkages between SHGs, individual entrepreneurs, government agencies, and financial institutions, ensuring access to credit, livelihood entitlements, and resource mobilization through targeted Human Resource Development (HRD) programs. Sustainability is further reinforced through strategic collaborations with the Agricultural Technology Information Centre (ATIC) of CMFRI and Krishi Vigyan Kendra (KVK), with the ATIC sales outlet serving as a dedicated platform for marketing SHG-produced goods, ensuring long-term viability even beyond the project's funding period.

Additionally, the fully digitized STI Hub at CMFRI operates within an extensive network of institutional and community partnerships, including Knowledge Institutions (KIs), local NGOs, voluntary organizations (VOs), and last-mile delivery systems. The project integrates backward linkages with scientific organizations and agricultural/fisheries universities for technology transfer and innovation, while also establishing forward linkages with SHGs, Farmer Producer Organizations (FPOs), and Farmer Producer Companies (FPCs) to ensure the sustainability and scalability of fisheries-based entrepreneurial ventures.

Integrated farming at Thengathara

Mussel farming unit at Kottappuram

Ornamental fish culture unit under construction at Pulprapadi

Training programme for Clam processing unit at Panambukadu, Vaikom

Bund preparation for fish culture at Tharavattom

Fertilizer unit at Puthanchira

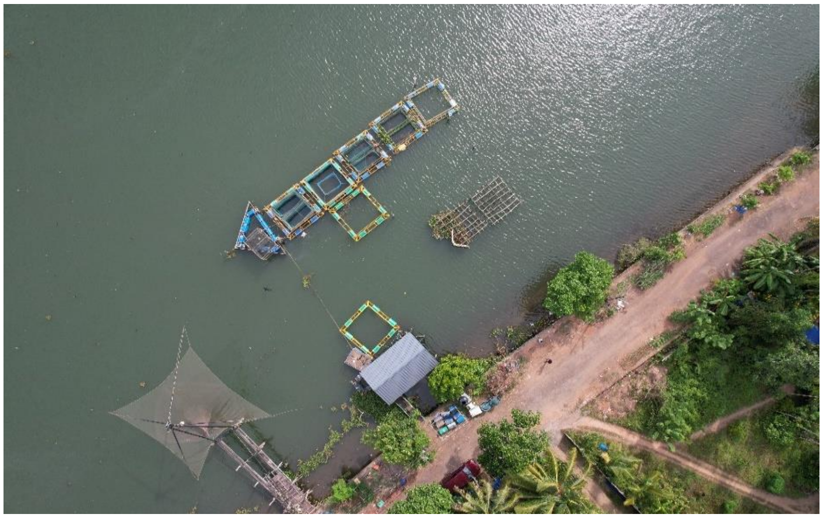
Fish culture at Ezhikkara

Sample collection of Cage culture unit in Thuruthipuram

Bund Preparation for fish culture

Fish culture seed stocking at Thravattom

Cage culture site of STI Hub in Thuruthipuram



Mussel & Oyster Culture site at Kottappuram, Kodungallur

Major Economic Indicators for Assessing the Profitability of Farming Operations – A Practical Approach

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Farming is not just about growing crops—it's about running a successful business. Whether a farmer is growing bananas, vegetables, or rearing livestock, they must make smart economic decisions to ensure that their work is profitable, sustainable, and efficient. To do this, we rely on economic indicators—tools that help farmers measure and evaluate the financial performance of their farming activities. These indicators provide answers to key questions like: Am I making a profit from my farm? How much return do I get for every rupee invested? When will I recover the money, I spent? Is my cost of production too high? At what point will I break even?

The costs involved in farming operations are generally categorized into initial investment, fixed costs, and variable costs. To evaluate the profitability and financial feasibility of such operations, several key economic indicators are used. These indicators provide insights into income generation, cost recovery, investment efficiency, and long-term viability. The most important economic indicators for assessing the profitability of farming operations include: Gross Income, Net Income, Benefit-Cost Ratio (BCR), Payback Period, Break-Even Point (BEP), Cash Flow and Interest Costs, Net Present Value (NPV), and Internal Rate of Return (IRR).

