Souvenir 2022

12th Indian Fisheries & Aquaculture Forum

5 - 7 MAY, 2022 | Chennai

Theme

Fish for Nutritional Security and Economic Sustainability

Organised by

Tamil Nadu Dr. J. Jayalalithaa Fisheries University

In association with

Asian Fisheries Society Indian Branch (AFSIB)

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Vice-Chancellor
Tamil Nadu Dr.J.Jayalalithaa Fisheries University
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May, 2022

Preface

Tamil Nadu Dr. J. Jayalalithaa Fisheries University (TNJFU) established on 19 June 2012 with its headquarters at Nagapattinam has been constantly active in quality human resource development, need-based research and technology development and organizing outreach programmes to reach the community in the fisheries sector. This young University is progressing with a bold vision of "Harnessing the Science of Fisheries for Food, Nutrition & Livelihood". A focus on excellence and engagement in equity has led to remarkable growth in student intake strength, new courses, spectacular campuses, state-of-art infrastructures, research impact and reputation.

TNJFU believes in connecting all professionals and stakeholders of the fisheries sector for realizing its vision. In that context, several awareness programmes, skill development training, scientific sessions, seminars, and symposia are held regularly to reach the masses. In this line, presently we are going to have 12th edition of Indian Fisheries and Aquaculture Forum. We are indeed happy to host this prestigious triennial event at Chennai bringing together the scientific community in fisheries to deliberate on the current research and identify the Research & Development needs of the sector.

There will be ten technical sessions in the 12th IFAF, where over 900 research outputs will be deliberated with the lead presentations from eminent speakers from across the world who will be guiding to chalk-out useful recommendations generated out of the deliberations. In addition, we have collaborated with BoBP, GAFS of the AFS, SAP and NFDB to organize four parallel events to add further value to the 12th IFAF. On top of all, we are supported by NFDB to have one Farmers' Meet wherein progressive and proven farmers are going to share their experiences. Another highlight of this event is that the selected and peer-reviewed full papers will be brought out as a special issue by the Indian Journal of Fisheries.

In this backdrop, it is more appropriate that a Souvenir is brought out to mark such an important event. The lead presentations of eminent speakers are compiled in the Souvenir to give relevance to the readers, especially the young and aspiring researchers. The entire organizing team acknowledges the support of our sponsors without whose contributions, this 12th IFAF would not have been a reality.

I thank the Asian Fisheries Society-Indian Branch for joining us in hosting the event. We gratefully acknowledge the overwhelming response from the ICAR fisheries research institutions especially the CMFRI and CIBA and the untiring support provided by the Deputy Director General (Fisheries) and AFSIB Executive Committee Chairman Dr. J.K. Jena. I also thank all the invited speakers, chairpersons of sessions and delegates from various research institutes and universities who have gathered at this scientific congregation to deliberate on the issues in the fisheries sector and add valuable inputs to fisheries science.

I wish all the delegates a memorable participation.

Convenor of the 12th IFAF
&
Vice-Chancellor, TNJFU

INDIAN BRANCH

डि. प्रशांत कुमार रेड्डी, भा.प्रशा.से.
D. Prasanth Kumar Reddy, IAS

भारत के उप-राष्ट्रपति के निजी सचिव
PRIVATE SECRETARY
TO THE VICE-PRESIDENT OF INDIA
नई दिल्ली / NEW DELHI - 110011
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MESSAGE

The Hon'ble Vice-President of India is happy to know that Tamil Nadu Dr. J. Jayalalithaa Fisheries University (TNJFU), Chennai is organizing 12th Indian Fisheries and Aquaculture Forum on the theme "Fish for Nutritional Security and Economic Sustainability" during May 5 – 7, 2022 in Chennai, Tamil Nadu.

The Hon'ble Vice-President extends his greetings and congratulations to the organizers and the participants and wishes the event all success.

(D. Prasanth Kumar Reddy)

New Delhi
05th April, 2022.

ANITHA R. RADHAKRISHNAN
MINISTER FOR FISHERIES - FISHERMEN WELFARE AND ANIMAL HUSBANDRY

GOVERNMENT OF TAMILNADU
TRUTH ALONE TRIUMPHS

SECRETARIAT
CHENNAI - 600 009.

Date. 22.04.2022

MESSAGE

The Fisheries sector which is at par with Agriculture and Animal Husbandry in terms of income generating potential, plays a vital role in uplifting the economy of rural fishers. The Government of Tamil Nadu, under the able leadership and guidance of Hon'ble Chief Minister Thiru. M.K. Stalin, has taken proactive steps for enhancing fish production, for improving the economic status of more than 13 lakhs fishermen in the state.

The Department of Fisheries and Fishermen Welfare, Tamil Nadu is implementing various welfare schemes to improve the livelihood of fishermen. The Government of Tamil Nadu is constantly endeavouring to improve the fishing avocation by ensuring the safety, security and wellbeing of the fishermen of the State through a series of measures. I, as the Pro Chancellor of the University, I am happy that Tamil Nadu Fisheries University is hosting the 12th Indian Fisheries and Aquaculture forum on the theme 'Fish for Nutritional Security and Economic sustainability.

This forum is important in the present context, as it provides ample scope to deliberate the various issues faced by the stakeholders and the way forward so that the policy objectives and the targets envisaged by the Government of Tamil Nadu can be achieved and of our sector can lead India in a sustainable manner. I am sure the various sessions lined up will facilitate an enabling environment for thought provoking discussions for the experts, researchers, fish farmers and entrepreneurs to share the views and new technologies.

I express my warm wishes and greetings to the organizing committee and the participants. I wish the programme all success.

(ANITHA R. RADHAKRISHNAN)

INDIAN BRANCH

TENKASI S JAWAHAR IAS.,
Additional Chief Secretary to Government

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MESSAGE

The fisheries sector in Tamil Nadu has been an important contributor for the rural economy, nutritional security, self-employment, and foreign exchange earnings. The State of Tamil Nadu has supported an export of 1.10 lakh tons of marine products and paved way for the foreign exchange of Rs.5,565.46 Crore during 2020-21 and the sector has contributed 5.4 % to the Agriculture Gross State Domestic Produce (GSDP) and 0.64% to Gross State Domestic Produce (GSDP) of the State of Tamil Nadu during 2019-20.

In line with the Nation's goals to raise fish production to 200 lakh tons by 2022-23 and raise fishery exports to Rs.1 lakh Crore by 2024-25, the State Government is striving to achieve a fish production of 10 lakh tons from the present production of 7.23 lakh tons and thereby, plans to marginally increase the exports from the present 1.10 lakh MT to 2.50 lakh MT in the next few years in a sustainable manner.Visualizing the importance of mariculture, integrated mariculture with seaweeds as a mainstay, the aquaculture in open sea is being promoted in the State. In the light of the above, I consider organising a scientific forum to discuss the latest developments in fisheries is an important step towards the development.

I am extremely happy to record my sincere wishes for the grand success of 12th Indian Fisheries & Aquaculture Forum (IFAF). I am confident that this Forum will provide a scientific platform to deliberate the current research outputs and identify the research and development needs of the fisheries sector in the country. I congratulate the Organisers and Tamil Nadu Dr. J Jayalalithaa Fisheries University for their sincere efforts to have a good scientific meet in Chennai. Let this 12th IFAF be a historical occasion and I extend my sincere appreciation and best wishes for the grand success.

(Tenkasi S Jawahar)

NABARD

National Bank for Agriculture and Rural Development | राष्ट्रीय कृषि और ग्रामीण विकास बैंक
Website: www.nabard.org | Follow us on: /nabardonline

MESSAGE

I am glad to be informed about the National Conference entitled the 12th Indian Fisheries and Aquaculture Forum being organised by Tamil Nadu Dr. J. Jayalalithaa Fisheries University. It is very pertinent that the theme of the conference this year will be Fish for Nutritional Security and Economic Sustainability.

Studies show that food security depends on both biophysical and social vulnerabilities. Low-income producers and consumers are most likely to be affected because of lack of resources to invest in adaptation and diversification measures. India is host to one-sixth of humanity, and Indian agriculture is dominated by small and marginal farmers. 60% of our net sown area is rain-fed, which produces nutritious commodities like millets, pulses, oilseeds, and horticultural crops. Empirical studies have also indicated that long-term climate change has more adverse impacts in unirrigated areas compared to irrigated areas and could reduce annual agricultural incomes. All these outcomes would impact food security significantly.

Almost all studies have so far focussed on one dimension of food security only i.e., food availability, while adequate food production is not a sufficient condition for ensuring food security. It is amply clear that India has attained self-sufficiency in food grain production, however, in terms of the 2020 Global Hunger Index, we rank 94th out of the 107 counties in food security.

The fisheries sector is identified as the sun rise sector that has immense potential to contribute to the food and nutritional security, livelihood, export earnings, and also the goal of doubling farmers' income. The fisheries and aquaculture sector has the potential to contribute to many of the Sustainable Development Goals covering poverty, hunger, food security, protection, restoration and management of inland water resources, ecosystems and biodiversity, economic growth, employment, and decent work. But the sector is also faced with challenges of Natural Resources Management, issues of conservation of biodiversity, and Climate change. Fisheries have been recognized as an important component of an integrated farming system being advocated as an economically sustainable practice, and one of the strategies for doubling farmers' income.

I hope, this conference will provide a platform for discussion at the national level on issues of research, development, and policies related to fisheries and aquaculture, by bringing together experts from different related domains. It shall be also my desire that the conference deliberates on issues of sustainability concerning the fisheries sector and address the livelihood aspects of fisherfolk.

I wish the Conference all success.

Dr. G R Chintala
Chairman, NABARD

INDIAN BRANCH

न्यायमूर्ति अमर सिंह चौहान
अध्यक्ष
Justice AMAR SINGH CHAUHAN
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Phone: (044) 2951 5437
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भारत सरकार
मत्स्यपालन, पशुपालन और डेयरी मंत्रालय
मत्स्यपालन विभाग
तटीय जलकृषि प्राधिकरण
Government of India
Ministry of Fisheries, Animal Husbandry and Dairying
Department of Fisheries
COASTAL AQUACULTURE AUTHORITY

April 12, 2022

Message

I am happy to note that 12th edition of Indian Fisheries and Aquaculture Forum (IFAF) is jointly hosted by Tamil Nadu Dr.J. Jayalalithaa Fisheries University (TNJFU), Nagapattinam and the Asian Fisheries Society Indian Branch (AFSIB) during May 5-7, 2022 in Chennai with its theme **"Fish for Nutritional Security and Economic Sustainability"**.

The IFAF is playing a pivotal role in Indian fisheries sector to realize its ambitious target, revisit the developments and to redefine the goals. It will pave the way for a robust blue economy in the country.

I wish every success for the event and hope that the event would be the catalyst of fisheries developments in the years to come in the country.

(Justice Amar Singh Chauhan)

5वीं मंजिल, इंटीग्रेटेड ऑफिस कॉम्प्लेक्स पशुपालन व मत्स्यपालन विभाग, पशु चिकित्सालय रोड,
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सत्यमेव जयते

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मुख्य कार्यपालक

Dr. C. Suvarna, IFS
Chief Executive

NFDB
राष्ट्रीय मात्स्यिकी विकास बोर्ड
National Fisheries Development Board
मत्स्य पालन विभाग
Department of Fisheries
(मत्स्यपालन, पशुपालन एवं डेयरी मंत्रालय, भारत सरकार
(Ministry of Fisheries, Animal Husbandry and Dairying, Govt. of India)
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Message

India is one of the major biodiversity hotspots in the globe. Tropical climate together with the supporting environment assure better prospects for the biological prosperity. India is the second largest fish producing country in the world accounting for 7.56% of global production and contributing about 1.24% to the country's Gross Value Added (GVA) and over 7.28% to the agricultural GVA (2020-21). Aquaculture productivity can be achieved through optimal use of resources and quality inputs. The adoption of technology cannot be ignored for the aquaculture development. Quality fish seed is the prime requirement for aquaculture and it is the major area of concern for species diversification. In this context, I feel the conduct of this kind of Conferences and Seminars are very much essential.

NFDB has been extensively promoting adaptable technologies viz., Propagation and production of Indigenous Species of Minor & Major Carps: Demonstration of RAS, Bio-floc and Aquaponics technologies, Brood stock development, hatchery technology & seed rearing while focusing on diversification of aquaculture species. NFDB under the guidance of the Department of Fisheries, Ministry of Fisheries, and Animal Husbandry & Dairying, Government of India has been playing a vital role in enhancement of fish production and productivity in the country and in coordinating fisheries development in an integrated and holistic manner.

I congratulate the Tamil Nadu Dr. J. Jayalalithaa Fisheries University and the organising team, the speakers and participants. Also I am pleased to be a part of this event and I am confident that an outcome from 12th IFAF which will be held from 5th to 7th May, 2022 would definitely benefit the country to make specific policy decisions in Fisheries sector.

(Dr. C. Suvarna)

Dated: 08.04.2022

डॉ. जे.के. जेना
उप महानिदेशक (मत्स्य विज्ञान)
Dr J.K. Jena
Deputy Director General (Fisheries Science)

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MESSAGE

The Indian Fisheries and Aquaculture Forum (IFAF), organized under the aegis of the Asian Fisheries Society Indian Branch (AFSIB) every three years forthe last 35 years in different parts of the country, has been thefavourite meeting point for the researchers, academicians, policymakers, farmers, entrepreneurs and all associated in fisheries and aquaculture sector in the country. The12th Indian Fisheries and Aquaculture Forum being organized on the theme "Fish for Nutritional Security and Economic Sustainability"by the Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam, Tamil Nadu during 5-7 May 2022 at Chennai, Tamil Naduhas given another unique opportunity for all associated with the sector to share their thoughts to take the Indian fisheries to a newer height. When the country is celebrating its 75th year of independence 'Azadi Ka Amrit Mahotsav' and formulating the road map for the next 25 years of development, I am sure, this mega-event being organized after two years of a wait due to the Covid situation will be an important platform to deliberate every aspect of the fisheries and aquaculture sector and will be able to provide appropriate direction towards its accelerated development in the country.

Indian Fisheries has emergedas a high-growth agricultural sector representing an essential part of the country's economy. Increasing domestic and export demandsover the years are providing enough room for sustainable growth of the sector. Besides contributing to food and nutritional security,the sector also serves as a significant employer to millions of peoplein marginalized and vulnerable communities, especially in remote and rural areas. Several developmental programmes, reforms, schemes, and policies are being implemented to build a sustainable and resilient system that contributes to increasedfish production and farmers' income. I sincerely believe the interactions between the participants and deliberations at the Conference will bring forth coherent strategies to achieve the goals in a timely and efficient way.

I extend my warm greetings and felicitations to the organizers and the participants and wish the 12th Indian Fisheries and Aquaculture Forum every success.

(J.K. Jena)

डॉ.वी. कृपा
सदस्य सचिव
Dr. V. KRIPA
Member Secretary

तटीय जलकृषि प्राधिकरण
मत्स्यपालन विभाग
मत्स्यपालन, पशुपालन और डेयरी मंत्रालय
भारत सरकार
COASTAL AQUACULTURE AUTHORITY
Department of Fisheries
Ministry of Fisheries, Animal Husbandry and Dairying
Government of India

April 13, 2022

Message

Greetings to all from the Coastal Aquaculture Authority, Chennai

It is indeed a proud moment for the entire Fisheries Sector that the 12th Indian Fisheries and Aquaculture Forum (IFAF) is organised at Chennai during May 5-7th, 2022 with the theme "Fish for Nutritional Security and Economic Sustainability".

Appreciate the far sightedness of the organizers, Tamil Nadu Dr. J. Jayalalithaa Fisheries University (TNJFU), Nagapattinam and the Asian Fisheries Society Indian Branch (AFSIB) in identifying ten key theme areas. I am confident that the event will become one of the most productive scientific platforms of the decade and pave way for strong networking among technology developers and the stakeholders. The Exhibition organised during the event showcasing the latest developments in Fisheries & Aquaculture sectors would definitely educate and ignite the minds of the participants.

Compliments to the entire team of organizers for the effort put in to make 12th IFAF a memorable event and wishing the program all success.

(V.KRIPA)

5वीं मंजिल, इंटीग्रेटेड ऑफिस कॉम्प्लेक्स पशुपालन व मत्स्यपालन विभाग, पशु चिकित्सालय रोड,
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वेबसाइट/ website : http://www.caa.gov.in

12th IFAF Sponsors

Government of Tamil Nadu

Indian Council of Agricultural Research (ICAR)

Indian National Science Academy (INSA)

National Fisheries Development Board (NFDB)

Science and Engineering Research Board (SERB)

Council of Scientific and Industrial Research (CSIR)

Department of Scientific and Industrial Research (DSIR)

The World Bank

Society of Aquaculture Professionals

Seafood Exporters Association of India

Growel Feeds Pvt. Ltd.

Vaisakhi Bio resources Pvt. Ltd.

Kings Infra Ventures Pvt. Ltd.

RR Thulasi Builders

Sri Ganesh Constructions

SK Marine Technologies Pvt. Ltd., Chennai

United Research Pvt. Ltd., Singapore
M/s. Thomas Seafood, Nagercoil
M/s. Jayashri Hatchery, Chennai
Mr. M. Selvam, Contractor, Chennai
Nandhini Constructions, Erode
Mr. Venkatesh, Contractor, Thiruvarur
MKMS Builders, Chennai
Mr. M. Kumar, Thirunelveli

Smart Infratech Developers, Erode
Sri Balaji Electricals, Nagercoil
Star Construction, Thirunelveli
Sri Angalamman Builders, Erode
Mr. P. Sankar, Thanjavur
Mahalakshmi Electricals, Chennai
Sun Engineering, Chennai

Profile of TNJFU – An Overview

Tamil Nadu Dr. J Jayalalithaa Fisheries University (TNJFU), a professional Fisheries University of the State Government was established as per Tamil Nadu Fisheries University Act 2012, on 19.06.2012 at Nagapattinam, to impart professional fisheries education, conduct research and training for enhancing fish productivity and utilisation in the state, by following State Agricultural University (SAU) pattern and syllabi.

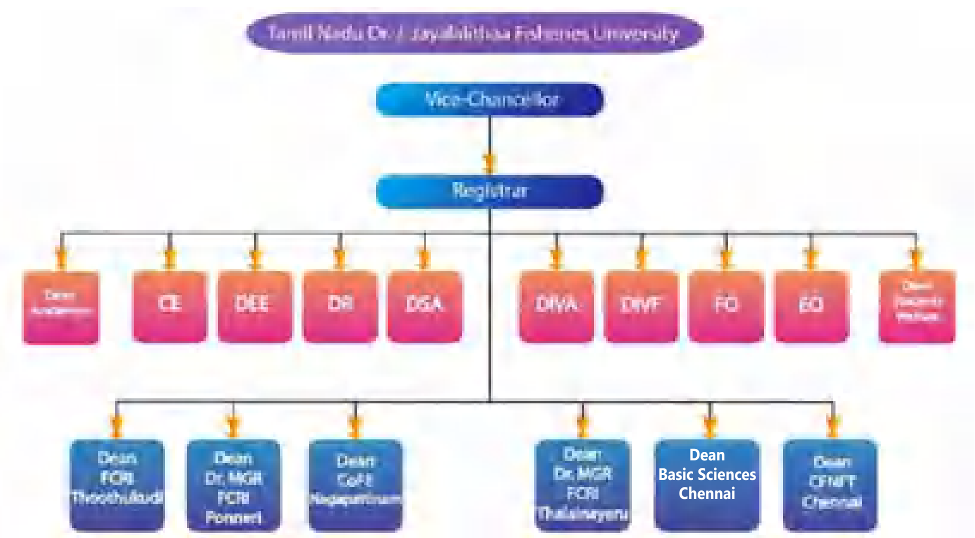
Vision

"Harnessing the Science of Fisheries for Food, Nutrition and Livelihood".

Mission

Excelling in teaching, research, and extension initiatives in fisheries sciences to produce professionally acclaimed and socially responsible graduates achieving nutritional security and sustainable development of the fisheries sector.

Organogram



Objectives

To impart quality education in different branches of Fisheries Sciences as the University may determine.

To conduct organised research in the frontier area to develop cutting-edge technologies in Fisheries Science.

To provide extension services like training, consultancy, project formulation to fish farmers, fisherfolk, unemployed youth and entrepreneurs in Fisheries Sciences.

To facilitate comprehensive development of Fisheries Sciences for increased contribution to the state's economy and set benchmark standards through appropriate interventions in fisheries teaching, research and extensions.

Recognitions

TNJFU has been accredited by the ICAR (2016-21). The self-study report for the University and colleges have already been submitted to the ICAR accreditation board and the renewal process of getting accreditation is underway. The University has got 12B Status awarded by the University Grants Commission in 2017-18 and AICTE approval for the College of Fisheries Engineering (2019-20).

TNJFU's Technical Directorates

There are five technical Directorates viz., Directorate of Research, Directorate of Extension Education, Directorate of Sustainable Aquaculture (DSA) with 7 Centres, Directorate of Incubation & Vocational Training in Aquaculture (DIVA) with 3 Centres and Directorate of Incubation & Vocational Training in Fisheries (DIVF) with 3 Centres.

Education

Constituent Units of TNJFU

The University at present has four Faculties. All these faculties together offer 6 Professional degree programs and 3 Paraprofessional degree programs through 8 professional colleges and 3 paraprofessional colleges. TNJFU has altogether 39 constituent units including Centres and Referral Labs.

Major Academic Achievements of TNJFU with a Multi-Disciplinary Approach

TNJFU is offering the maximum number of UG, PG and Ph.D programmes among the Fisheries Universities [39 Courses (9-UG; 16-PG; 14-Ph.D.)]. TNJFU is the only University to produce engineering graduates with specialization in fisheries to meet the demands of industries.

Students Excel in Academics

In total, twenty-eight students got their admission through All India Entrance Examination for Admission for post graduate studies [AIEEA (PG) -2021], among them 10 students were within 25 ranks and won 7 PGS. TNJFU has secured first position (2020-21) under the Veterinary and Fisheries Sciences group (9 PGS) during counselling held for PG admissions (AIEEA-PG-2020). University encourages UG students to have Overseas Internship Programme. Top ranking students in fisheries faculty are sent to foreign countries for a month stay to visit Fisheries Institutes, fish farms, hatcheries, fish products processing factories, fish markets and fisheries educational institutes. University intends to continue this initiative as this has ensured competitive spirit among the students.

Academic Programmes offered

Undergraduate programmes

Bachelor of Fisheries Science (B.F.Sc.) *

B. Tech. (Fisheries Engineering) ***

B.Tech. (Energy and Environmental Engineering) ^

B.Tech. (Biotechnology) ^

B.Tech. (Food Technology) ^

B.B.A. (Fisheries Enterprises Management) ^

B.Voc. (Industrial Fish Processing Technology) **

B.Voc. (Industrial Aquaculture) **

B.Voc. (Industrial Fishing Technology) **

^Self-supporting courses

** ICAR approved course*

*** UGC approved courses*

**** AICTE approved course*

Postgraduate programmes

M.F.Sc. & Ph.D. (Aquaculture)

M.F.Sc. & Ph.D. (Aquatic Animal Health)

M.F.Sc. & Ph.D. (Aquatic Environment Management)

M.F.Sc. & Ph.D. (Fisheries Economics)

M.F.Sc. & Ph.D. (Fisheries Engineering & Technology)

M.F.Sc. & Ph.D. (Fisheries Extension)

M.F.Sc. & Ph.D. (Fish Processing Technology)

M.F.Sc. & Ph.D. (Fisheries Resource Management)

M.F.Sc. & Ph.D. (Fish Quality Assurance & Management)

M.F.Sc. & Ph.D. (Fish Nutrition & Feed Technology)

M.F.Sc. & Ph.D. (Fish Genetics and Breeding)

M.F.Sc. & Ph.D. (Fish Pharmacology and Toxicology)

M.F.Sc. & Ph.D. (Fish Biotechnology)

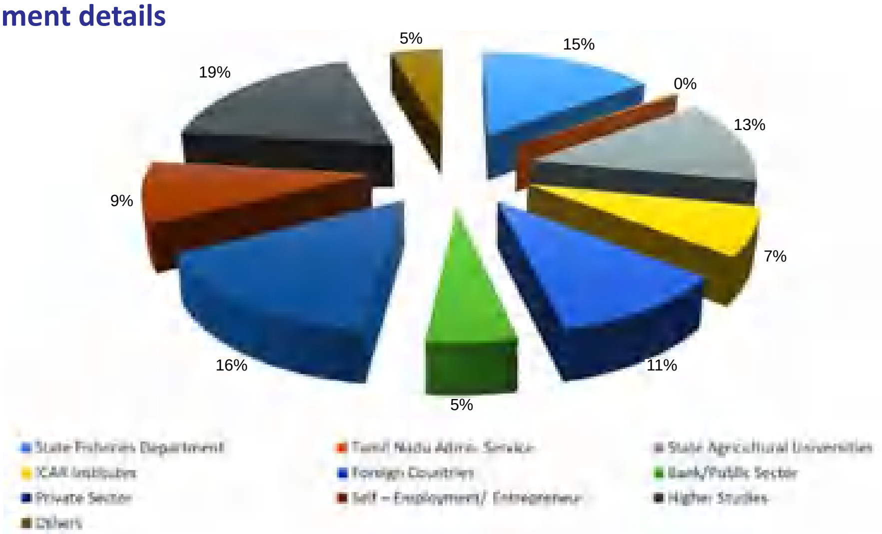
M.Tech. (Aquaculture Engineering)

M.Tech. (Fish Process Engineering)

M.B.A. (Fisheries Enterprises Management)

Ph.D. (Life Sciences)

Students Placement details



TNJFU - DIRECTORATE OF RESEARCH

The University has a strong research base with an exclusive Directorate of Research involved in strategic planning of research programmes, establishment of linkage with research organisations at National and International level, monitoring of research projects/schemes and research documentation. This office facilitates in research publications, patents, technologies and products through ethical conduct of research.

Completed projects since 2013

Funding agency	No of Projects	Value in lakh
DBT	5	168.04
DST-SERB	3	100.68
NABARD	2	1515.00
NCSCM	1	27.12
ICAR	3	338.85
ICSSR	1	8
GOMBRT	1	10.505
IAMWARM & Part II scheme (GoTN)	3	67.09
NADP	16	3981.519
NFDB	6	198.86
Part II Scheme (GoTN)	2	28.2
TANII	3	1095.6
DBT-BBSRC	1	109.912
NAFCC	2	26
FSSAI	1	9.52
SPC	1	18
ICAR NFDB & PMSSY	1	113.10
Total	52	8415.996

Projects in Operation

Funding agency	No of Projects	Value in lakh
DST-SERB	2	72.958
NFDB	1	277.60
TANII	1	430.66
NADP	13	2504.909
TN-IAMP	1	250.00
State Fund	2	649.00
EDII	1	250.00
NABARD	1	350.00
ICAR-NICRA	2	68.25
TNSLURB	2	26.364
Total	26	4879.741

Referral Laboratories

1. NABL Accredited TNJFU Referral Laboratory for Fish Quality Monitoring and Certification at Fisheries College and Research Institute, Thoothukudi
2. State Referral Laboratory for Aquatic Animal Health at TNJFU Madhavaram campus, Chennai
3. TNJFU Referral Laboratory for Aquatic Animal Health at Fisheries College and Research Institute, Thoothukudi
4. TNJFU Referral Laboratory for Aquatic Animal Health at Tamil Nadu Dr. J. Jayalalithaa Fisheries University Headquarters, Nagapattinam
5. State Referral Laboratory for Fish Feed Quality Testing at Institute of Fisheries Postgraduate Studies, Vaniyanchavadi, Madhavaram, Chennai.

Patents Granted

1. Multiplex PCR Assay for authentication of processed *Portunus pelagicus* and *Portunus sanguinolentus* (No.384288, dated 14.12.2021- Inventors: Dr. G. Jeyasekaran, Mr. Dineshkumar and Dr. R. Jeya Shakila)
2. Designing of genus specific primer for *Lutjanus* from 16S rRNA mitochondrial region for authentication of snapper products by single step PCR (No. 373138, dated 29.07.2021 - Inventors: Dr. G. Jeyasekaran, Dr. B. Sivaraman and Dr. R. Jeya Shakila)
3. Designing and fabrication of Inland raceways for intensive rearing of ornamental fishes (No. 362943, dated 24.03.2021 - Inventor: Dr. S. Felix)
4. Method of preparing Anti-oxidative Edible Film from Carp Gelatin and Fucoidan (No. 342498, dated 27.07.2020 - Inventors: Dr. R. Jeya Shakila, Mr. G. Raghu and Dr. G. Jeyasekaran)
5. Development of Primers for detection of Hepatopancreatic parvovirus (HPV) in shrimp by polymerase chain reaction (No.300445, dated 29.08.2018 – Inventor: Dr.A.Uma) (TANUVAS).
6. Development of PCR Primers for white spot syndrome virus (WSSV) in shrimp (No.275411, dated 02.09.2016 – Inventor: Dr.A.Uma) (TANUVAS).

Patents Published

1. Multiplex polymerase chain reaction (MPCR) kit for the simultaneous detection of *Salmonella, Vibrio cholerae* and *Escherichia coli* from seafood products (No. 201641003818, dated 25.03.2016)
2. Designing and fabrication Technology of floating Lobster rearing marine FRP cage for Lobster fattening (Fibre reinforced plastic) (No.1094/CHE/2013A, dated 21.11.2014)
3. Configuration of intensive advanced culture system for Aerobic microbial floc driven super intensive nursery raceways Technology for *Litopenaeus vannamei* (No.201641014450, dated 27.10.2017)
4. Use of MF-CEED as carbon source in Aerobic Microbial Floc (AMF) driven Nursery Raceway Technology for *Litopenaeus vannamei* (No. 201641014451, dated 27.10.2017)

Patents Filed

1. Designing and fabrication of multi shaped (adjustable) floating FRP cage for Inland Aquaculture (No.1097/CHE/2013, dated 14.03.2013

Publications & Technologies since University formation

1. Research Publications (International and National) – 657 Nos.
2. Technologies Released – 74 Nos.
3. Fish and Seaweed Products Released – 21 Nos.

Details of Research Publications of TNJFU form 2013-2014 to 2021-2022

* Since 2018-19, peer reviewed journal with NAAS score above 6.0 alone considered

Fish Products: Myocubes - Fish protein product, Fish myocubes in retortable pouches, Barbequed Fish Briyani in retortable pouch, Fish Biscuit, Fish Kure, Barbequed Prawn Briyani in retortable pouch, Prawn Biscuit, Prawn Kure, Prawn Cake, Instant fish and shrimp soup cubes, Crab Cake, Squid Protein based Beverage Mix, Green Mussel Meat Cracker, Marine Protein Bread.

Seaweed products: Seaweed Cake, Seaweed Soup, Seaweed Kure, Seaweed Wafer, Seaweed Biscuit, Seaweed Liquid Fertilizer (SLF), Seaweed Tea

MoUs Signed

1. International Universities / Institutes - 10 Nos.
   Important are Curtin University, Australia, Auburn University, USA, Prince of Songkala, Thailand, James Cook University, Australia, University of Arizona, USA, Asian Institute of Technology, Thailand, University of Las Palmas de Gran Canaria (ULPGC), Spain.

2. National Universities / Institutes - 31 Nos.
   Important are Central Institute of Fisheries Education, Mumbai, Central Institute of Fisheries Technology, Cochin, Central Institute of Brackiswater Aquaculture, Chennai, Central Institute of Freshwater Aquaculture, Bhubaneswar, National Fisheries Development Board, Hyderabad, National Institute of Ocean Technology, Chennai, Indian Institute of Food Processing Technology, Thanjavur, Indian Institute of Technology, Kharagpur, National Academy of Agricultural Research Management, Hyderabad, National Cooperative Development Corporation, New Delhi, Bay of Bengal Programme Inter-Governmental Organization (BOBP-IGO), Chennai

3. International / National Industries - 42 Nos.

TNJFU - DIRECTORATE OF EXTENSION EDUCATION

This directorate oversees the extension activities at all the constituent units of the University. It coordinates the ODL programmes and brings out a monthly newsletter and a quarterly magazine, Meenvazhasudar. The KVK of the University located at Sikkal in Nagapattinam district is functioning under the administrative control of the directorate.

TNJFU-ICAR-KRISHI VIGYAN KENDRA, SIKKAL, NAGAPATTINAM

Krishi Vigyan Kendra of Nagapattinam district was established on 01.08.2004 at Sikkal village of about area 22.60 ha, to work as resource and knowledge centre for agricultural and allied enterprises. Previously this KVK was functioning under the control of Tamil Nadu Agricultural University, Coimbatore from 01.08.2004 to 31.03.2018. From 01.04.2018 the administrative control was transferred from Tamil Nadu Agricultural University to Tamil Nadu Dr. J. Jayalalithaa Fisheries University. The operational jurisdiction of KVK covers 8 Tehsils, 11 blocks and 434 villages.

KVK has developed different demonstration units for the training purpose. During the year 2020-21, KVK has organized 120 training programmes covering 4768 participants, Extension activities covering 74232 participants. Conducted 9 OFTs in 41 farmer's field and 20 FLDs in 207 farmer's field. Presently KVK is handling 6 externally funded projects (NBB, New Delhi; ICAR-SCSP & IIRR, Hyderabad; NABARD) worth of Rs. 11.7 lakh.

TNJFU - FISHERIES COLLEGE AND RESEARCH INSTITUTE, THOOTHUKUDI

The Fisheries College was established by Tamil Nadu Agricultural University (TNAU) in Thoothukudi in October 1977 as India's second Fisheries College, and was brought to Tamil Nadu Veterinary and Animal Sciences University (TANUVAS) on September 19, 1989. In 1990, the college was renamed Fisheries College and Research Institute (FC&RI) to focus research and extension.

The FC&RI has three campuses: the Main Campus, the Staff Quarters Complex, and the Mariculture Research Farm Facility (MRFF), which is located in Tharuvaikulam, a coastal village 17KM from the main campus, for undertaking mariculture/coastal aquaculture activities. The FC&RI is adequately staffed with a sanctioned strength of 42 teaching and 105 non-teaching positions. The institute has 8 departments and 2 referral labs (Aquatic Animal Health and Fish Quality Monitoring and Certification (NABL Accredited)). The academic programmes offered are B.F.Sc.; M.F.Sc. (in 8 disciplines) and Ph.D. (in 8 disciplines). At present, Fisheries College and Research Institute is handling 15 projects to the tune of Rs 11.2073 crores (2 NADP, 2 DBT, 1 DST, 1 FSSAI, 1 NFDB, 1 EDII, 2 Industry and 5 University).

TNJFU - DR. M.G.R. FISHERIES COLLEGE AND RESEARCH INSTITUTE, PONNERI

Dr. M.G.R. Fisheries College and Research Institute, Ponneri was started as the Institute of Fisheries Technology, Ponneri on 20.02.2013 by the Government of Tamil Nadu, subsequently upgraded as a college on 23.4.2015. The College is functioning with seven departments which are equipped with Faculty and Facility to impart quality education, perform cutting edge research and provide efficient extension and advisory services to the fisher folk and fish farming community. Two instructional farm centers are presently functioning viz. Advanced Research Farm Facility at Madhavaram and Pulicat Field Farm Facility at Pazhaverkadu. The academic programmes offered were B.F.Sc.; M.F.Sc. (in 5 disciplines) and Ph.D. (in 5 disciplines). At present, there are 27 teaching faculty [Professors – 7; Associate Professors– 1; Assistant Professors – 19] and 6 projects worth of Rs. 14.71 Crores are being operated by the Dr MGR Fisheries College and Research Institute.

TNJFU - Dr. M.G.R. FISHERIES COLLEGE AND RESEARCH INSTITUTE, THALAINAYERU

Dr.MGR Fisheries College and Research Institute was established at Thalainayeru, Nagapattinam District with the financial outlay of Rs.6816.78 lakhs for 5 years. As per G.O. (Ms.) No.184 dt. 21.09.2017 and G.O. (Ms.) No.189 dt. 04.10.2018 of the Animal Husbandry, Dairying and Fisheries (FS4) Department, Government of Tamil Nadu, the college has started functioning from 12.10.2017 onwards and offers B.F.Sc., degree programme from the academic year 2017-18. There are seven departments with the total teaching staff strength of 20. Presently, the college has one DST – SERB funded 3 year project with a budget of Rs. 39.67 lakhs and two University Research Projects.

TNJFU - COLLEGE OF FISHERIES ENGINEERING, NAGAPATTINAM

Institute of Fisheries Technology, Nagapattinam was established by the Government of Tamil Nadu with a budget provision of Rs.34.08 crores located at the coastal town of Melavanjore area. Subsequently the Institute of Fisheries Technology has been renamed as College of Fisheries Engineering (CoFE) considering the growing importance and emerging needs of fisheries engineering in the fisheries engineering sector. The College is first of its kind in the Country established in 2015 with aim of developing engineering personnel for the fisheries industries. The academic programmes offered were B.Tech. (Fisheries Engineering); B.Tech. (Energy and Environmental Engineering) and M.Tech. (in 2 disciplines).

TNJFU - COLLEGE OF FISH NUTRITION AND FOOD TECHNOLOGY, MADHAVARAM MILK COLONY, CHENNAI

The College of Fish Nutrition and Food Technology was instituted at the Madhavaram Campus by TNJFU on 17 September 2018 and the B.Tech. (Food Technology) programme commenced on 18 September 2018. The college operates with a sanctioned strength of 40 students in a batch. The students are given exposure to the food sector through various guest lectures, webinar and industry visits which help them understand the subjects better. This undergraduate programme includes three years of course work and one year of hands-on-training. The syllabus followed has been designed as recommended by the Indian Council of Agricultural Research (ICAR), New Delhi.

TNJFU - INSTITUTE OF FISHERIES POST GRADUATE STUDIES, OMR CAMPUS, CHENNAI

TNJFU OMR Campus established in 2017 houses three constituent Institutes viz. Institute of Fisheries Postgraduate studies, Institute of Fisheries Biotechnology and TNJFU Business School (Fisheries) under the Faculty of Basic Sciences. Institute of Fisheries Postgraduate Studies (IFPGS) offers M.F.Sc. and Ph.D. programmes in four disciplines in Fisheries Science namely, Fish Biotechnology, Fish Genetics and Breeding, Fish Nutrition and Feed Technology, and Fish Pharmacology and Toxicology. In addition, this Institute also offers Ph.D. (Life Sciences) programme.

The Institute of Fisheries Biotechnology (IFBT) was started in 2017. This Institute offers B.Tech (Biotechnology), four-year professional degree programme. TNJFU Business School (fisheries) was established in 2018. The Business School (Fisheries) offers full time MBA (Fisheries Enterprises Management) from the academic year 2018-19 and full time BBA (Fisheries Enterprises Management) a four year professional degree program from the academic year 2019-2020 through self-supporting mode.

The State Referral Laboratory for Fish Feed Testing and Quality Certification is important facility established under the NADP scheme to analyze and certify the qualities of the feed samples from fish farmers, researchers, feed manufacturers and other stakeholders. Consultancy on Fish feed preparation and quality testing has been given to the fish farms, feed Industries and Government agencies.