Understanding these indicators is essential for all agriculture students and aspiring agri-preneurs. They play a crucial role in effective planning, budgeting, risk evaluation, and informed decision-making in farm enterprises. In this chapter, each concept is explained in simple language with relatable, real-world examples—particularly focusing on a banana farmer in Kerala. This practical approach will help you clearly grasp the economic principles and apply them effectively in actual farming situations.

Note: All values used in the examples are indicative and intended solely to illustrate the concepts.

Investments and Costs of Farm Operations
Initial Investment

The initial investment refers to the total upfront amount of money required to start a farming project or enterprise. It typically includes: Purchase of fixed assets (e.g., land development, irrigation system, buildings, equipment), One-time establishment costs (e.g., cost of planting material, land preparation), Any working capital needed to start operations. In a farmer's perspective, it can be thought as ""How much money do I need at the beginning to get this project up and running?". Initial investments are one-time costs and appear only in Year 1 under initial investment, not repeated in Years 2 or 3.

Fixed Cost

Fixed costs refer to the recurring annual expenses that remain constant regardless of the level of production. They are incurred each year—whether the farmer produces one unit or 10,000 units—and are typically related to owning, maintaining, or financing long-term assets, as well as operating the basic infrastructure of the farm. These costs do not vary with output and must be paid even if production is temporarily halted. They are critical for understanding the baseline cost of staying operational. In economic analysis, fixed costs are shown under Annual Fixed Charges and aggregated as Total Fixed Cost for each operating year. They are distinct from initial investments, which are incurred only in the first year to set up the farm.

Common examples of fixed costs in farming include:

- Depreciation on fixed assets such as drip irrigation systems, farm tools, or pumps
- Insurance premiums on infrastructure or equipment
- Interest on capital investment (either actual or imputed as opportunity cost)
- Administrative and overhead expenses, such as record-keeping, general maintenance, or minimal salaries

***Depreciation*:** Depreciation is the loss in value of a fixed asset over time due to usage or age. The most commonly used method in farm economics is the Straight-Line Depreciation Method.

$$Annual\ Depreciation = \frac{Cost\ of\ Asset - Salvage\ Value}{Useful\ Life\ of\ the\ Asset\ (in\ years)}$$

Where: Cost of Asset = The original purchase cost, Salvage Value = Estimated value of the asset at the end of its useful life (can be zero if negligible) and Useful Life = The expected number of years the asset will be used.

Example: If a farmer has invested in a drip irrigation system worth ₹40,000 with a useful life of 5 years, an annual depreciation of ₹8,000 is considered a fixed cost, regardless of how many banana plants are grown or harvested.

$$Annual\ Depreciation = \frac{40{,}000 - 0}{5} = 8{,}000$$

So, every year, ₹8,000 will be accounted as a fixed cost for depreciation.

In this case, depreciation is calculated on the initial fixed assets (capital items), which include: Drip Irrigation System – ₹40,000, Farm Tools – ₹5,000

Capital Assets (from Initial Investment):

Item	Cost (₹)	Useful Life (Years)	Annual Depreciation (₹)
Drip Irrigation System	₹40,000	5 years	₹8,000
Farm Tools	₹5,000	5 years	₹1,000
Total	₹45,000	-	₹9,000 per year

Insurance Premium: This is the cost paid to insure the crop or farm equipment against risks like natural calamities, pest attacks, fire, etc. In the given example, it is assumed that the farmer insures irrigation system and farm tools

Item	Value (₹)
Drip Irrigation System	₹40,000
Farm Tools	₹5,000
Total Insured Assets	**₹45,000**

Insurance Rate: 2% per annum

Annual Insurance Premium=₹45,000×0.02=₹900

***Interest on Capital Investment*:** This is the cost of borrowed money (or opportunity cost of using your own capital).

If a farmer borrows ₹78,750 (which is 75% of the total initial investment of ₹1,05,000) for setting up the banana plantation at 12% annual interest, the interest cost amounts to ₹9,450 per year. Even if the farmer uses their own money, we assume an "imputed interest" to reflect the opportunity cost of investing capital elsewhere

***Administrative/Other Expenses*:** These are miscellaneous costs related to running the farm business but not directly linked to production. Example: Registration fees, Phone calls, travel for marketing, Farm record keeping. In the banana farming example, administrative expenses are taken as ₹500 per year.

Variable Cost

Variable costs change with the scale of production. The more you produce, the more you spend. Example: If each banana plant costs ₹20 and you plant 1,000 plants, then the variable cost for planting is ₹20,000. If you plant 1,500, the cost rises to ₹30,000

Examples in banana farming: Seedlings cost (tissue culture banana plants), Fertilizers and pesticides, Labour for planting, weeding, harvesting, Irrigation water charges (if based on usage)

Total Operating Cost

This is the sum of all recurring costs incurred in a production cycle — including variable costs + depreciation + interest + insurance + admin costs. (Here total variable costs (₹1,00,000) + total annual fixed costs (₹19,850) = ₹1,19,850)

Returns and Profitability Indicators

Gross Return

The total money earned from selling your produce before subtracting any cost.

Example: If the farmer sells 18,000 bunches at ₹10 each, gross return = ₹1,80,000

Net Return

This is the profit after subtracting total operating cost from gross return.

Net Return=Gross Return -Total Operating Cost

Example: Gross return = ₹1,80,000
Total Operating Cost = ₹ 1,19,850
Net return = ₹60,150

Benefit-Cost Ratio (BCR)

BCR shows the return per rupee invested. It is calculated as:

$$BCR = \frac{Gross\ Return}{Total\ Cost}$$

Example: If gross return = ₹1,80,000 and total cost = ₹1,19,850
BCR = 1.50 (means you earn ₹1.50 for every ₹1 spent)

Break-Even Point (BEP)

BEP is the minimum quantity of produce you need to sell to cover your total cost.

$$BEP\ (units) = \frac{Total\ Cost}{Selling\ Price\ per\ Unit}$$

Example: Break-Even Point (BEP) = ₹1,19,850 ÷ ₹10 = 11,985 banana bunches. This means you must sell 11,985 banana bunches to avoid loss.

Payback Period

The time it takes to recover your investment from the net income earned annually.

$$Payback\ Period = \frac{Initial\ Investment}{Annual\ Net\ Retun}$$

Example: ₹1,05,000 ÷ ₹60,150 = 1.75 years (~1 year and 9 months)

Net Present Value (NPV)

Net Present Value (NPV) is the difference between the present value of returns and the present value of costs over time. It helps us understand if a project is financially worthwhile after considering the time value of money (i.e., a rupee today is worth more than a rupee tomorrow).

$$\mathrm{NPV} = \sum \left(\frac{\mathrm{Net\ Return}_t}{(1+r)^t} \right) - \mathrm{Initial\ Investment}$$

Where:

- t = year

- r = discount rate (usually 10–12%)
- Net Return$_t$ = profit in year t

Example (Banana Farming, 3 Years)

- Initial Investment: ₹1,05,000
- Net return per year: ₹60,150
- Discount rate: 10%

$$NPV = \left(\frac{60{,}150}{(1+0.10)^1} + \frac{60{,}150}{(1+0.10)^2} + \frac{60{,}150}{(1+0.10)^3}\right) - 1{,}05{,}000$$

$NPV = 54{,}682 + 49{,}711 + 45{,}182 - 1{,}05{,}000$ = ₹44,575

A positive NPV means the project is profitable even after adjusting for the time value of money. A higher NPV indicates a more attractive investment.

Internal Rate of Return (IRR)

IRR is the rate at which the NPV becomes zero. In other words, it's the discount rate where the total present value of returns = total cost. IRR helps answer: "What is the maximum interest rate this investment can bear and still break even?". Imagine you invest ₹1,05,000 in banana farming. Over the next 3 years, you earn ₹60,150 every year. You ask yourself: "If I put this ₹1,05,000 in a bank, what interest rate would give me the same returns over 3 years as this banana farming project?". The answer to that interest rate is the IRR. Using trial-and-error or Excel IRR formula with the same cash flows:

Why IRR is Useful?