TNJFU - DIRECTORATE OF SUSTAINABLE AQUACULTURE, NAGAPATTINAM

This Directorate was started on 01.01.2016 and later based on the discussion and significance of the Directorate it has been renamed as “Directorate of Sustainable Aquaculture”. Presently it is having its Head Quarters in Nagapattinam.

Centres under the Directorate:

1. This Directorate has 7 (Seven) Stations under its control with specific mandates:
2. Thanjavur Centre for Sustainable Aquaculture (TCeSA), Soorakkotai, Thanjavur – to focus on inland aquaculture and innovative aquaculture practices.
3. Mandapam Centre for Sustainable Aquaculture (MCeSA), Seeniappa Dargha, Mandapam – to focus on marine finfish culture and breeding.
4. Kanyakumari Ganapathipuram Centre for Sustainable Aquaculture (KKGCeSA), Ayiramkal Pozhimugam, Kanyakumari Dt – to focus on marine crustacean seed production, research and development of indigenous shrimps for future shrimp farming and SPF broodstock development.
5. Krishnagiri Barur Centre for Sustainable Aquaculture (KBCeSA), Barur Krishnagiri Dt – to focus on tilapia farming and propagation of pure line seeds.
6. Erode Bhavanisagar Centre for Sustainable Aquaculture (EBCeSA), Bhavanisagar – to focus on commercially important freshwater fishes and their farm production in addition to seed production of endemic fishes.
7. Kanyakumari Parakkai Centre for Sustainable Aquaculture (KKPCeSA), Parakkai, Kanyakumari Dt – to focus on the high value inland fishes such as Loaches and production of endemic ornamental fish varieties.



Trichy Centre for Sustainable Aquaculture (Trichy CeSA), Jeeyepuram,Trichy – to work on the development of technologies to enhance farm pond aquaculture production and operating the Brood bank for freshwater ornamental fishes.

Directorate has 10 teaching faculty staff and 23 non-teaching staff working at various Centres. All the centres are extending their facilities for students' experiential learning and research and training and development of entrepreneurs in aquaculture. Dissemination of technology through training, publications, release of technical bulletins, etc are regular works in these Centres.

TNJFU - DIRECTORATE OF INCUBATION AND VOCATIONAL TRAINING IN AQUACULTURE (DIVA), MUTTUKADU, CHENNAI

The Fisheries Institute of Technology and Training (FITT), Chennai functioned till 14.07.2015 under the state Fisheries Department was transferred to Tamil Nadu Fisheries University on 15.07.2015 as per the TNFU Act No.21 of 2012. At present, the FITT renamed as Directorate of Incubation and Vocational training

in Aquaculture is functioning at Muttukadu, Chengalpattu District under the University with the mandates to benefit the fisherfolk, farmers, unemployed youth by conducting skill training programmes and also offering job ready programmes like Certificate, Diploma, Advanced Diploma and Vocational degree for the plus 2 passed out students. Post graduate diploma programme in shrimp farming management and advanced aquaculture systems are offered from 2022-23. TNJFU Business School has been started functioning from DIVA, Muttukadu campus from 2022.

Institutes/Centres functioning under this Directorate are Paraprofessional institute of Aquaculture Technology; Centre for Incubation and Vocational training in Aquaculture, Muttukadu, Chennai for conducting feed validation test prepared in the aquafeed mill and to study the palatability and digestibility of various experimental feeds; Centre for Incubation and Vocational training in Aquaculture, Poondi reservoir, Tiruvallur - 24 cages were installed for the culture of Tilapia and Pangasius and Centre for Incubation and Vocational training in Aquaculture, Kolavai, Chengalpattu - 32 HDPE floating cages were installed for the culture of Tilapia and Carps with Growpia feed. At present, DIVA is operating 5 external funded schemes (NABARD, NADP and IAMWARM) and 3 industry institute projects worth of Rs. 1692.8 lakh and 16.8 lakh respectively.

TNJFU-DIRECTORATE OF INCUBATION AND VOCATIONAL TRAINING IN FISHERIES, RAMANATHAPURAM

The erstwhile Centre of Fisheries Management, Planning and Policy (CEFIMAPP) created on 18.08.2016 at TNFU, OMR campus, Chennai was renamed as Directorate of Incubation and Vocational Training in Fisheries (DIVF) and started functioning from Ramanathapuram on 30.09.2019 with view to create technical manpower in the fields of Harvesting and Post-harvesting technology.

Constituent Units

Institute of Industrial Fishing Technology, Ariyaman beach, Ramanathapuram was created to offer B.Voc. (Industrial Fishing Technology) with the intake capacity of 20 students per year from 2019-20. Apart from this, institute has been offering awareness training programme on responsible fishing and Navigation, Seamanship and Marine Engine maintenance and certificate course on “Fishing Technology and Fish Product Preparation” with the duration of three months. Paraprofessional Institute of Fisheries Technology, Madhavaram, Chennai was created to offer B.Voc (Industrial Fish Processing Technology) since academic 2018-2019 with the intake capacity of 30 students per year.

Centre for Incubation and Vocational Training in Fisheries (CIVF) Thoothukudi has offered five one week training programmes with the total participation of 124 mechanized fishing vessel operators / fishermen have been completed on Sea safety and Engine maintenance aspects. Further, CIVF, Thoothukudi developed a fish gelatin based bait incorporated with bio-attractants derived from squid wastes for long line fishing has been successfully developed. Centre for Incubation and Vocational Training in Fisheries at Thengapattinam would acquire a deep-sea fishing vessel (22.7 mtr OAL) being constructed at the Cochin Shipyard for offering training and demonstration to students and fishermen.

Contents

Sustainable Aquaculture 2025 - Need for region specific macro and micro-level implementable road maps

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Abstract

Aquaculture in Asia is one of the most vibrant sectors providing livelihood directly through the production systems and indirectly through the ancillary system including the processing and marketing sectors to millions of coastal populace. During the last decade, the Indian Sub-continent haspromoted aquaculture of diverse species in coastal areas. Among the various resources promoted, farming of an exotic species *Litopenaeus vennamei*, has seen more growth than other resources and these developments are mainly in the maritime states of East coast, which revived the shrimp farming sector. Similarly, edible bivalve farming in the estuaries of West coast (except Gujarat) by women Self Help Groups and *Kappaphycus alwarezi* farming in the near-shore waters of Tamil Nadu, highlighted the importance of local ecology and market demand in technology adoption. SWOT analysis showed that though there are more Strengths and Opportunities for development, the Weakness and Threats continue to hamper it.

Based on the strength and potential for aquaculture development of each nation it is suggested that a Strategic Frame work be developed between the Asian countries with regional collaborations. This would ensure more contribution from these nations in global aquaculture production and also ensure that there is sufficient species diversification in aquaculture thereby improving the Effective Number of Species (ENS) farmed, which is at present very low.

Within the Indian sub-continent, a national and state macro plan has to be developed considering each state's strengths and weaknesses for Aquaculture. Additionally, it is suggested that a district level (micro) action plan for aquaculture development which will sustainthe sudden climate shocks and market fluctuations and improve the local economy be prepared. The present article evaluates briefly the strengths weakness, opportunities and threats (SWOT) in Indian sub-continent and concludes with suggestions for sustainable development and also promote restoration aquaculture which would revive and rejuvenate the rapidly declining coastal habitats.

Introduction

The global Aquaculture production was estimated as 85.3 million tonnes (mt) in 2019 with major production from China (48.2 mt) followed by India (7.8 mt) (FAO,2021). Other Asian countries like Indonesia (6.0 mt), Vietnam (4.4 mt) and Bangladesh (2.5 mt) were also among the top five countries in aquaculture production. There is no doubt that this sector is one of the most important sectors recognised world over for livelihoods that are provided especially in the developing nations apart from the role it plays in producing high quality seafood.

Right from ancient days there existed a value chain for aquaculture with diverse methods to preserve the quality of the produce and market it to distant locations. The progress made in Aquaculture sector including species-specific farming systems, Ecosystem-based Aquaculture, high quality seed production techniques, disease diagnostics and prevention and several other innovations focussed research targeting sustainability has contributed to the growth of the sector. Needless to say, the Information Technology Era has helped in widening the market of aquaculture produce and creating new economies in the developing countries. Taking advantage of the strengths of the aquaculture sector, the need of the hour is to plan and implement programs for transformation to more efficient, resilient and sustainable productions systems supporting the FAOs Strategic Framework for 2022-2031.

The coastal aquaculture sector in India has progressed considerably during the last decade. Shrimps have been the preferred candidate species for aquaculture in India in both extensive and semi-intensive systems even during the past century. The trend continued in the last decade also. In 2021, the country produced 843361 tonnes shrimp, of which 96.7% (815745 tonnes) was *Litopenaeus vannamei* followed by *Penaeus monodon* (27, 615 tonnes). The development of finfish farming in cages in open waters especially in estuaries, edible bivalve farming, crab fattening, and farming of the seaweed *Kappaphycus alwarazi*in near-shore coastal waters has also added to the production from aquaculture sector in the last decade. Though there is immense potential to expand and intensify the farming activities of species other than shrimp, there seems to be several stumbling blocks preventing the horizontal spread.

A brief review of the shrimp production indifferent maritime states during the period 2009-10 to 2020-21 is presented, followed by SWOT analysis (Strength, Weakness, Opportunities and Threat) of the sector. The analysis presented below has highlighted the need for a broader macro level planning along with detailed micro-level planning.

SHRIMP FARMING

Production and area under Shrimp farming in India : 2009-10 vs 2020-21

One of the major decisions of the Government of India to permit culture of exotic species, *Litopenaeus vannamei* commonly known as pacific white-leg shrimp was like a lifeline to the shrimp industry which was going through a series of set-backs including disease spread and poor growth of tiger shrimp which was the predominant species. The spectacular growth in shrimp production from 97,650 tonnes in 2009-10 to the present level of 8.4 lakh tonnes can be attributed to the adoption of *L. vannamei* farming in the country (Fig 1). Almost all maritime states except few states along west coast of India increased area under shrimp farming which resulted in progressive increase in *L. vannamai* production from 2009-10 to 2020-21 (Fig 2) (data source: MPEDA website).

Fig 1 Producon trend of Litopenaus vannamei and P.monodon in the country

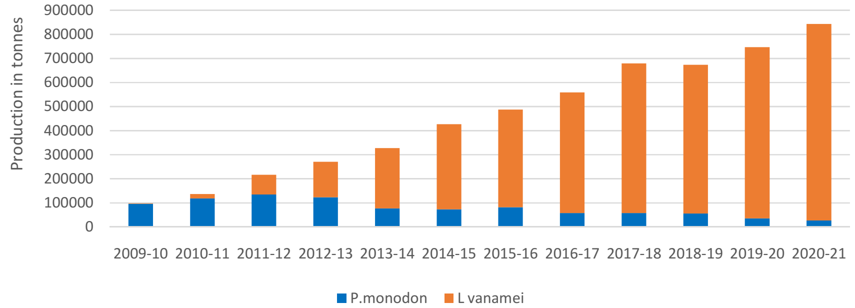
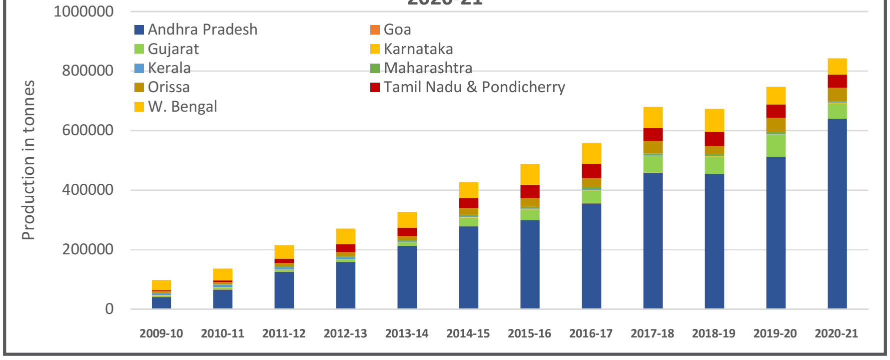


FIG 2 Shrimp production in maritime states of India during 2009-10 to 2020-21



Support industries for shrimp farming: One of the most important inputs for aquaculture is seed and for the growth of *L. vannamei* faming is the SPF seed produced from imported broodstock which are first quarantined at the AQF operated by the Rajiv Gandhi Centre for Aquaculture of MPEDA. There are currently 303 SPF *L. vannamei* hatcheries and 163 Nauplii Rearing Hatcheries spread across the maritime states with a seed production capacity of 125,000 million. The Coastal Aquaculture Authority (CAA) has given permission for import of 10,64,400 nos of SPF brood stock through the registered hatcheries. Seed produced in the hatcheries or in the Nauplii Rearing Hatcheries through SPF brood stock are sold to the farmers.

Aqua-inputs: The shrimp farming is supported by different other inputs such as the, feed, water sanitisers, water and soil probiotics, health and growth supplements and other inputs. Though there is no apparent regulation currently available to regulate the quality of these inputs. The CAA has aprogram of issuing Certificate of compliance for antibiotic free aquaculture inputs through a set of guidelines to complyfor the antibiotic free status. In addition, the country has National Residue Control Plan for Aquaculture Products implemented mainly by Export Inspection Council (EIC) of Ministry of Commerce and Industries in association with MPEDA and CAA which regularly evaluates the antibiotic free status in hatcheries and farms.

FINFISH FARMING

During the last one and half decade, various research organisations under Indian Council of Agricultural Research (ICAR), RGCA and Fisheries Universities of maritime states have made susbstantial efforts to develop seed production technologies for important candidate species like sea bass, cobia, groupers, Pompano and other groups which are low in the food chain like pearl spot, Milk Fish and mullets. These organizations have succeeded to a very large extent and the *Pradhan Mantri Matsya Sampada Yojana* (PMMSY) scheme of the Department of Fisheries of the MFAHD supported the commercialisation of the production techniques which helped in motivating the aqua farmers to start small scale fish farming in cages and earthen ponds.

Availability of domesticated broostock and Production of high-quality seed sufficient to meet the demand from the farmers is yet to be established. Commercial farming of cobia, groupers and Pompano in cages is still in its initial stages.

In global analysis of species diversification by Cai et al (2022), the "effective number of species" (ENS) farmed is low. This clearly points out the need for species diversification in Indian aquaculture.

BIVALVE FARMING

Two species of bivalves, the Indian backwater oyster *Crassostrea madrasensis* and the green mussel *Perna viridis* have very fast growth rates and are suitable for farming in the estuarine regions where the pollution is not high. The states along the west coast, mainly Kerala, Karnataka, Goa, and Maharashtra have farmers especially women SHG earning a livelihood from this particular aquaculture activity. The farmers still depend on natural spatfall (seed settlement) and this controls the productivity of the farm. The Central Marin Fisheries Research Institute (CMFRI) has developed the technology for seed production and also the protocols for depuration which would ensure high quality nutritious bivalves to the consumers. These developments were also cited as success story in the Asia-Pacific region (Mohamed et al., 2016)

Though this can be taken up extensively in areas along the Indian coast, there has not been much progress due to various factors like lack of awareness and seed availability.

CRAB FARMING

The mud crab *Scylla serrata* is a preferred candidate species for farming in many coastal villages. The RGCA is supporting the farmers by supplying seed and also various training programs. ICAR institutes are creating awareness on crab farming and fattening. However, farming of mud crab is limited and yet to achieve its full potential.

SEAWEED FARMING

Farming of *Kappaphycus alvarezi* has become very popular along the East coast especially in Tamil Nadu. Seaweed farming has been promoted under the PMMSY of GoI. Annually about 5000 tonnes of *K. alwarezi* is produced through farming. Though there are other seaweed resources available, farming is restricted to one species. However, being a very simple technology, seaweed farming has become a very popular activity along TN coast.

PEARL CULTURE

Marine pearl production revolutionized the Gem and jewellery trade during last century. Variety of pearls of different hues and sizes were produced from species of the genus *Pinctada*. Though the Indian sub-continent was famous for the lustrous oriental pearls produced in *Pinctada fucata* from the *paars* of Gulf of Mannar and Palk Bay and from the Gulf of Kutch, the country could not take advantage of the strengths available for developing a full-fledged pearl industry. Now without a different approach, the country cannot build a strong marine pearl industry. In an era of international experts facilitating aquaculture through networks, it is time to develop a plan of action for marine pearl culture including, akoya pearls, black pearls and mabe pearls.

MARINE ORNAMENTALS

It is well known that trade of marine ornamentals has been expanding is estimated as a $5 billion industry. This is a relatively new sector which is often ignored by mainstream aquaculture entrepreneurs.

However, the growing market demand provides opportunities for coastal communities to start marine ornamental breeding and sale as a livelihood program. The country has successfully developed breeding and seed production techniques for several species of ornamental fishes (Gopakumar et al., 2011). With proper planning and support, India can become the capital of marine ornamental in South Asia.

SWOT ANALYSIS

Review of the developments that have taken place in the aquaculture sector during the last decade clearly indicates that there is large scope for diversification and expansion. The SWOT analysis indicates the strengths of the sector and the weakness and threats which can be easily be converted to strength. The opportunities can be capitalised upon and for each State a defined road map has to be prepared.

The ecological characteristics of the aquatic ecosystems and the intensity of natural disasters like floods, droughts and cyclones are not uniform along the Indian coast. These may necessitate modifications in farming methods, protocols and cropping period. The success for *L. vannamei* farming along the east coast can be attributed partly to the biological ability of the species to withstand wide environmental variations especially salinity and temperature.

Table 1 List of Strengths, Weakness Opportunities and Threats pertaining to Indian coastal aquaculture

Strength	Weakness
• Fast growing indigenous species • Extensive water resources • Skilled and Unskilled manpower • Market demand • Technologies for farming for diverse species • Technologies for seed production • Good connectivity • State-of-art disease diagnostic labs • Aquatic Quarantine Facility	• Limited knowledge on technical aspects of new farming methods • Low of confidence in economic viability of new aquaculture practices • Lack of security in open water farming systems • Dependence on one or two species • Shortage of seed for species other than shrimp • Absence of SPF / domesticated brood stock for candidate indigenous species • Lack of full- fledged insurance cover • Lack of Policy guidelines and regulations • Lack of market intelligence
Opportunities	**Threat**
• Financial support from Government • Good connectivity • Need for nutritional security of human population • Availability of labour for aquaculture and related industries • Potential for IT interventions • Advanced spatial mapping technologies in different Government organizations which can support traceability and monitoring globally	• Vulnerability to extreme events and natural disasters • Climate induced vulnerability • Disease outbreak • Increasing cost of production • Use of poor-quality brood stock and seed

The strengths listed here are not common for all resources and regions. Each region has its own strengths, weaknesses, threats and opportunities. The success of bivalve farming in states along the west coast is a typical example of region based strengths needed for aquaculture which includes biological, social and ecological parameters. Similarly adoption of seaweed farming along the TN coast where extensive calm shallow areas with fairly stable salinity and low turbidity facilitate the present method farming.

While extensive areas are present all along the Indian coast, progress can be made only if we make region-wise SWOT analysis for each resource and prepare an action plan supported by financial as well as regulatory measures. Uncontrolled development can pose a threat to coastal ecosystem also. Keeping in view the ecological carrying capacity of the area, each maritime state can bring out an overall macro-level plan and then consider micro-level aquaculture development plans and entrepreneur guidance programs at district level.

Concluding Remarks

Potential for Aquaculture development is vast in Asia and most nations of the continent have succeeded in identifying their candidate species and developed highly efficient profitable systems with ecological sustainability. As the latest AR-6 IPCC report of Working Group II, Asia is vulnerable to more extreme events and there is threat of loss of livelihood. These impacts will have cascading impacts on the aquaculture production and distribution systems too. Considering the strengths of the each nation it is suggested that a strong network is developed between the Asian countries to develop an Aquaculture Development Plan with regional collaborations.

Within the Indian sub-continent, a national and state macro plan has to be developed considering each states strengths and weaknesses for Aquaculture. Additionally, it is suggested that district level (micro) action plans for aquaculture development to combat sudden climate shocks and market fluctuations and improve the local economy are prepared in consultation with the stakeholders and technology developers. It is well known that both climate change and unplanned anthropogenic activities had affected the natural aquatic resources impacting the biodiversity through recruitment failures. The present progress made in restorative and conservation mariculture should also be an integral part of aquaculture development plan targeting 2025. Overall progress in production from aquaculture and development of a vibrant sustained market is well within our reach.

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Bio-engineering and biotechnological applications in nutrition and feeding

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Aquaculture's contribution in the provision of "seafood" or "bluefood" (generic terms which comprise all food products from water, be it farmed or otherwise) for the human food basket is significant (FAO, 2020). At a global level, annual per capita consumption of seafood has indeed more than doubled from ~7 kg to nearly 16 kg over the past sixty years and there is apparently a continued increase in the demand for bluefood (Naylor et al. 2021). The potential of "aquatic foods" to reduce food and nutrition insecurity and address issues of malnutrition is well recognised (Golden et al. 2021).The high seas fisheries possibly play a negligible role in addressing global food security (Schiller et al. 2018). The contribution of coastal or inland aquaculture to meet the needs and demand for "bluefood" or "aquatic animal food" is clear, despite unwanted controversies over whether future development will be from freshwater or marine resources (Belton et al. 2020; Costa-Pierce et al. 2021). We should however recognise that when it comes to per capita protein, fat or calory supply, the contribution of "seafood" to the human food basket is relatively very small, in comparison to those provided by plant or other land animal protein sources (OCDE/FAO, 2019). Seafood intake in the Indian subcontinent is relatively high in comparison to other countries.

Indian aquaculture has seen almost seven-fold growth over the last two decades, with freshwater aquaculture contributing over 95% of the total aquaculture production (Jayasankar, 2018; Kaushik et al. 2018). It definitely contributes in economic terms (GDP, export) and value generation, production of specialty foods, niche products or bioactive compounds of interest and can address environmental conservation issues such as restocking of endangered populations.

Dealing with the production of all kinds of aquatic organisms through human intervention, aquaculture is extremely diversified in terms of the kind and number of species, types of environments, modes of rearing systems. However, practically half of aquaculture production is represented by seaweeds in the marine waters (27 %) and filter-feeding fish in freshwater (23 %) accomplished without a supply of additional feeds into the system. Majority of fish or shrimp famed today in the dominant Asian aquaculture scene relies on pond rearing systems relying empirically on the management of natural productivity, with the supply of supplementary or complementary feedstuffs or formulated specifically designed pelleted feeds.

It follows naturally that the technologies involved in the production of such organisms in diverse conditions are also very variable. One major challenge for strengthening or sustaining such production systems is to develop tools and methods for modelling nutrient flow in ponds and for smart assessment, monitoring and tailoring natural productivity in these farming systems, where both indigenous empirical approaches as well as sophisticated tools have a role to play. Nutrient flow dynamic modelling under such open water bodies is both a necessity and a scientific challenge.

Biotechnology, Nutrition and Feeds

Notwithstanding the importance of low-trophic level species in the global seafood production scene and its continued prospects (OCDE/FAO, 2019), there is a clear world-wide trend towards intensification of production (Belton et al. 2018) of finfish and shrimp and an interest for rearing species belonging to more and more high trophic levels (FAO, 2020). This leads to a strong need for the development and use of appropriate formulated complete feeds. As in all animal production systems, the cost of feeds remains the major proportion of the production costs. Sustainable development of aquaculture is dependent on feeds derived from the application of sound nutritional principles meeting the physiological needs for growth, development, health, welfare and reproduction. Contrary to land animal food production relying on a relatively small number of species from a low trophic level, aquatic animal food producers come from relatively high trophic levels (Duarte et al. 2009; Cottrell et al. 2021) exhibiting significant differences in terms of protein energy, fatty acid or mineral nutrition. Quantitative data on the nutritional requirements of fish and shrimp have been updated (NRC, 2011; Hardy and Kaushik, 2021). It is clear that formulation and development of species-specific feeds for the hundreds of species reared under diverse environmental and climatic conditions and rearing systems around the world is practically impossible to achieve. One good thing is that although aquaculture involves a large number of species, a major portion of this production concerns less than a score species.

But, there are many commonalities in the nutritional specificities of aquatic animals (fish and shrimp) such as the poikilothermy, ammonotelism, low energy needs, high apparent dietary protein needs, poor carbohydrate utilisation, a dietary need for pre-formed long-chain w3 polyunsaturated fatty acids etc. Therefore, systematic reviews of existing data available on different species should facilitate this task to some extent (Antony Jesu Prabhu et al. 2014; Salze et al. 2017; Oliva-Teles et al. 2020). Nutrient flow or nutrient demand dynamic models are useful tools to predict essential amino acid (EAA) requirements and to arrive at ideal protein profiles (Rollin et al. 2003; Furuya et al. 2004; Kaushik and Seiliez, 2010; Glencross, 2021).

The aquafeed industry necessarily involves a high degree of technological expertise, in order to develop and produce feeds tailored to meet the behavioural demands of target organisms as well as to ensure nutrient bioavailability in the aquatic milieu. The technologies involved enable the production of feeds having extremely diverse physical characteristics (hard or soft, floating or sinking, water stable or release of substances) or dimensions (ranging from a few microns to few cms in diameter) needed to meet the behavioural needs of animals of different life stages and living and feeding in an aquatic environment. The technologies needed for improving the nutritional quality of feedstuffs themselves (Kaushik, 2000; Drew et al. 2007; Hardy and Brezas, 2021) and to obtain diets with desired physical, chemical characteristics or nutritional profiles involve specific expertise in bio / chemical / mechanical engineering as well as in nutrition and feed science.

Bioengineering is very much used already in an empirical manner for the production of microalgae and live prey and for the improvement of the nutritional values of live prey used for rearing larvae of fish or shrimp. Progress made in the development of larval feeds from first feeding onwards of freshwater or marine finfish larvae (Cahu et al. 1998) has yet to be fully exploited not only for improving hatchery performance but also for gaining knowledge on the nutritional specificities of larval fish (Gouillou-Coustans et al. 1998).

Control of the microbial environment is a very promising area for reaping the full benefits of health and welfare of fish or shrimp. The application of greenwater or biofloc technologies for rearing larvae or through the whole life cycle where fine control of nutrient supply and microbial management is another example of biotechnology.

Reduced reliance on capture fishery derived feedstuffs

Reliance on capture fishery based feedstuffs such as the fishmeals and fish oils for inclusion in the feeds of farmed fish and shrimp is often cited as a major issue of concern and very correctly recognised as an unsustainable practice (FAO, 2020). Such precious nutrient sources should be used with talent and parsimony. Over the past decade, concrete and verifiable advances have been made in aquatic animal nutrition research and application to develop fish or shrimp feeds with low levels of fishmeal and / or fish oil using alternative protein and lipid sources (Aas et al. 2019; Hua et al. 2019; Tocher et al. 2019). When it comes to plant protein sources, techniques for the reduction of the anti-nutritional factors present in most plant-based feedstuffs involve either dedicated biotechnological tools such as selection of appropriate cultivars and genetic improvement of plants for target traits (Le et al. 2016; Osmond and Colombo, 2019). Genetic improvement of plants has indeed led to much progress towards the reduction of anti-nutritional factors present in seeds such as for instance low-trypsin inhibitor soybean or low glucosinolate, high-linoleic acid rapeseeds. Appropriate physical processing technologies involving pressure or heat such as cooking extrusion also lead to the reduction / elimination of anti-nutritional factors present in plant protein feedstuffs (Kaushik, 1990).

Of late, quite a large number of "novel" protein sources have regained interest which include single cell proteins (SCP) from bacteria, fungi or yeast, insect meals, plant cell wall materials and so on (Overland et al. 2017; Glencross et al. 2020; Albrektsen et al. 2022). The production of all these imply biotechnological tools addressing circularity and sustainability issues to convert waste into precious nutrient sources, one such example is that of SCP from methanophilic bacteria such as "Pruteen" found to be of interest in the feeds of salmonids long back (Kaushik and Luquet, 1980) which has had several new "avatars" (Jones et al. 2020) including that from an Indian biotechnology company (StringBio, Bengaluru), found to be a very interesting fishmeal substitute in rainbow trout diets (Rajesh et al. 2022). The production of insect meals be it from black soldier fly or mealworms (Makkar et al. 2014; Henry et al. 2015; Gasco et al. 2020) have gained much interest. Even robotics are apparently being used to produce insects. There are indeed some questions remain as regards sustainability and food safety linked to substrates utilised for the production of such animal proteins (EFSA, 2015; van Huis and Oonincx, 2017).

As regards fatty acids, recent genetic-engineering techniques applied for instance in camelina seeds, also pave way for the production of plant oils containing high levels of very long-chain omega-3 polyunsaturated fatty acids, very much of interest for aquaculture where fish and shrimp require dietary pre-formed EPA and DHA. In this context, the development and production of microalgal oils rich in EPA and / or DHA holds much promise be it for salmonids or for marine teleosts (Santiigos et al. 2020; 2021). The origins and compositions of some potential new sources of EPA and DHA have been summarised (Sprague et al. 2017; Tocher et al. 2019; Napier et al. 2020; Turchini et al. 2022). Such developments have a significant implication for ensuring the essential fatty acid supply to aquatic animals, for ensuring the nutritional value of farmed seafood for the humans, besides reducing possible presence of undesirable substances such as dioxins or PCBs (Sprague et al. 2016).

The health implications of the regular consumption of seafood is well recognised and sufficiently documented. It is known since some time that, compared to capture fisheries, farming under controlled conditions using nutritionally well-balanced feeds composed of ingredients from reliable and sustainable sources can ensure desired tailoring of organoleptic quality, food safety and nutritional value of seafood (Regost et al. 2003; Robin et al. 2003; Bell et al. 2003; Glencross et al. 2003). Modulating tissue composition and ensuring muscle characteristics is a major challenge in all animal production systems. Tailoring fatty acid composition or reducing the levels of feed-borne undesirables or contaminants can be achieved through proper nutrition. For assessing the organoleptic quality of flesh, there are also specific objective metrics and tools adapted to measure for instance, texture, flesh pigmentation using chromameters or sensory attributes using appropriate tools such as electronic nose.

Another approach for tailoring the fatty acid profile is perhaps to intervene at the metabolic level, trying to induce the expression / activities of enzymes involved in the w3 fatty acid bioconversion pathways (Monroig et al. 2022). A reduction in the dietary supply of preformed LC-w3 PUFA (long chain w3 polyunsaturated fatty acids) can possibly induce an increase in the expression and activities of some of the key enzymes involved in the desaturation-elongation pathways (Seiliez et al. 2003; Turchini et al. 2022). Some recent works suggest that we should carefully analyse the potential of early nutritional programming for instance to prepare aquatic animals to be metabolically / physiologically prepared for unavoidable changing scenarios, be it in terms of global warming or in terms of different nutritional challenges. Another venue of interest is to induce metabolic changes in broodstock through proper nutritional intervention with a consequence of producing offsprings having a greater potential of bioconversion of fatty acids of interest, as has been attempted with gilthead seabream (Xu et al. 2020; Ferosekhan et al. 2020).

Improving resource utilization efficiency Fish Nutrition: Interaction with production system and water quality

Improving resource utilization efficiency is a major and necessary challenge that aquaculture nutrition research should address (Waite et al. 2014; Froehlich et al. 2018). Here, the generation and application of solid basic nutrition science is a must to ensure the sustainable development of aquaculture under diverse systems. That there is an intimate interaction between aquatic organisms and the immediate environment in which they live: for the extraction of oxygen, food and nutrients, for the regulation of osmotic balance and also for discarding the digestive and metabolic wastes. The physiological mechanisms of poikilothermy (adjustment of body temperature), ammonotelism (elimination of nitrogenous wastes as ammonia as and when produced) and the low energy expenditure are all linked to the aquatic life. Thus, it is only natural that the maintenance of good physico-chemical quality of water bodies is primordial for the existence and success of any aquaculture operation. Therefore, due consideration of the quality of the immediate environment bears greater significance in the context of aquaculture than in land animal production systems. There is a large amount of data showing that improved feeds and feeding strategies (Cowey, 1995) have beneficial effects in terms of reduced environmental impacts and efficient use of feed resources. The bioenergetics principles behind feed allocation and reduction of nitrogenous or phosphorus excretion in different species of fish and shrimp all indicate that the underlying nutritional principles are equally applicable to all species (Cho and Kaushik, 1990; Kaushik and Schrama, 2021). Over the years, much effort has indeed been put to analyse such interactions between the organisms and the environment from different perspectives (biological, environmental, legislative) and at different levels (organisms, farm, ecosystem, habitat, regional or even global). The close interaction between environment and the aquatic organisms imposes appropriate measures involving one or more biotechnological or bioengineering tools. These can range from simple aerators to sophisticated sensors, monitors and data management tools and applications.

Precision farming and AI

One big husbandry-related challenge for fish or shrimp farmers is linked to feeding the right kind of feed at the right time in right quantities. Feed distribution in an aquatic environment to large groups of animals reared together in diverse systems (ponds, raceways, cages, tanks etc.) is thus a serious issue affecting overall production or environmental performance of aquaculture. Precision fish farming like precision livestock farming currently deals with monitoring environmental factors or biomass using visual, acoustic or other physical tools which stand to benefit largely by incorporating valid biomarkers of physiological responses. Any attempt towards precision-faming will require precise knowledge of the biomass (number, mass) within a given rearing unit, be it a pond or an open sea cage. Improving the farming environment through precise control of parameters such as oxygenation, automated feeding devices, visual control of stock, feeding behaviour, growth, welfare and health of fish address the concerns of the farmer as well as the ecosystem. Continuous monitoring of physico-chemical parameters of the water bodies, nutrient loads introduced into the system due to farming also require appropriate tolls of measurement and management. Such devices of visual control of biomass and feeding behaviour are already being used in several Atlantic salmon production operations. Precise control of environmental parameters and of feed intake have induced significant improvement in feed efficiency in such operations.

Wide deployment of precision feeding systems should be based on reliable bioenergetic or nutrient utilisation dynamic models (Kaushik and Schrama, 2022) and real-time monitoring of physio-chemical quality of the environment are applicable also in pond culture systems. Developments in underwater monitoring, image analyses for monitoring growth and physiological welfare, identification of species, continuous monitoring of biomass, predators or parasites are already under way (Zion, 2012; Fore et al. 2018; Antonuci and Costa, 2019). Similarly, application of robotics, 3D printing and automation, if done properly, have shown improvements in farm operations, making them less tedious potentially improving the welfare of farmers.

Seafood is the most traded commodity around the world. This is also the unique sector where products derived from capture fisheries and those from aquaculture complement each other, sometimes leading to confusion in the minds of the ultimate consumer. Given the possible differences in the quality of products which can be affected by the fishing areas, production methods, processing methods, duration between slaughter and availability to consumer, shelf life, stability necessitate stringent quality control methods. The whole sector stands to win by exerting strict control measures at each and every stage of the supply chain, from wild catches or harvest of farmed seafood to processing and retailing in order to ensure traceability and for providing objective information to consumers. This can go from combating fraud to address issues pertaining to the nutritional value and food safety aspects. Development of appropriate and simple tools to ensure this traceability and quality assurance is a promising area research and developments in bioengineering. In harvest and post-harvest sectors, engineering techniques have considerably improved collection and processing of end products to suit volatile consumer demands. Block chain technologies (Blaha and Katafono, 2020; Yue and Shen, 2021) are already being implemented to ensure accurate traceability and controlled seafood production and through the value chain to the end consumer.

Nutrition research Challenges

In the research front, there are a quite a few challenges with opportunities offered by the application of appropriate modern biotechnological tools and applications. Molecular biological tools are increasingly being used but their utility is consolidated only when fully supported by information at the organism levels. We should look for clear concordance between gene expression level and protein expression/function in order to propose reliable biomarkers of interest. Selection of candidate genes should be based on well-established metabolic role(s) of such candidates. Changes in gene expression patterns should be complemented by clear demonstration of the functional roles of proteins involved. Given the extreme diversity of species involved in aquaculture, challenges are high to draw generalisations on key metabolic functions as affected by environmental factors including feeds or specific nutrients.

Since aquaculture is confronted with a large number of candidate species, reliable methods and approaches towards the understanding of the process of domestication are warranted. This again will require full control of the biological cycles intimately linked with the environmental factors. Progress made in understanding reproductive physiology of different species has indeed facilitated the domestication of many species farmed today.

Given the long life-spans of most fish or shrimp, studies on nutrition research need to be undertaken over sufficiently long periods using appropriate experimental designs, adequate number of replications and statistical treatment of data. Assessment of the impacts of nutrients are and should be undertaken using diverse criteria with complementary approaches involving responses at different levels: whole organism, tissue, cellular, molecular or the expression levels of relevant genes. The application of high-throughput, integrative "omics" tools in fish/crustacean nutrition research should rely on pertinent, duly validated biomarkers of response to specific nutritional challenges rather than testing the effects of two diets. In the absence of precise quantitative data on the requirements of all farmed species for the forty-odd nutrients, applying appropriate approaches, such as the factorial models, hold much promise.

The duration of the life cycles of fish and shrimp imposes long-term commitment is needed at the sector level, both from academics as well as producers, for studies linked with the genetic improvement of farmed fish, shrimp and even algae. Progress made in the genetic improvement of fish / shellfish has been useful for improving growth and towards improved resistance to diseases in some cases. Such reductions in the duration of rearing for producing seafood available to the consumer should bear in mind the implications both from an environmental impact point of view, such as improving overall resource use efficiency (feed utilisation, nutrient retention, fatty acid deposition etc) which will also have impacts on other traits ensuring food safety and nutritional value. Such work on feed x breed interactions will also benefit from progress made in genomics, marker assisted selection or SNPs. With the advent of genome editing tools (Blix et al. 2021), nutrition research should be able to target metabolically important traits.

Although aquaculture is recognized as an efficient animal production system, there is room for improvement in terms of resource efficiency. Not withstanding the diversity of species or methods of production, there is a clear need to have an ecosystem approach to aquaculture taking full advantage of the biological potential of the organisms with adequate consideration to environmental and societal factors. We can collectively build blue food production using green technologies in a concrete manner.

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Nutrition and environment interactions in aquaculture

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Globally as well as in India, more than half of the fish and seafood commodities for human consumption comes from aquaculture. With the expanding footprint of aquaculture and its increasing role in the global food system, the interactions between diverse aquaculture systems and environment has come under intense scrutiny. Nutrition, feeds and feeding practices are considered to be a vital cog in the bidirectional relationship between fish production systems and aquatic environment. While the regulatory role of aquaculture feeds in deciding the environmental impact and sustainability of aquaculture systems is well recognised, the impact of environmental changes on the nutritional requirements of fish and biological efficiency of feed compositions is also gradually gaining attention.

Historically, environmental sustainability (minimizing pollution due to wet feeds) was one of the major factors that triggered the development of dry feeds and the present-day feed industry. With further technological progress, dry feeds have led to optimal use of feed resources, minimum spoilage and higher production yields in aquaculture. However, feed transition is presently driven by bioeconomic policies without adequately assessing challenges related to environmental sustainability, protection and climate change consequences. According to one estimate, the use of feed in aquaculture has grown at an average annual rate of 10.3% since 2000 and the aquaculture industry presently uses nearly 50 million tonnes of feed. The net environmental nutrient loading (i.e., the nutrients lost from feed and fertilizers) varies depending on the production system, cultured species and type of feed used.In the last decade itself, an annual environmental nutrient load of 1.7 million metric tonnes of nitrogen and 0.46 million metric tonnes of phosphorus could be attributed to aquaculture production of finfish and crustaceans. Life cycle assessments suggest that fish feed (as a crucial input factor) is responsible for more than 90% of the environmental impact of aquaculture production. Hence, innovations in feed is a pre-requisite to make aquaculture more sustainable.