- Helps you compare different investment options.
- Tells you if your farm project is better than putting money in a bank.
- If IRR > bank interest rate, the project is profitable.

$$\text{IRR} = \text{Rate that solves: } -1,05,000 + \frac{60,150}{(1+r)^1} + \frac{60,150}{(1+r)^2} + \frac{60,150}{(1+r)^3} = 0$$

So, IRR is somewhere around 22.6 %. This means: Your banana farming project is giving you around 23% annual return, which is much better than a bank giving 10% interest.

Economic Analysis (Indicative) Table: Banana Farming in Kerala (1 Acre)

All values in ₹ (Indian Rupees)

Particulars	***Year 1***	***Year 2***	***Year 3***
Initial Investment			
Drip Irrigation System	*₹40,000*	–	–
Land Preparation	*₹10,000*	–	–
Farm Tools	*₹5,000*	–	–
Tissue Culture Plants	*₹40,000*	–	–
Planting Labour	*₹10,000*	–	–
Total Initial Investment	*₹1,05,000*	–	–
Annual Variable Costs			
Replacement Plants	–	*₹40,000*	*₹40,000*
Fertilizers & Manure	*₹15,000*	*₹15,000*	*₹15,000*
Pesticides & Weed Control	*₹5,000*	*₹5,000*	*₹5,000*
Labour	*₹25,000*	*₹25,000*	*₹25,000*
Irrigation / Electricity	*₹5,000*	*₹5,000*	*₹5,000*
Harvesting & Marketing	*₹10,000*	*₹10,000*	*₹10,000*
Total Variable Cost	*₹1,00,000*	*₹1,00,000*	*₹1,00,000*
Annual Fixed Charges			
Depreciation (on fixed assets)	*₹9,000*	*₹9,000*	*₹9,000*
Insurance (2% on ₹45,000)	*₹900*	*₹900*	*₹900*
Interest (12% on 75% of ₹1,05,000)	*₹9,450*	*₹9,450*	*₹9,450*
Admin Expenses	*₹500*	*₹500*	*₹500*

Total Fixed Cost	*₹19,850*	*₹19,850*	*₹19,850*
Total Operating Cost	*₹1,19,850*	*₹1,19,850*	*₹1,19,850*
Production & Returns			
Yield (Bunches)	*18,000*	*18,000*	*18,000*
Price per Bunch	*₹10*	*₹10*	*₹10*
Gross Return	*₹1,80,000*	*₹1,80,000*	*₹1,80,000*
Net Return	*₹60,150*	*₹60,150*	*₹60,150*
Benefit-Cost Ratio	*1.50*	*1.50*	*1.50*

Note: The figures provided in this table are indicative and used solely for educational and illustrative purposes.

Final Summary Indicators

- Average Annual Net Return = ₹60,150
- Total Initial Investment = ₹1,05,000
- Break-Even Point (BEP) = ₹1,19,850 ÷ ₹10 = 11,985 banana bunches
- Payback Period = ₹1,05,000 ÷ ₹60,150 = 1.75 years (~1 year and 9 months)
- Cost per Unit (C) = ₹1,19,850 ÷ 18,000 = ₹6.66
- Profit per Unit (P − C) = ₹10 − ₹6.66 = ₹3.34
- NPV =₹44,575
- IRR ~ 22.6%

Economic viability lies at the core of every successful farming enterprise. This chapter introduced key economic indicators that enable farmers, students, and agri-preneurs to assess and enhance the profitability of their farming operations. Using a practical example of banana farming, we demonstrated how to classify costs, estimate returns, and apply tools such as the Benefit-Cost Ratio (BCR), Payback Period, Break-Even Point (BEP), Net Present Value (NPV), and Internal Rate of Return (IRR) for informed financial decision-making. Mastering these indicators equips agriculture students with the practical skills needed to critically evaluate farm ventures, allocate resources efficiently, and design agri-businesses that are both profitable and sustainable

References

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