As the focus on environmental sustainability increases, there is greater emphasis on the use of feed resources in a responsible and environmentally efficient manner. This includes enhanced 0 traceability of aquaculture feed ingredients; limiting the inclusion of fish meal and fish oil sourced from over-exploited wild fishes; and the use of novel plant, animal and micro-organism based raw materials which has less ecological costs. As we continue to look for solutions to diminishing marine feed ingredient resources, the harmful environmental consequences of terrestrial crop (soybean) monoculture should also be considered. Likewise, full-scale shift towards insect meals, microalgal products and single cell proteins (bacteria and yeast) should be accompanied by environmental impact assessments regarding potential conflicts in the use and production of these resources and cross-system effects on neighbouring ecosystems. The use of highly efficient feeds coupled with feed quotas could be another effective measure to mitigate the environmental problems at the intersection of aquaculture and natural ecosystems, as a typical aquaculture nutrient mass balance includes feed input, uneaten feed, biomass gain, faecal and non-faecal losses. Besides the major nutrients

(N and P) and suspended solids, the environmental impact of the relatively minor release of other feed additives (synthetic pigments, chemicals and therapeutic drugs) from intensive production systems have not been studied, but their potential impact can not be totally dismissed. Optimizing feed manufacturing technology (producing less than 1% fine particles in the feed) and feeding strategies according to the rearing conditions and production systems may minimise the loss of nutrients into the environment. In carp polyculture ponds that receive supplementary feeds and fertilizers (for natural food production), environmental nutrient loading from manure (75-95% of N-input and 89-95% of P-input) can be much more than from feed (47-79% of N-input and 72-89% of P-input). Therefore, more use of low pollution formulated feeds and adoption of fine-tuned feeding strategies may help to reduce the environmental footprint of aquaculture.

On the other hand, there is less information on the changes in nutritional requirements of fish and their response to low fish meal/oil feed compositions, under varying environmental stressors. Inadequate nutrition may aggravate the effect of sub-optimal culture conditions and lead to impaired metabolic and immune status, and physiological homeostasis. Dietary interventions (functional feeds) is a practically feasible strategy for environmental stress management in aquaculture. For instance, in salmon farming, extra provision of n-3 long chain polyunsaturated fatty acids is known to improve fish health and performance under challenging environmental conditions. Similarly, dietary fortification with natural antioxidants (vitamin C and E), amino acids (tryptophan), phospholipids, trace elements (selenium) and phytobiotics have been reported to ameliorate environmental stressors in fish. Nevertheless, it should be noted that supplement dosage can be specific to species, life-stages and culture environment.

Aquaculture breeding programs and application of genetics and genomics

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Abstract

The global aquaculture is dominated by carps, salmonids, tilapia, shrimps, other finish, and shellfish species. Although most aquaculture production comes from the unselected bloodstock, more than thirty active commercial breeding programs for different fish/shrimp worldwide significantly enhance aquaculture production. A few commercial companies own the salmonid breeding programs (Atlantic Salmon, Coho Salmon, and Rainbow trout). They are the most advanced in terms of traits selected and technologies used, followed by Shrimp, Tilapia, and other marine fish (seabass, seabream, etc.) breeding programs. The carp production still heavily depends on unselected bloodstock, managed by medium to small scale hatcheries, often unorganized. A full-fledged advanced breeding program with Atlantic Salmon as an example comprises commercial grow-out cages, bloodstock management units (open sea or complete recirculation system), hatchery units, and smolt production units with strong technical support from the geneticists, fish biologists, production experts, fish health experts, marketing, finance, and the management. More than ten traits are currently under selection in Salmon using traditional quantitative genetics and genomics methodologies. Other less advanced breeding programs, such as tilapia, shrimp, etc., select for a few traits, mainly growth and disease resistance. The market assisted selection (MAS) and genomic selection (GS) is actively used genomic technologies, and future technologies are likely to focus on gene editing and other upcoming methods.

Innovations in Fish Genetics and Biotechnology; The need for future investment in India

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1.0. INTRODUCTION

The world's population is predicted to rise from 7.9 billion to 9 billion by 2050. To meet rising food demand, global agricultural and associated commodity production would need to expand by 70% by 2030. Fishery management and aquaculture will play a major role in food and nutrition security in times to come. Climate vulnerability and its impact need deep research to find a sustainable solution to upkeep production and productivity while achieving sustainable developmental goals (SDG). There is a need to adopt innovation and apply modern genetics and biotechnology tools to support ongoing and future research. Indian Aquaculture has been homogenized as a production system of Indian Major Carps (IMCs) in freshwater and shrimps, in particular monodon, in brackish water aquacultures. Despite the fact that mariculture diversification is still in its early stages, re-diversifying aquaculture production is crucial to promote a wider choice of healthier foods as well as more sustainable and stable production methods. Diversification of species, ecosystems, and research, on the other hand, necessitates a shift in policy, investment, entrepreneurship, and research agendas. In addition to diversification, development of elite germplasm having high genetic potential is the need of the hour.

2.0. DEVELOPING SCENARIOS FOR FISH GENETICS RESEARCH

Genetics contribute significantly to enhance aquaculture production and productivity. In fact it is one of the most potential means at present to make the aquaculture industry sustainable and dependable. The genetic potential of many commercially important species has not been properly and fully exploited until now. Many fish and shellfish species have been domesticated relatively recently compared to other livestock species, resulting in diversified gene pools with significant selective breeding potential. The development of methods to acquire insight into these species' genetics, as well as their use for breeding and management, presents opportunity to unleash that potential. Most aquaculture species can generate a huge number of offspring, allowing large populations with enhanced genetics to bered fast for increased productivity. Improved growth, disease resistance, and robustness in a variety of farming conditions could all be advantages. As farmed fish replaces wild fish as the primary source of seafood, genetic tools and knowledge are in great demand to improve the efficiency and sustainability aquaculture systems, which currently rely on unselected stocks. Understanding species genomes can aid in the careful selection of a farming population with desirable qualities, and monitoring genomic variation can aid in the preservation of genetic variety as farm populations grow. In the future, technology like genome editing may be used to bring desirable qualities into farmed species, such as disease resistance, and surrogate breeding may be utilised to promote the production of chosen species.

In terms of selective breeding technology use, aquaculture lags considerably behind plant and terrestrial farm animals. Many fish and shellfish companies continue to employ wild stocks or production stocks that are only a few generations old (Tave, 1986). However, one of the first reported fish selection trials began in 1919 (Embody and Hyford, 1925), with brook trout being selected for increased survival against furunculosis. Since then, there have been a number of selection experiments to improve growth rate and disease resistance (see e.g. Argue et al., 2002; Bondary, 1983; Dunham, 2006; Gitterle et al., 2006; Hetzel et al., 2000; Hussain et al., 2002; Ilyassov, 1987; Kincaid et al., 1977; Kirpichnikov, 1987; Kuzema, 1971; Langdon et al., 2003; Moav and Wohlfarth, 1963, 1973, 1976; Nell and Hand, 2003; Newkirk and Haley, 1983; Schaperclaus, 1962). Large-scale family-based breeding programmes for salmonids (Atlantic salmon and rainbow trout) were first introduced in the 1970s (Gjedrem, 1985), for Nile tilapia in 1988 (Eknath et al., 1991), and for marine shrimp *P. vannamei* in 1993, and are now the industry standard for genetic improvement of aquaculture species (Fjalestad et al., 1997). Since then, selection procedures based on sib data have been established for a variety of aquaculture species all over the world. The high genetic gains obtained in many aquaculture breeding programmes are explained by the relatively high heritabilities for commercially essential traits in fish and shellfish, along with high fecundity and short generation intervals (1–4 years) in most species. Thus, genetics plays an important role in the improvement of economically important traits from both a producer and consumer point of view such as growth rate, disease resistance, flesh quality, FCR, tolerance to cold/salinity, body shapes, and muscle fat percentage in fish and shellfish. Environmental management and low inputs will play a big role in future to make aquaculture a sustainable venture. Thus, through the genetic research strategies new varieties can be developed which will grow fast, use fewer inputs and robust to changing climatic conditions.

2.1 Selective breeding programs in India and way forward for future investments in breeding programs across the country.

Genetic improvement through selective breeding is one option to increase the aquaculture production and productivity in sustainable manner. Use of genomic selection as tools would help to increase the accuracy of selection in traditional family based selection. By replacing the local stock with improved strains the production can be increased with existing resources. We have strength in form of 25 years' experience in selective breeding program of 6 species including, Rohu (Jayanti), Catla, Scampi (CIFA GI Scampi) by ICAR-CIFA, Magur and common carp by ICAR-CIFE, and Amur carp by UAS Bangalore. Along with that we have huge genetic resources available and number of hatcheries of fish and shellfish to scale up the dissemination of improved varieties. In India opportunities are available for fish breeder such as for many species breeding and culture methods are standardized, compared to farm animals generation interval is short and fecundity is high so we can have large number of fish sample in pedigree for genetic parameters estimation.

The possible threat for existing breeding programs such as Competition from outside agencies, rapidly changing technology, shift in species preference by stakeholder, undulating policy decision, emerging diseases and unknown impact of climate change needs to be taken care of. For sustainable genetic gain from the breeding program researcher may take stock of genetic variation, genetic defects, G/E interaction based on culture system and unfavourable relation between selection traits time to time. Along with that the impact of improved strain on climate change (environmental footprint) may be taken care of. Some important issues hindering the success of breeding programs in the country are no networking among the institutes, most of them are operated in small scales, absence of national breeding plan for any species, low funding assistance, weak dissemination channel of improved varieties, mind-set of one suits for all environment, absence of breeders association and lack of awareness at all level. Other constraints like lack of seed certification for genetically improved seed in the country, lack of phenotypic or genotypic markers to differentiate improved strain from local stock, lack of bio-secured infrastructure facility and lack of national guideline for these improved varieties for breeding and dissemination.

In future there is need of huge investments for establishment of breeding companies both in private and government sector for genetic improvement programs based on genomic selection to improve economically important traits in commercially cultured fish and shellfish species from freshwater, brackishwater and marine aquaculture.

3.0. STEERING FOCUS IN FISH BIOTECHNOLOGY INNOVATIVE RESEARCH

By 2050, biotechnology discovery research will likely be at the core of one of the many new technologies. However, depending on how the future unfolds, today's biotechnology research advancement has a higher or lesser potential to serve as the foundation for future innovation. For example, it is apparent,that demand for climate change-related biotechnology innovation will be high, and that policymakers will encourage it. However, it is still unknown what the unmet demands will be for the various stakeholder groups. The effects of weather fluctuations and volatility on aquatic organisms, water bodies, and crop fields, as well as the consequent novel environmental conditions, including new parasite and diseases, are not yet fully understood. As a result, a translational step from an innovation opportunity that necessitates new knowledge is not readily apparent. Similarly, how to bring innovation into products is unclear. It might be anything from gene editing to yet-to-be-implemented knowledge-driven, societally approved procedures. The first activity, developing climate change know-how, has a low risk of not being of relevance. The second, using biotechnology innovation to combat climate change is more risky because it is dependent on how policies evolve around the world.

3.1. MICROBIOME:

Another example is related to the microbial exploitation. Because bacteria have an impact on most, if not all, complex ecological systems, exploiting biological know-how is projected to provide innovation opportunities in a wide range of biotechnology sectors, as well as being at the heart of aquaculture expansion. These include aqua-medicine, animal welfare, food systems, and post-harvest technology. To make this a reality, broad fundamental biotechnology discovery research on microbiomes must achieve a critical mass, enabling for research and investment in smaller and larger possibilities across the value chain. This demands a large public effort to enhance pre-competitive know-how and enablement to a level suitable for sector adoption while maintaining a fair risk of return on investment. However, in order for this to happen, an entrepreneurial ecosystem is required, meaning that such innovations are more likely to occur in a bio-innovation/blue economy scenario, or even in a food emergency scenario, if society prioritises food rights.

3.2. GENOMICS:

With the emergence of genomic methods such as metagenomics, a new window into the world of microbes has opened. In the last decade, metagenomics has emerged as a promising way of analysing the multiple genomes present within a microbial niche or biome. In aquaculture habitats, metagenomics can be used to investigate microbial diversity, microbial roles, and antibiotic resistance genes. Through counting sequenced reads, NGS can offer quantitative or semiquantitative data on the concentration of organisms in a sample, which is important for polymicrobial samples or cases where more than one pathogen has been implicated in the disease process.

3.3. GENOMIC SELECTION

By enhancing our knowledge of the genomes of cultivated organisms and a better understanding of the dynamic interactions between genes and the environment, genomics offers the potential to address many of these restrictions, allowing us to maximise food production. A timely opportunity exists to maximise the potential of farmed aquatic species in order to assure food security for a growing population. This process can be sped up by genomic selection and biotechnology, and recent advances in these domains will soon enhance aquaculture output for many of these species around the world. Genomic selection has been implemented in several aquaculture selection programs to achieve higher body growth, resistance to disease, better fillet quality, and improved feed conversion. This has put forward the need to carry out genetic and molecular research in aquaculture to dissect biological questions. The development of computational tools and advances in sequencing technologies has led to a greater understanding of the various features of organism cells on a genome-wide scale. To date, some farmed fish genome data is available in the database, which is highly informative and provides useful knowledge regarding genes functions at a wide scale. Genome of any organism will facilitate in-depth understanding of molecular basis of its biology in particular its physiology with respect to, production and reproduction. But, still, many questions are not resolved due to a lack of proper studies and expertise. To solve those problems researchers, have to gain expertise in the field of structural as well as functional genomics. Hence, integrative analysis of the biological systems of fishes with the help of sequencing technologies and bioinformatics tools is required to get a deep understanding. Thus, for commercial important aquaculture species, the future challenge is to understand the vast number of fish genomes along with their overall gene functions, their association with production traits for gene-assisted selection, and their evolution

3.4. GENOME EDITING:

Genome editing has the potential to change at the genome level and has progressed rapidly in recent years. This is considered as one of the most important disruptive technologies in the biological sciences. The CRISPR/Cas9 genome editing technology is the most convenient and easy to use genome editing technology and has the capacity to be used in any organism, including aquaculture species. Using this technology now, it is possible to knock-out or knock-in genes/promoters/elements to develop a customised phenotype in aquaculture species. This method has been successfully applied to edit genes of interest in model organisms. However, it has been applied to a few aquaculture species, such as yellow catfish (*Silurus lanzhouensis*, Dong et al., 2011) Nile tilapia (*Oreochromis niloticus*, Li et al., 2013; Li et al., 2014; Jiang et al., 2017), Atlantic killifish (*Fundulus heteroclitus*, Aluru et al., 2015), Atlantic salmon (*Salmo salar*, Edvardsen. 2014), olive flounder (*Paralichthys olivaceus*, Wang et al., 2021) to develop some phenotype of interest. When the basic know-how generated from discovery research is not widely available and accessible in a useful format, as in the biotechnology instances mentioned above, there is a risk of low innovation output. The implementation of learning scenarios and the assessment of success against indicators for these situations can considerably increase the timely availability of founding know-how. Appropriate business models and governance concepts to deal with, among other things, data ownership and intellectual property must be developed, and specialised data stewardship teams must be installed to make this feasible and sustainable. This will necessitate numerous rounds of optimization to get the best balance of stakeholder interests. Yet, in an ever-changing environment, it is well positioned to increase the entire flow of innovation to the market and to provide the needed flexibility to deal with forthcoming trends.

4.0. CONCLUDING REMARKS

The utility of different genetic improvement approaches can be established by comparative study on fish and crustaceans across the domestication continuum. Further practical testing of the above approach would also reveal if 'redomestication' of major species from wild relatives and progenitors as a strategy for efficiently accessing wild gene pools for traits lost in the development of advanced phenotype but now considered beneficial for addressing aquaculture sustainability challenges has merit. Recent research employing CRISPR/Cas9 gene editing of target domestication-related genes has showed promise for redomestications, with domesticated phenotypes that maintain essential wild traits, which can be achieved starting from crop wild progenitors in the case of tomatoes. Wild relatives, progenitors, and landraces of a number of major crops have been found to have more variation in traits related to resource use efficiency and a plant's ability to interact positively with other crops and noncrop biotic components in complex production systems than narrowly diverse advanced monoculture cultivars. This principle can be easily applied in aquatic species too.

We should not be satisfied in future investment only. Beyond 2050, assume we are in 2050 and the projections we have presented have come true. How should we speculate about future developments, say, to 2100? Can our projections for the period up to 2050 provide us any insight into what might happen after 2050?

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Enterocytozoon hepatopenaei (EHP) and White Feces Disease: From Obscurity to Global Attention in Shrimp Disease

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Emergence of diseases in shrimp aquaculture mirrors the expansion of the industry worldwide for the past four decades. As the disease scenario started evolving, new diseases emerge and previously known diseases become less threatening and no longer cause economic losses to the tunecompared to when it first emerged. In the 80's through early 2000, viral disease caught much of the attention for the enormous losses they caused in shrimp aquaculture. In the late 2000, a lethal disease, acute hepatopancreatic necrosis disease (AHPND, initially called early mortality syndrome, EMS), that swept through the major shrimp producing countries in Asia with the economic impact being felt not only in Asia but also in the shrimp importing countries as the price of commodity shrimp increased. While the attention was focused on AHPND to prevent the spread of the disease, a yet lesser known disease, identified as hepatopancreatic, microsporidiosis (HPM) caused by a microsporidia *Enterocytozoon hepatopenaei.* The disease started spreading from its origin in Thailand to other countries in Asia and eventually reached the Americas. Today, HPM caused by EHP pose a serious threat to shrimp farming worldwide. Surprisingly, in a recent report from India it has been estimated that the external of economic loss even surpass, losses caused by the white spot disease. Recently, the association of EHP and Vibrio sp. was shown to cause white fecal disease (WFD). Considering Vibrio spp are ubiquitous in marine environment, as EHP spreads to many shrimp producing countries, it is possible WFD will also spread. While diagnostic tools have been developed to detect EHP, there is no method to amplify EHP rapidly either in vivo or in vitro. Recently we developed a simple yet a robust and reproducible method in amplifying EHP in live shrimp. The method involves injecting EHP inoculum directly into the hepatopancreas of live Specific Pathogen Free (SPF) *Penaeus vannamei* shrimp. The parasite load in the injected animals increases significantly within 15 days post-injection. When hepatopancreas was dissected from the injected animals and fed to SPF *P. vannamei* shrimp, orally challenged animals displayed lesions characteristics of EHP infection in the hepatopancreas within 15 days post-feeding. This provided a rapid means to amplify EHP in live SPF *P. vannamei* shrimp and thus enabling screening of genetic lines of *P. vannamei* shrimp for EHP resistance.

Biosecurity and pond management remain as the two preventative measures for limiting the introduction of EHP in ponds and hatcheries. To prevent EHP infection in shrimp, the manipulation of the gut microbiota has been suggested. We assessed the modulation of the microbiome (bacteria/fungi) and its predicted functions during disease progression in experimentally challenged shrimp using high throughput 16S rRNA and ITS amplicon sequencing. Using quantitative digitalhistopathology, the intensity of infection was graded into three disease-stages: early, developmental and late stages. In the early stage, a high diversity of potentially beneficial microorganisms related to nutrient assimilation were detected. In the development-stage, as the intensity of infection increased, there was a decrease in beneficial microorganisms and an increase in opportunistic/pathogenic fungi. Finally, during the late-stage infection, animals displayed varying levels of infection intensities and a displacement of beneficial microorganisms by opportunistic/pathogenic bacteria and fungi related to pathogen infection processes and depletion of energetic were observed. These findings suggest HPM results a degenerative cyclic pattern of EHP infection and modulates the beneficial microorganisms and associated functions. These findings highlight the importance of beneficial gut microbes in shrimp health and immunity and enables to develop strategies to prevent HPM in shrimp aquaculture.

The need for a comprehensive and coordinated approach in aquatic animal health management

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A major constraint to global aquaculture production is the loss due to diseases. Over the last four decades, the industry has expanded with diversification and intensive farming. The delicate balance that exists between the host, the pathogen and the environment is very important for health of aquatic animals. A breakdown in any one of the triads is likely to cause disturbance with the outcome being a disease outbreak. Climate change impacts can affect any one or all of the sectors of the triad: the environment, the host, the pathogen.

The economic losses due to diseases in aquaculture industry are generally colossal impacting food and nutritional security globally. Disease caused by white spot syndrome virus has resulted in maximum loss to shrimp aquaculture worldwide and in recent years, Acute Hepatopancreatic Necrosis Disease due to the bacteria, *Vibrio parahemolyticus* carrying the pir genes, has been a scourge to the already suffering industry. Not far behind is the loss in fish production due to a variety of bacteria, parasite, viral and fungal agents that affect freshwater fish. Epizootic ulcerative syndrome in fresh water aquaculture has been raising its ugly head now and then. Marine fishes have been affected by viral and bacterial disease outbreaks and that has impacted production considerably.

Identification has depended on three levels of diagnosis: Level I - Pond side observations of clinical signs, pond records; Level II - Basic laboratory based diagnosis including parasitology, histopathology, microbiology; Level III - Applications of molecular biology, immunology and other advanced techniques such as Electron microscopy, flow cytometry, microarrays etc. Antibody based methods are available but have much lower sensitivity than nucleic acid based methods. There is an urgent need for simplified but real time amplification methods such as Hand held real time PCR, Isothermal amplification, tests based on use of CRISPER technology etc.

E-consultations with experts for disease diagnosis and management, use of artificial intelligence for management of water quality, feed management and the use of drones for monitoring water quality, fish behaviour and AI based Level I diagnostics is the need of the hour. While early diagnosis is paramount, the key to successful aquaculture lies in using alternative approaches such as disease prevention by vaccination, genetic selection for higher resistance, improving the resistance in animals through use of immunostimulants, probiotics, prebiotics, phages for therapy, functional feeds, specific pathogen - free broodstock and larvae.

With regard to vaccines for invertebrates, there is a need for better understanding of the immune system. The basic question in dealing with invertebrates is "Does immunological memory exist?" It has now been proved beyond doubt that there does exist a primary response and memory responsible for anamnestic response. There are several experimental studies in shrimp on subunit and recombinant protein vaccines and the protection offered by DNA vaccines, siRNA and dsRNA molecules delivered appropriately through carriers. However they are yet to become available commercially at an affordable cost to all parts of the world where shrimp aquaculture is carried out.

Aquatic animal health and welfare is based on optimising health, minimising stress, disease risks and maintaining healthy culture environment. Significant impact on reducing disease risk has been made by advances in Biotechnology. As already mentioned, rapid molecular and immunological detection methods have been developed for the pathogens of cultured vertebrates and invertebrates. Though vaccination has been highly successful in prevention of diseases in fish, the production of vaccines for all the economically significant diseases on a commercial scale has had limitations. Innovative approaches using the genome information of the pathogen, gene function, proteomics, knock-out technologies are being constantly devised for more efficient vaccines. Above all, for vaccines to be applied in large scale, they must be made at low cost since the volume required for vaccination would be large. Mode of application is an important challenge for optimal protection .

Environmental integrity rests on practicing aquaculture in an environmentally responsible way. For this, of prime importance is to encourage restoration of habitats damaged by previous uses, identify the environmental impacts, manage adverse impacts or mitigate them to an acceptable level. Certification schemes should not be prescriptive, but set measurable benchmarks that encourage improvement and innovation in environmental performance of aquaculture. Risk assessments should follow scientific approach and promote internalisation of environmental costs considering the approach that 'polluter pays' with due regard to public interest.

The criteria must include environmental impact assessment which should be conducted before approval of aquaculture. Regular monitoring of on-farm and off-farm environmental quality must be carried out with good record keeping. It is imperative to promote efficient water and effluent management. To the extent possible, hatchery raised seeds should be used for stocking. If wild seeds are required to be stocked, it must be done so in an environmentally responsible way without deleting the natural resources. Exotic species is to be used, only when the risk to environment, biodiversity and ecosystem health has been evaluated and is acceptable. A science based risk assessment must be done in case of any GMO use and infrastructure construction and waste management to be carried out in a responsible way.

Farm location must be in areas where risk of contamination can be minimized and source of pollution can be controlled or mitigated. It is mandatory to avoid feed contaminated with pesticides, veterinary drugs, other contaminants. The responsible use of veterinary drugs, safe water for aquaculture, assessing the risks while sourcing broodstock/larvae, adoption of Good Hygienic Practice in farms (Codex Code of Practice), traceability and record keeping of inputs that may impact food safety and good personal hygiene for workers must be practiced. Monitoring the use of antibiotic is essential to prevent their indiscriminate application resulting in the development of antimicrobial resistance, a topic of great significance globally in the context of ONE HEALTH. Their use as a prophylactic must be banned as it is a major reason for the emergence and spread of antibiotic resistance.

In summary, disease outbreaks are a major constraint for aquaculture development. Technological inputs such as rapid diagnostics, vaccines, water and sediment management technologies and other recent health management tools have potential to overcome the problems. Collaboration with other disciplines such as engineering, veterinary, basic sciences, and social sciences for community welfare and development is important while keeping environmental sustainability as a primary consideration for development in aquaculture. An inter and multidisciplinary holistic approach to understand and address issues related to aquatic health management to make the industry sustainable would include diagnostics, immunology, nutrition design, genetic selection, environment and ecology, toxicology, *insilico* approach to genomics and proteomics aspects in vaccinology, host-pathogen-environment interactions and more.

Expanding the scope of sustainable marine fisheries management with multiple objectives and inclusive approach

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Introduction

Marine resources, particularly marine fisheries, are viewed as frontier for many developmental and conservation activities (World Bank, 2017). This is evident from expanding activities to sustain fisheries production and/or increase profits, combined with complex fisheries management. Many international/ regional fisheries agreements and policies stand testimony to this (FAO, 2020). In a comprehensive analysis, the World Bank (2010) has summarised that India's marine fisheries has a high potential capital value, but these values are not being fully realised. The report further states that the sector can generate greater net benefits and become a stronger engine for rural economic growth and social development in India. However, to achieve this potential, carefully implemented management plan over an extended period of time at both national and state levels must address core policy, legal, institutional and fisheries management issues. After publication of the World Bank report, the major development is the preparation of a draft National Policy on Marine Fisheries 2017 (DAHDF, 2017). The draft Policy envisages a strategized way forward to develop, harness, manage and regulate capture and culture fisheries in a responsible and sustainable manner. Initiatives on Blue Economy, which aims to capitalise on living and non-living resources are also gaining momentum (GoI, 2020).

There are many causes for the marine fisheries not yielding their full potential value. Overfishing occurs when more fish are caught than how much the fish population can replace through reproduction and growth. Gathering as many fish as possible may seem like a profitable practice, but overfishing has serious negative consequences. A basic knowledge that needs to be understood is that management measures should ensure that fishing effort is commensurate with the productive capacity of the fishery resources and their sustainable utilisation (FAO, 1996). Recently, it has been assessed that one-third of the marine fish stocks fished in India, has been overfished (Sathianandan et al., 2021). Overfishing not only affects the balance of life in the oceans, but also the social and economic well-being of the coastal communities who depend on fish for their way of life. In addition to overfishing, the fish resources are suffering mounting effects of environmental degradation, pollution and climate change (BOBLME, 2012; Vivekanandan et al., 2019). For sustaining fish resources, it is important that other species in the habitats also remain healthy. Minimising negative environmental impacts will improve the health of the ecosystems where the fishes live. Hence, for sustaining marine fisheries, it is important to leave enough fish in the sea, respect habitats of fish populations, ensure healthy oceans and maintain livelihoods of dependent human populations.

A significant shortcoming of many existing approaches to sustainable fisheries management is the narrow outlook of sustainability. Although in theory sustainability should include social, cultural, institutional, and ethical dimensions of fisheries, too often the scope of sustainability in fisheries is limited to a small set of biological and economic considerations (Stephenson et al., 2018). These limitations can be attributed to the challenges in integrating multidimensional solutions to a wide array of ever changing issues. For example, increasing environmental uncertainty due climate change, strong livelihood dependence on natural resources, and emphasis on sustained economic growth and equitability, place enormous pressures on fisheries managers to develop a management plan with a wide range of objectives (Angel et al., 2019). This is an extremely difficult situation to handle in tropical countries like India. While highly industrialised fisheries could perform with a few actors in managing the fisheries, a fishery with many types of craft, gear, fish species and smallscale fishers in different social contexts, as in India, needs a more complex management framework. A narrow approach focusing on abundance of single species that are of economic interest fails to satisfy the concerns of a host of other stakeholders. The view that fisheries management has to encompass broader scale of considerations such as environmental, societal and transboundary agenda, is becoming a conventional wisdom. It is in the interest of fisheries that the managers embrace a broader approach and recognise that adopting an inclusive approach with multiple objectives is a priority to fisheries sustainability.

India's first nine Five Year Plans from 1951 to 2001 focused on increasing fish production through technological and infrastructure development (mechanisation, building new port and landing facilities, etc), aquaculture development, and through the expansion of fishing into relatively under-utilised offshore fisheries. The tenth Plan (2002-2007) recognised that marine fisheries was facing sustainability problems, but the focus of government expenditure continued to be on technological and infrastructure development to increase production. In 2004, the Government of India brought out the first Comprehensive Marine Fishing Policy, which set the framework for sustainable development of the sector. A Working Group set up by the Government in 2011 indicated overcapacity in territorial waters of different categories of mechanised fishing vessels and suggested an optimum fleet. Being a dynamic sector, many new requirements were evident from management point of view in the last ten years. Consequently, the National Policy on Marine Fisheries, 2017 was brought out emphasising the sustainability of the resources at the core of all actions. Thus the emphasis in marine fisheries sector gradually shifted from increasing production to sustainability. However, a holistic and proactive attention to inclusive decision-making is needed across marine fisheries management and conservation.

Identifying goals and a broad spectrum of objectives

The Mission of the National Policy on Marine Fisheries 2017 states "*While keeping sustainability of the resources at the core of all actions, the policy framework will meet the national social and economic goals, livelihood sustainability and socio-economic upliftment of the fisher community and is intended to guide the coordination and management of marine fisheries in the country during the next ten years*" (DAHDF, 2017). From the Mission Statement, the need to identify a broader spectrum of goals and objectives are discernible.

Taking cognisance of the Mission Statement, the following seven objectives could be identified (Fig. 1): (1) Enhancing the health of marine living resources by promoting best fishing practices; (2) Restoring and conserving the fish habitats and ecosystems; (3) Investing in fisheries development for enhancing economic wealth; (4) Improving the well-being and equity among fishing communities; (5) Promoting coordination and implementation of regional and global initiatives; (6) Generating and managing fisheries data, information and knowledge; and (7) Engaging stakeholders at multiple levels. The seven objectives, cover three goals of fisheries management, namely ecological sustainability (Objectives 1 & 2), socio-economic prosperity (Objectives 3 & 4) and good governance (Objectives 5, 6 & 7). Objectives 6 and 7 are common through the first five objectives.

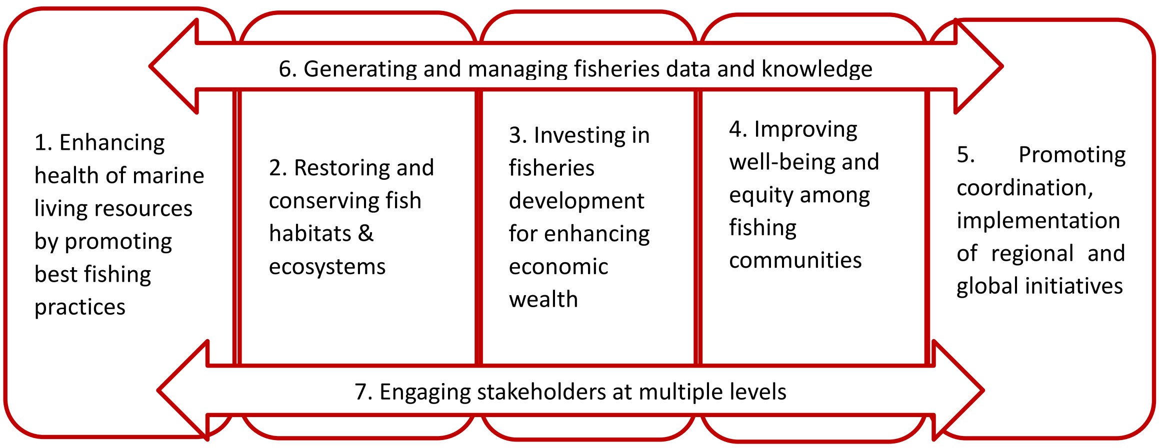

Fig. 1. Suggested objectives of marine fisheries management in India

Aligning objectives with issues

Identifying objectives in fisheries needs aligning with issues. Issues are dynamic and change over time with the development of fisheries. Issues are the areas of concern, a condition to be improved, that need to be identified. While objectives are the ones what are intended to be achieved, issues build the background of objectives. To achieve the objectives, actions have to be taken to address specific issues. Hence, it should be checked that issues and objectives are interconnected and interrelated. Objectives are often broad-based, but the issues are specific. One objective may address many issues, and one issue may saddle through more than one objective. The key management issues and potential management measures have been listed in Table 1.

Table 1. Key management issues and opportunities, potential management measures to resolve the issues

General issue	Specific issue	Current management measure	Recommended measure
Objective 1. Enhancing health of marine living resources by promoting best fishing practices			
Fishing leads to potential overfishing	Too many boats than required to realise MSY (DAHDF, 2018)	Boat registration, licensing	Regulate the number of boats; Strengthen licensing; Preparation of National Plan of Action – Fishing capacity
	Excess fishing effort in inshore waters	Inshore waters reserved for artisanal boats	Strengthen effort to divert fishing to offshore waters
		Closure of fishing for 2 months	Closure of fishing for 2 months to continue
		Subsidies for capacity enhancement	Redistribute capacity enhancing subsidies to reward good practices
		Other input control measures like closed areas, MPAs in place in selected locations	Strengthening input control measures; introduce output control measures like TAC and ITQ

	Some species need specific management plans.	Except 'pelagic fisheries' (in Kerala) and 'hilsa fisheries' (in West Bengal), all species are considered under a common management plan.	Developing and implementing specific management plans for iconic species such as oil sardine, Indian mackerel, hilsa, sharks and tunas
Bycatch	Large amounts of Juveniles caught before spawning and at sub-optimal size leading to growth overfishing and realising low value, particularly by trawlers	Space/Time closures and Minimum Legal Size (in some States) exist	Strengthening current measures; identification of areas and times of breeding and nursery; gear modification by engaging industries (mesh size, panels, grids) to exclude juveniles and under-sized fish; engaging the buyers particularly aquaculture feed plants
	Incidental capture of Endangered, Threatened or Protected species (ETP)	Space/Time closures exist; Bycatch Reduction Device being attempted.	Strengthening current measures; identification of areas and times of breeding and nursery; gear modification (mesh size, panels, grids) to exclude ETP species; reducing mortality through on-deck release practices; incentive to fishers to reduce mortality; Preparation of NPoA – Sharks, Marine Mammals
Illegal, Unreported, Unregulated (IUU) fishing	Fishing boats operating illegally, not reporting or unregulated; weak Monitoring, Control & Surveillance	Boat registration and licensing system exist; Automatic Identification System (AIS) installed in some boats	Strengthening existing measures; legislation for fishing beyond 12 nm; MCS to be strengthened and enforced by installing AIS in all mechanised boats, introducing electronic monitoring including Vessel Monitoring System, standard boat construction licences, skipper licenses, on-board logbooks and observer programmes; preparation of NPoA – IUU Fishing
Negative impacts of climate change on fish availability	Increasing sea surface temperature, ocean acidification may displace fish populations	Some existing measures like seasonal closure will help partial recovery of fish stocks.	Reducing the negative impacts of other stressors (listed above) will help recovery of fish stocks; accessibility of smallscale fisheries to fish stocks to be improved by disseminating Potential Fishing Zone and installation of artificial reefs; closed fishing areas will be effective.
Objective 2. Restoring and conserving the fish habitats and ecosystems			
Habitat impacts	Fishing, particularly trawling affects and disturbs benthic habitats	Two months' closure of trawling	Continuation of current measures; conversion of trawlers into longliners; government/private buy-back of trawlers; installation of artificial reefs to discourage trawling; modification of trawl gear to reduce bottom contact
Loss and degradation of areas of critical habitats	Loss in coral reef, mangrove, and seagrass areas	Restoration programmes exist	Strengthening mangrove and sea grass plantation and coral reef restoration programmes

Effects on ecosystem structure and function	Fishing Down Marine Food Web	Closed areas like MPAs	Increasing the number and extent of closed areas; balanced harvesting; adopting ecosystem approach to fisheries management (EAFM)
Ghost fishing	Gear abandoned in the sea continue to fish, wastefully	No measure as of now	Gear marking to trace owners of abandoned gears; incentives to fishers to retrieve abandoned gear
Pollution and water quality	Sewage-borne pathogens and organic load entering coastal waters	Sewage treatment protocol exists	Setting specific targets and implementing strict measures to reduce discharge of untreated sewage to rivers and seas, at least primary treatment of all waste water by participation and industries and environmental groups
	Dumping and accumulation of oil, solid waste and marine litter	Solid waste and plastics collection and disposal being implemented	Developing/strengthening management plans to address issues of oil spill, solid waste and marine litter; enforcing pollution management measures strictly
	Increasing nutrient load in coastal waters leading to eutrophication	Organic farming encouraged in agriculture and aquaculture	Applying nutrient modelling to reduce nutrient load
Carbon footprint by fishing boats	Increasing CO_2 emission due to increasing boat size and fish scouting time	Technologies to reduce fuel consumption and use of alternative energy in experimental stage.	Research and development of viable, cost-effective alternative technologies
Objective 3. Investing in fisheries development for enhancing economic wealth			
Offshore fish resources not fully utilised	Infrastructure facilities and human skill for offshore fishing inadequate	A few States like Tamil Nadu have initiated offshore fishing programmes	Re-designing craft and gear types to harvest specific resources like the tunas; developing skills of fishers in on-board handling, processing and marketing
Landed catch does not realise full economic benefits	Not many diversified fish products	A few value added products developed	Scope for introducing more value added products (like canned products, sashimi, etc) by establishing canneries, cottage-level production of value added products
	Deterioration in the quality of fish along the value chain	Fish storage facilities exist along the value chain, but needs improvement	Improving the facilities in boats, fishing harbours and markets for on-board and post-harvest fish preservation and handling; improving cleanliness and hygiene of fishing harbours and markets
	Domestic marketing system not modernised	Fisheries Corporations making efforts to improve markets and marketing.	Improving the fish markets; marketing system, expanding online marketing; assurance of seafood quality
Non-tariff trade barrier for export of marine products	Restrictions imposed by other countries to trade fisheries products with India, raising environmental concerns	India's negotiations in WTO; Introduction of bycatch reduction devices in fishing boats (like Turtle Excluder Device)	Government-sponsoring of eco-labelling, certification and traceability of fish products; reducing bycatch by following appropriate methods and technologies

Objective 4. Improving the well-being and equity among fishing communities			
Relatively low standard of living and working conditions of fishers	Insecure income, poor and hazardous condition in fishing boats, exploitation of migrant workers	Centrally-sponsored schemes exist for housing, compensation during closed season, group insurance.	Promoting and following internationally accepted human rights standards; addressing structural issues; developing and reforming laws and policies focusing on vulnerable and marginalised people.
Fishers and coastal communities are often not participating in decision making and management	Inadequate representation of fishers' concerns and needs	Coastal communities and fishers consulted for management and policy decisions.	Engaging coastal communities in research, policy and management processes; promoting co-management across the supply chain; appropriate fisheries legislation to be put in place for inclusive, participatory fisheries governance and resource management through co-management approach.
Gender inequality	Disparity in working condition for women, no access and control over resources	Governments have introduced schemes for women in fish vending	Establishing accessibility for women to credit and finance; empowering equal participation/ leadership in fisheries value chain including consultative and decision making process; training women in on-line retail marketing
Fishing related fatalities at sea	Ignoring safety-at-sea; accidents at sea cause injuries and loss of lives and boats	Sea safety implements available in a few boats	Inculcating safety culture; designing and construction of boats in approved boat building yards; ensuring operational safety at times of natural hazards; developing government mechanism for regularly assessing safety protocol followed by fishing boats; improving communication facilities between boats and shore.
Vulnerability of fishing villages to natural hazards, climate variability and climate change	Increasing intensity and frequency of cyclones, increasing sea level, and net erosion of coastal areas	Sea walls and cyclone shelters constructed in selected villages along the coastline.	Government's commitment to adapt to sea level rise by following shoreline protection strategies; mapping the vulnerable coastal areas and developing location-specific adaptation strategies
Objective 5. Promoting coordination and implementation of regional and global initiatives			
Transboundary nature of issues	Initiatives to manage transboundary fish stocks are not effective.	Many regional and global organisations and guidelines available for managing transboundary stocks.	Strengthening coordination and implementation of agreed management actions on a regional scale
	Need to recognize and improve implementation of global initiatives	India is a signatory to many regional and global fisheries voluntary and binding guidelines	Developing action plan for implementing Ecosystem Approach to Fisheries Management, Code of Conduct for Responsible Fisheries, Guidelines on Smallscale Fisheries, Marine Spatial Planning, etc.
	Regulating fishing capacity, and protecting fish species	Regional Plans of Action available to address specific issues	Preparation and adopting of National Plan of Action – Sharks; Fishing Capacity; IUU Fishing

Objective 6. Generating and managing fisheries data, information and knowledge			
Fisheries data requirements	High resolution data on many fisheries parameters such as actual catches and fishing area not available	CMFRI, State Departments and MPEDA collect data on landings	Introduction and submission of onboard logbooks by fishers; promoting electronic logbook using smart phones, tablets, etc.
	Data accuracy inadequate	CMFRI and State Departments collect data on landings	Ensuring compliance for filling correct data by regular portside monitoring; introducing observer programmes in large fisheries; supporting data collection by legislation
	Results on stock assessments not available on regular basis	CMFRI conducts stock assessment studies	Strengthening stock assessments regularly from data on catch & effort; habitat, ecosystem and biological investigations; and economics of fishing.
Objective 7. Engaging stakeholders at multiple levels			
Stakeholders engagement not adequate for addressing multiple objectives	Stakeholders at different levels not given opportunity to participate in decision-making	Stakeholders provide opinion on specific management measure or on policies as and when asked for	Supporting institutional strengthening for engaging key stakeholders; networking at all levels to enable nurturing the processes related to fisheries management and environmental conservation.
	Co-management need to be strengthened	Co-management councils exist in a few States.	Encouraging and nurturing Co-management Councils and their functioning in all the States; legislative support for formalising the functioning of the Councils.

Table 1 is a toolkit of potential measures that have the capacity to address specific issues. The aim of the toolkit is to provide the resource for those involved in fisheries management decision making process. Appropriate measures will have to be selected for a specific fishery/location after identifying the issues. A tool that gives positive solution to an issue in a specific location/fishery may not yield the desired result in another location/fishery. Often it is necessary to prioritise the issues for the selected target fisheries or the location for developing a fisheries management plan. The management measures that will have the most chance of success are those that are developed with the specifics of the fishery in mind and recognition of what capacity is available to administer and enforce them, and the prospects of compliance.

Ecosystem approach to fisheries management

With improvements in fisheries research over the last few decades, evidence-based solutions are emerging forshifting the focus and/or strengthening the prevailing management measures. It would be appropriate to consider the advanced knowledge to gainfully apply to transform fisheries management into a contemporary, effective management regime. Ecosystem Approach to Fisheries Management (EAFM) offers a practical and effective means to manage fisheries more holistically (FAO, 2003). EAFM has the capacity to address multiple objectives with inclusive approach. EAFM is an extension of the conventional principles for sustainable development in general, and sustainable fisheries development in particular, to cover the ecosystem as a whole. The EAFM aims to ensure that the capacity of ecosystems to produce fish and shellfish for food, employment and livelihoods, and to provide other essential services, is maintained for the benefit of the present and future generations in the face of variability, uncertainty and natural changes to coastal environments (Heenan et al., 2015). The key features of an EAFM include: consideration of the ecological, social, and governance processes over broad spatial and temporal scales; a focus on resilience; adaptive management, co-management, institutional cooperation and coordination, and a precautionary approach. The features of EAFM facilitate managing fisheries facing multiple issues (Vivekanandan et al., 2019). EAFM represents a move away from conventional fisheries management and focuses on target species and towards decision making processes that balance ecological and human well-being with improved governance frameworks. This concept, which is relatively new to the country, needs to be adopted by the fisheries and develop management plans that not only work locally, but also fits into broader fishery/ecosystem strategies.

Conclusion

Fisheries management has been challenged to move beyond the tendency to focus exclusively on threats to fish stocks and economic viability, but to incorporate fundamental ecological and social issues. In addition, with the aspirations of blue economy in the country, it is becoming important to realise that fisheries have to increasingly share the waters with other sectors and industries. Thus, fisheries management is also challenged to incorporate considerations of other relevant activities in the marine environment in more holistic and integrated way. These changes call for consideration of fisheries as part of social-ecological systems requiring a different, interdisciplinary concept of sustainability that is broader than those focused now. There is need to adjust policies and decisions to multiple objectives and dimensions of sustainability from simplistic means to more complex and comprehensive management approaches.

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Valorization of shrimp processing byproducts

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Abstract

Shrimp has been popular for consumers due to its delicacy with nutritive value. Shrimp can be processed into different types of products, including headless shrimp, peeled and deveined shrimp, etc. During processing, cephalothorax and shell are removed and considered as wastes with low market value. Since those discards contain the valuable compounds, they can be recovered or converted to the marketable products with high value. In addition, the cost for treatment can be reduced and the environmental pollution from improper management can be minimized. Cephalothorax was used as a potential raw material for shrimp oil production using solvent as the extracting medium. The use of isopropanol/hexane mixture (1:1, v/v) rendered the shrimp oil rich in polyunsaturated fatty acids, including EPA (20:5) and DHA (22:6). It also contained a high amount of astaxanthin, making it different from general fish oil. To increase the extraction efficacy, the use of ultrasonication under the optimal amplitude and time could increase the yield, mainly due to the cavitation effect. In addition, the use of vacuum-microwave pretreatment prior to ultrasound-aided extraction process further increased the yield. Nevertheless, this ultrasonication showed the negative impact on quality of resulting oil since it induced the oxidation, as indicated by the augmented peroxide value and thiobarbituric acid reactive substances (TBARS). Therefore, the use of nitrogen atmosphere along with the selected antioxidants, tannic acid, could prevent the oxidation of extracted oil and maintain PUFA and astaxanthin.

Chitooligosaccharide (COS) is another product derived from shrimp shell chitosan. It is produced via hydrolysis of chitosan by specific enzyme, namely chitosanase or non-specific enzymes such as lipase, amylase or protease. However, chitosanase is costly and not practical for large scale production. The use of H_2O_2 or H_2O_2/ascorbic redox pair reaction could yield the COS with the superior properties with antioxidant and antimicrobial activities, which can be used as the alternative food additives. However, the latter exhibited the higher hydrolysis efficiency. COS could inhibit both gram$^+$ and gram$^-$ bacteria, either spoilage or pathogenic bacteria. COS with reducing power can be used to maintain the redness of raw tuna slices and lower the lipid oxidation. Lowered discoloration was in line with the decreased formation of metmyoglobin. Simultaneously, it could reduce the microbial growth during the refrigerated storage, thus extending the shelf life of tuna slices. Furthermore, bioactivities of COS can be markedly enhanced via conjugation with plant polyphenols such as epigallocatechin gallate (EGCG).

Overall, shrimp byproducts should be utilized fully under the concept of ‘zero wastes’, in which the potential technologies are employed to attain the active components or nutrients, which can be used as the supplement or nutraceutical for health promotion or as the preservative in perishable food such as seafoods, etc. for shelf life extension.

Seafood Exports from India – Status and Way Forward

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The Marine Products Export Development Authority (MPEDA) was set up by an act of Parliament during 1972. The erstwhile Marine Products Export Promotion Council established by the Government of India in September 1961 was converged in to MPEDA on 24th August 1972. MPEDA is given the mandate to promote the marine products industry with special reference to exports from the country.

MPEDA plays a major role in the development of seafood export from India. The various milestones achieved by MPEDA beginning with 1970 to the current year has helped to boostseafood exports. There has been a tremendous growth in Indian Seafood from early 70's to the present. The seafood export value from India increased from USD 490 million in 1990 reached a value of around USD 2 billion in 2008 and now it has attained an all time high of USD 7704 million during 2021-22. The successful introduction and commercial farming of specific pathogen free (SPF) *L vannamei* (white leg shrimp or pacific white shrimp) in India has helped revive the aquaculture sector and enhance the seafood exports. At present almost 70% of the overall seafood exports by value is contributed by *L vannamei*.

The major species contributing to export are shrimp, fish, cephalopod and others. Share of capture fisheries in export is 56% in quantity and 36.5% in value whereas culture fishery contributes 44% in quantity & 63.5% in value. During 2014-15, share of capture fishery was 72.55% in quantity & 44.71% in value whereas culture fishery contributed a share of 27.45% in quantity & 55.25% in value. The share of culture fishery increased to 46.44 % in quantity and 68.06% in value in 2020-21, capture fishery share decreased to 53.56% in quantity & 31.94% in value.

The infrastructure facility for seafood sector has improved over years and there has been an increase in the processing unit from 271 numbers with 2661.16 MT in 1990 to 621 units with 35928.65 MT in 2022. There are 1316 number of exporters and 621 processing unit registered with MPEDA. The processing plants have a total installed capacity of 35,928 MT/ day.

Marine products exports from India reached all time high of US$ 7,740 million during 2021-22, despite the heavy odds faced by the sector. India now occupies the 4th position in seafood export world over. The seafood export Compound Annual Growth Rate (CAGR) from India during the past decade was 8.23% compared to the 3.27 % of World Seafood Trade. India's share during 2020 is around 4% in world export.

India has exported to 121 countries during 2021-22 and US remained as top destination for Indian seafood with a share of 43%. China, EU and Japan are the other major destinations of exports. The higher exports have been achieved despite the heavy odds faced by the sector on account of increase in freight rates, container shortage, trade barriers imposed by China on account of Covid testing, lower air connectivity affecting live/chilled fish export etc.

The Government of India has proposed to enhance the seafood export and achieve a seafood export of USD 14 Billion (Rs. 1.0 lakh Crore) by 2025. Achievement of this steep target will require bigger focus on augmenting production/productivity in shrimp culture sector, diversification of export oriented aquaculture, tapping distant water fishery resources, reducing post harvest losses in marine sector, enhancing unit value through value addition, addressing trade barriers, addressing antibiotic, biosecurity, sustainability, certification and traceability issues, brand promotion and overarching export strategy.

Implementation of Food Safety in Aquaculture Value Chain in India

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With an increasing demand for seafood combined with the dwindling marine catches, the world is looking at the aquaculture sector to provide sustainable and safe seafood. The aquaculture sector in India is on a meteoric rise and will continue to grow over the next several decades. However, the consumers within the country and across the world are becoming conscious about food safety and Governments are imposing stricter measures on exporting countries to ensure food safety. From the aquaculture production standpoint, Global Good Aquaculture Practices (Global GAqP) is the main standard that is modified at regional level e.g. ASEAN GAqP or at a country level. The GAqP documents are a set of guidelines for the aquaculture value chain actors including farmers to produce safe products.

Depending on the country, economic condition of the farmers, market conditions among other factor dictate the acceptance and implementation of GAqP. Most importantly, the value derived by farmers upon implementation of GAqP is a leading factor in acceptance/implementation of GAqP which is otherwise seen as a financial and time burden. Aquaculture farmers, barely making any profits, are looking for financial incentives for adopting such measures which in certain cases the market fails to provide. Another factor to be considered is the governance of aquaculture sector in India which falls under two categories viz, fragmented, and structured. The later, structured category involves a certain level of vertical integration wherein one company owns multiple value chain steps including the hatchery, feed mill, farms, processing plant as well as export operations. Such vertical integration allows a company to implement quality and food safety standards throughout their company and reap benefits from it. On the contrary, the fragmented aquaculture sector which includes individual farmers may compete in the open markets and often opt for cheaper feed, seed, medicine, and lower price for their product. It becomes increasing difficult for individual farmers to implement food safety standards such as GAqP on their farms.

It becomes important to develop standards such that they are user friendly while ensuring high quality aquaculture products. Through this presentation, I propose the development of three tiers of GAqP standards based on implementation. Tier 1 can include a basic set of standards that will improve food safety without significant investment of time, money and other resources on behalf of the farmer. Tier 2 will include slightly higher levels of standards and Tier 3 will include the full suite of GAqP standards in addition to any other standards being requested by an importing country. A seal of quality based on the tiers can be provided to the farmers and to their products such that consumers can identify the product and the safety associated with it. One of the important aspects of implementing GAqP is auditing in the form of announced/unannounced third-party audits.

Implementation of food safety practices will be highly valuable for the Indian aquaculture sector in maintain its leadership in the world!

International standards and guidelines in Seafood Safety and Quality

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According to FAO estimates, global fish production in 2018 reached 179 million tonnes and the first sale value of this is estimated to be $410 billion. Of this, 82 million tonnes came from aquaculture with an estimated value of $250 billion. Globally, fish provided more than 3.3 billion people with 20% of their protein intake. Primary production provided employment to about 60 million people. Fish is a highly internationally traded commodity. In 2018, thirty eight percent of fish production or 67 million tonnes valued at $167 billion entered international trade. China (14%) is the leading exporter followed by Norway (7%), Vietnam (5%) and India (4%).

Fish safety and quality are major issues in international trade. International trade rules are guided by the World Trade Organisation (WTO). WTO member countries have signed the Agreement on the Application of Sanitary and Phytosanitary (SPS) Agreement in 1995. The agreement encompasses plant health, animal heath and food safety. The agreement recognizes the sovereign rights of countries to take measures to protect human, animal or plant life or health and these measures may take many forms eg requirement that products should come from disease-free areas or be free from certain specified pests or be free from certain chemical additives or setting maximum allowable level for residues of pesticides or for levels of certain contaminants like heavy metals. But some of these measures can be barriers for trade. The purpose of SPS agreement is to ensure that while countries retain the sovereign right to take measures to protect consumers, animals and plants in their territory, these measures are not arbitrary and implemented to shield domestic producers from economic competition but are based on science and risk assessment.

Some of the key features of WTO SPS Agreement are:

Basic rights and obligations: Member countries have right to take sanitary and phytosanitary measures to protect human, animal, plant health and life, but these measures should not be arbitrary or unjustifiably discriminate between Members where identical or similar conditions prevail. The measures should be based on scientific risk assessment and applied only to the extent necessary.

Harmonisation: In order to ensure that the sanitary and phytosanitary measures are harmonised on as wide a basis as possible, the members should base their standards on international standards, where they exist. Codex Alimentarius Commission, a joint FAO/WHO body sets standards for food safety, while World Animal Health Organisation (Office International des Epizooties, OIE) sets standards for animal health and International Plant Protection Convention (IPPC) for plant health.

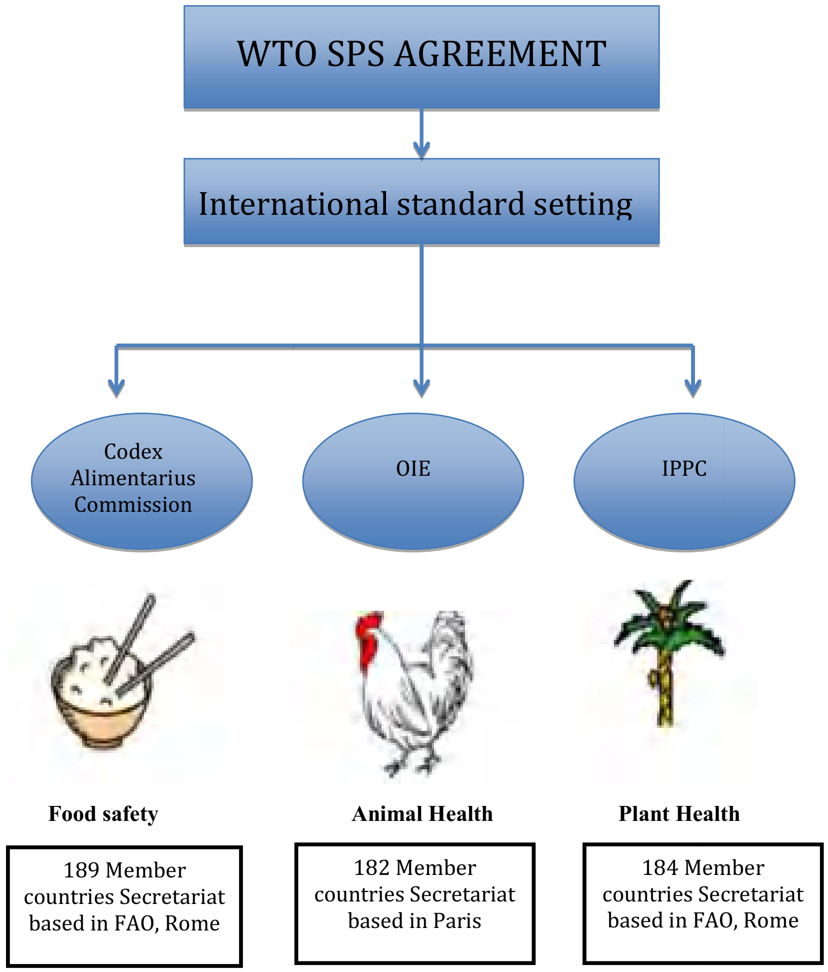

Fig 1. International standard setting bodies

Equivalence: Members may use different methods to achieve the required level of protection. Members should recognise measures adopted by other members as equivalent as long as they are able to achieve the same level of protection.

Assessment of risk and determination of appropriate level of protection: SPS measures should be based on risk assessment carried out in accordance with guidelines from International organisations (Fig 1). Codex Alimentarius Commission has developed guidelines for food safety risk assessment. OIE has guidelines for conducting animal health risk assessment and IPPC has guidelines for pest risk assessment. Risk assessment will be the basis for determination of the appropriate level of sanitary and phytosanitary protection.

Transparency: Members need to notify other members through WTO SPS site about the SPS measures and any changes brought about. Except under emergency situations, members should allow reasonable time interval between publication of SPS regulation and its entry into force to allow time for the producers in exporting countries to adapt their method of production to the requirement of the importing country.

Members should establish enquiry points, which would be responsible for provision of information on SPS measures, risk assessments and their outputs.

Control, inspection and approval procedures: Members need to notify the SPS control, inspection and approval procedures to other member countries. Members should implement these without causing undue delay and without discriminating between domestic and imported products.

Codex Alimentarius Commission standards are based on science

International standard setting bodies, Codex Alimentarius Commission, OIE and IPPC are made of representatives from all member countries and these organisations base their standards on international risk assessments performed by FAO/WHO or OIE. The Joint FAO/WHO Expert Meeting on Microbiological Risk Assessment (JEMRA) is involved in microbiological issues, Joint FAO/WHO Expert Committee on Food Additives (JECFA) deals with food additives, contaminants and residues of veterinary drugs; Joint FAO/WHO Meeting on Pesticide Residues (JMPR) deals with pesticide risk assessment. These international risk assessment bodies consist of global experts who provide independent risk assessment to FAO and WHO.

JEMRA risk assessments have helped address some of the international trade barriers. For example, in the 90's, countries reporting the prevalence of cholera to WHO (as per international requirement, used to face trade bans for fishery products though no contamination was detected in imported seafoods. To address this, the JEMRA Risk assessment for Choleragenic *Vibrio cholerae* O1/O139 in warm water shrimp in international trade (https://www.fao.org/documents/card/en/c/720e0ee6-fd07-5c6b-99d5-520b6a7d9eed/) looked at the risk of transmission of the disease cholera through imported warm water shrimp. The data from countries like Peru showed that even when there are ongoing outbreaks of cholera in a country, adopting good hygienic practice and Hazard Analysis Critical Control Point (HACCP) based food safety management can ensure that shrimp meeting international safety and quality requirements can be produced. This risk assessment showed that the risk of transmission of cholera through warm water shrimp in international trade is extremely low.

Codex approach to food safety is that food safety cannot be achieved by setting standards, inspecting and rejecting non-compliant products. Codex recommends preventive approach, where food business operators implement good hygienic practices all along the food chain. To guide food business operators, Codex has General Principles of Food Hygiene (CXC 1-1969 updated 2020) and sector specific codes eg Code of Practice for Fish and Fishery Products (CXC 52-2003 updated 2019). Both these Codes cover HACCP and these will be helpful to implement good hygienic practices on board fishing vessels, in aquaculture farms, in landing centers, fish transport, processing, packaging, retail and storage.

For those interested in detailed aspects of fish safety and quality, the FAO Aquaculture and Fisheries Technical Paper 574 – Assessment and management of fish safety and quality (https://www.fao.org/in-action/globefish/publications/details-publication/en/c/338305/) would be very important resource. This provides detailed information on biological, chemical hazards in seafood and how to manage them. This Technical paper will also be useful academic institutions and researchers since large number of references are cited for each chapter.

Fish for Nutritional Security

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Introduction

India ranks second in terms of population in the world. In terms of area, it is the seventh largest country with an area of 3.288 mi km^2. India has vast agro-ecological diversity across its length and breadth ranging from the Himalayas, the Thar desert, Gangetic delta and the Deccan Plateau. India is the world's largest producer of milk, pulses and jute, and ranks as the second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton. It is also one of the leading producers of spices, fish, poultry, livestock and plantation crops. Worth $ 2.1 trillion, India is the world's third largest economy after the US and China. Although India is the leading agricultural producer, the hunger and malnutrition are still the major problem faced by majority of India's population. The recent 2021 Global Hunger Index (GHI) report, which is based on indicators like a) undernourishment (based on calorie intake); b) Child wasting (proportion of children under five years of age who have low weight for height — representative of acute under-nutrition); c) Child stunting (proportion of children under five years of age who have low height for age — representative of chronic under-nutrition); and d) under-five mortality (deaths among children under five years of age) indicates 101st rank for India out of 116 countries, which has put our country in the worst performing nations. Although we have bettered this GHI scoreover the year from 38.8, 37.4, 28.8 during 2000, 2006, 2012, respectively to 27.5 in 2021, but still much is to be done to improve the status.

Hunger in simple word is the desire to consume food. But when human body gets used to having less food than necessary for healthy development, and after a while does not even demand more food. If people have always eaten less than their needs, their bodies adjust to less food. It is also possible to fill up the stomach with non-nutritious food, which does not provide the required calories or micronutrients like vitamins, iron, iodine, zinc, and calcium that are required in tiny amounts. Another situation could be when the essential calories, proteins, fats and micronutrients are not absorbed in the body due to ill-health and poor hygiene. In all such cases hunger is not articulated. This kind of hunger may be termed chronic or endemic hunger, as it is not felt, recognised or voiced by children or adults. Chronic hunger does not translate into hunger pains, but into subtle changes in the way the human body develops. For instance, an underfed child may be underweight or stunted for his or her age, if not consuming sufficient calories and fats. If the child is deficient in Vitamin A, he or she will not be able to see properly at dusk ("night blindness"), and respiratory ailments may also occur. In severe Vitamin A deficiency, the child may go totally blind. In the case of iron-deficiency anaemia, the child will slow down both mentally and physically, perform poorly in school and experience chronic tiredness. In the case of iodine deficiency, there will be mental retardation. In its severe form, a goitrous lump may grow at the base of the neck. Thus, prolonged hunger means that a predetermined "physiological requirement" or "human potential", defined in terms of norms for calorie and other essential nutrients and growth standards, is not reached.

Malnourished population accounts to 15.3% in India, which is down from 19.6% in 2005-07. Child stunting is 34.7% in India in 2020 which is improved from 54.2% in 2000. Child mortality, which is currently at 3.4% compared to 9.2% in 2000 is still a major concern in this current age. Wasting, which is reported 17.7%, is still highest in the world which is alarming as it has not changed from last 2 decades. The available data indicates, India is home to nearly 195 million undernourished people and it shares a quarter of the global hunger burden. Nearly 47 million or 4 out of 10 children in India are not meeting their full human potential because of chronic undernutrition or stunting. Stunting has consequences such as diminished learning capacity, poor school performance, reduced earnings and increased risks of chronic diseases. The impacts are multi-generational as malnourished girls and women often give birth to low birth-weight infants. There has also been an increase in the prevalence of overweight and obesity in children and adolescents in India, which has life-long consequences of non-communicable diseases in adulthood. Although India has moved away from dependence on food aid to become a self sufficient and exporter of many agricultural commodities, much more has to be done still to improve the prevailing alarming situation of poverty and malnutrition. Although Indian Government over many decades has introduced food security, anti-poverty programmes, doubling farmers income and e-marketplace, there is an urgent need to shift the focus from quantity to quality. Government schemes mainly aims to supply the food ration to the poor to overcome their hunger, but such schemes should focus move on nutritional value of such food instead of merely meeting calorie requirement. Fish and fishery products can be one of the best options to overcome hunger with the advantage of ensuring nutritional security.

Seafood has long been an important part of human diets, and increasingly a major source of economic value. Globally, fish accounted 6.7% of all protein consumed by humans, as well as offering a rich source of omega-3 fatty acids, particularly EPA and DHA, vitamins, calcium, zinc and iron. Globally, fishery products accounted for 1% of all global merchandise trade in terms of value, representing more than 9% of total agricultural exports. Worldwide exports accounted $150 billion in 2017, up from $8 billion in 1976. Developing countries accounted for 55% of fishery exports, providing higher net trade revenues than meat, tobacco, rice and sugar combined. The Indian fish and seafood industry touched an all-time high in the most recent years, with an annual export value of 7.08 billion USD in 2017-18 by exporting 13,77,244 tons of fish. The Indian seafood export found its largest market in the United States followed by South East Asia and the collective members of the European Union. Apart from its demand in export markets, huge demand exists in the domestic market as well. According to UN FAO, global aquaculture production is anticipated to exceed the 100 million tonne mark for the first time in 2025 and to reach 102 million tonnes by 2026 which poses further opportunity to diversify fishery products. India is on par with global trend in fish production. India ranks 2nd in aquaculture fish production and 6th in capture fish production. Fish export from India has seen an increasing trend with many decades and at present 1.37 MMT of fish is being exported worth US $ 7.08 billion.

There exists a great demand for seafood in international market due to its proven health benefits. Seafood business not only provides foreign exchange it also helps in ensuring nutritious food, employment to millions of people, many of whom are below the poverty line. As per FAO (2018), the world fish production in 2016 has reached 171 million tonnes and 88% of this was used for direct human consumption. Of the total fish produced, aquaculture represented 47%. Global sale value of fisheries in 2016 was estimated at US$ 362 billion of which US $ 232 billion was contribution from aquaculture production. The value of global fish exports in 2017 was USD 152 billion and 54% of this was originating from developing countries, indicating the contribution of seafood export to the building of nations. Nearly 57 million people are engaged in the primary fish production sector, a third of them in aquaculture. Of all the global merchandise trade, fishery products accounted for one percent in terms of value, representing more than 9% of total agricultural exports. Export of seafood is one of the major foreign exchange earner in developing countries, it accounts to over USD 80 billion, providing higher net trade revenues than meat, tobacco, rice and sugar combined. The per capita consumption during 2016 reached 20.3 kg and is expected to increase further. On an average, fish provides nearly 6.7% of all protein consumed by human beings. Although per capita availability of fish is 20.3 kg, it is not consumed uniformly throughout the world. According to consumption patter, countries are categorized into 6 groups and some countries representing this groups are given in the table 1 below.

Table. 1 Categories of countries as per fish consumption

Categories	Fish consumption level (kg/year)	Counties
I	< 5	Afghanistan, Algeria, Bolivia, Botswana, Ethiopia, Iraq, Kazakhstan, Madagascar, Mangolia, Nepal, Niger, Pakistan, Sudan
II	5 – 10	Argentina, Brazil, Columbia, Ecuador, India, Iran, Middle African countries, South Africa, Tanzania, Uruguay, Venezuela
III	10 – 20	Angola, Belarus, Belgium, Chile, French Giana, Luxembourg, Namibia, Netherlands, North Korea, Mexico, Poland, Saudi Arabia, Ukraine
IV	20 – 30	Australia, Canada, Guyana, New Zealand, Peru, Russia, United Kingdom, United States of America
V	30 – 50	Cambodia, China, Denmark, Finland, France, Indonesia, Japan, Spain, Sumatra, Sweden
VI	> 50	Greenland, Iceland, Malaysia, Myanmar, Norway, Portugal, South Korea

Fish in Human Nutrition

The fisheries and aquaculture sector is crucial for improving food security and human nutrition. The quantity of fish consumed and demand is increasing continuously. Aquaculture is considered as the world's fastest growing food production industry. Aquaculture has provided more fish for human consumption than capture fisheries, and by 2030 it is estimated that 60 % of the fish consumed by human will be from aquaculture. Increasingly intensive aquaculture production methods, with greater use of crop-based feedstuffs and lower fishmeal and fish oil inclusion rates, are likely to influence the nutrient content of farmed aquatic products. A focus on the nutrient content of farmed aquatic foods is especially important where they have a key role in food-based approaches to food security and nutrition. The awareness about the fish as a part of healthy diet is well accepted by the majority of the population. In addition to providing essential nutrients at affordable price, fish also contributes to the food and nutritional security of poor households in developing countries. Fish can be considered as a treasure store of nutrients. It provides more than 20 % of the average per capita animal protein intake for 3 billion people, and more than 50 % in some less developed countries. Fish and fish products are excellent sources of high-quality protein; bioavailability of protein from fish is approximately 5-15 % higher than that from plant sources. Fish contains all the amino acids essential for human health.

Many fish (especially fatty fish) are a source of long-chain omega-3 fatty acids, which contribute to visual and cognitive human development, especially during the first 1000 days of a child's life. The fat content and fatty acid profiles of farm raised fishes affected by the feed used in culture practice. Though the fish consumption has increased, people are obtaining smaller amounts of omega-3 fatty acids from aquatic foods, because these fats are more prevalent in marine fishes than in freshwater fish. Fish also provides essential minerals such as calcium, phosphorus, zinc, iron, selenium and iodine as well as vitamins A, D and B, thus helping to reduce the risks of both malnutrition and noncommunicable diseases which may co-occur when high energy intake is combined with a lack of balanced nutrition. Nutritional content is especially high in small fish species consumed whole and in fish parts that are not usually consumed (such as heads, bones and skin) which are having lower economic value. It is desirable to increase the production and consumption of small fish and to find ways of transforming the non-consumed parts into nutritionally rich products.

There remains considerable scope to increase the amount of nutrients derived from fish for human consumption by reducing post-harvest losses, especially from capture fisheries; by more efficient use of fishmeal and fish oil and in animal (especially aquaculture) feeds; and by improved feed formulations for farmed fish and crustaceans. The fish industry often only extracts fillets for human consumption consigning nutritious co-products to be used for animal feeds instead of exploring their use in tackling micronutrient deficiencies. Fish processing co-products, such as fish carcasses, which are increasingly used to produce fishmeal and fish oil, represent an underutilized source of nutrients and micronutrients for human consumption. The fishmeal and fish oil content of aquaculture feeds can be reduced without compromising the nutrient content of farmed aquatic products. Improvements in feed formulations and in feed manufacture, combined with better on-farm feed management, can hugely reduce the quantities of feed (and thus fishmeal and fish oil) used per kilogram of farmed aquatic food produced.

The FAO/INFOODS Global Food Composition Database for Fish and Shellfish (uFiSH) includes a complete nutrient profile (minerals, vitamins, amino acids and fatty acids) for 78 species in raw, cooked and processed forms. The data were extracted from 2630 food records from 250 data sources and compiled following international FAO/INFOODS (International Network of Food Data Systems) standards. Such information is much usefull to have better understanding the nutritional value of fish.

Nutritional Value of Fish and Shellfish

Fish Proteins

Proteins are building blocks of the body. Our body needs around 2,000-2,500 calories every day, and 10 to 35 per cent of the daily intake should be in the form of protein. Fish and shellfish are excellent sources of protein. A 100 g cooked serving of most types of fish and shellfish provides approximately 18-20 g of protein, or about a third of the average daily recommended protein intake. The recommended dietary allowance (RDA) of protein for human male and female adults is in the range of 45-65 g day. In accordance with this, an intake of 100 g of fish would contribute 15-25% of the total daily protein requirement of healthy adults and 70% of that of children. The fish protein is of high quality, containing an abundance of essential amino acids, and is very digestible by people of all ages. Both finfish and shellfish are highly valuable sources of proteins in human nutrition, supplying approximately 7.9% of the world's protein requirements and 15.3% of the total animal protein.

The protein content of fish flesh, in contrast to the fat content, is highly constant, independent of seasonal variations caused by the feeding and reproductive cycles, and shows only small differences among species. The approximate protein contents of the various finfish and shellfish groups are given in the following table.

Fish group	Percentage
White finfish	16–19
Fatty finfish	18–21
Crustaceans	18–22
Bivalves	10–12
Cephalopods	16–18

Fatty finfish and crustaceans have slightly higher than average protein concentrations. Bivalves have the lowest values if the whole-body mass is considered (most of them are usually eaten whole), whereas values are roughly average if specific muscular parts alone are consumed; this is the case with the scallop, in which only the adductor muscle is usually eaten. Fish proteins, with only slight differences among groups, possess a high nutritive value, similar to that of meat proteins and slightly lower than that of egg. It is worth pointing out the elevated supply, relative to meat, of essential amino acids such as lysine, methionine, and threonine. In addition, owing in part to the low collagen content, fish proteins are easily digestible, giving rise to a digestibility co-efficient of nearly 100.

Essential amino acids in fish and shellfish (g/100g)

Fish group	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Valine
Finfish	**5.3**	**8.5**	**9.8**	**2.9**	**4.2**	**4.8**	**1.1**	**5.8**
Crustaceans	**4.6**	**8.6**	**7.8**	**2.9**	**4.0**	**4.6**	**1.1**	**4.8**
Molluscs	**4.8**	**7.7**	**8.0**	**2.7**	**4.2**	**4.6**	**1.3**	**6.2**

Fish lipids

In fish, depot fat is liquid at room temperature (oil) and is seldom visible to the consumer; an exception is the belly flaps of certain fishes mainly farm arose. Many species of finfish and almost all shellfish contain less than 2.5% total fat, and less than 20% of the total calories come from fat. Almost all fish has less than 10% total fat, and even the fattiest fish, such as herring, mackerel, and salmon, contains no more than 20% fat. In order to obtain a good general idea of the fat contents of most finfish species, flesh color might be considered. The leanest species, such as cod and flounder, have a white or lighter color, whereas fattier fishes, such as salmon, herring, and mackerel, have a much darker color.

The triacylglycerol depot fat in edible fish muscle is subject to seasonal variation in all marine and freshwater fishes from all over the world. Fat levels tend to be higher during times of the year when fishes are feeding heavily (usually during the warmer months) and in older and healthier individual fishes. Fat levels tend to be lower during spawning or reproduction. When comparing fat contents between farmed and wild-caught food fish, it should be remembered that farmed species have a tendency to show a higher proportion of muscle fat than their wild counterparts. Also, the fatty acid composition of farmed fish depends on the type of dietary fat used in raising the fish.

Omega-3 PUFA in Fish and Shellfish

The PUFA of many fish lipids are dominated by two members of the omega-3 (n-3) family, C20:5 n-3 (EPA), and C22:6 n-3 (DHA). They are so named because the first of several double bonds occurs three carbon atoms away from the terminal end of the carbon chain. All fish and shellfish contain some omega-3, but the amount can vary, as their relative concentrations are species specific. Generally, the fattier fishes contain more omega-3 fatty acids than the leaner fishes. The amount of omega-3 fatty acids in farm-raised products can also vary greatly, depending on the diet of the fishes or shellfish. Many companies now recognize this fact and provide a source of omega-3 fatty acids in their fish diets. Omega-3 fatty acids can be destroyed by heat, air, and light, so the less processing, heat, air exposure, and storage time the better for preserving omega-3 in fish. Freezing and normal cooking cause minimal omega-3 losses, whereas deep frying and conditions leading to oxidation (rancidity) can destroy some omega-3 fatty acids. Fish lipids, especially PUFA are known to reduce risk of heart disease. Eating fatty fish is linked to reduction of heart attack in 15% of studied population. Fish is high in omega-3 fatty acids, which is essential for brain and eye development. It's recommended that pregnant and breastfeeding women get enough omega-3s but care should be taken to avoid large carnivorous fishes which may contain high mercury. Also, omega-3 fatty acids are known to combat depression both on their own and when taken with antidepressant medications. Eating at least one serving of fish per week has been linked to a reduced risk of heart attacks and strokes.

Cholesterol in Fish

Cholesterol is independent of fat content and is similar in wild and cultivated fishes. The fish and shellfish contain well under 100 mg of cholesterol per 100 g, and many of the leaner types of fish typically have 40-60 mg of cholesterol in each 100 g of edible muscle. It is known that most shellfish also contain less than 100 mg of cholesterol per 100 g. Shrimp contain somewhat higher amounts of cholesterol, over 150 mg per 100 g, and squid is the only fish product with a significantly elevated cholesterol content, which averages 300 mg per 100 g portion. Fish roe, caviar, internal organs of fishes (such as livers), the tomalley of lobsters, and the hepatopancreas of crabs can contain high amounts of cholesterol.

Vitamins in Fish

The vitamin content of fish and shellfish is rich and varied in composition, although somewhat variable in concentration. In fact, significant differences are neatly evident among groups, especially regarding fat-soluble vitamins. Furthermore, vitamin content shows large differences among species as a function of feeding regimes. Of the fat-soluble vitamins, vitamin E (tocopherol) is distributed most equally, showing relatively high concentrations in all fish groups, higher than those of meat. However, only a part of the vitamin E content is available as active tocopherol on consumption of fish, because it is oxidized in protecting fatty acids from oxidation. Vitamin D is a fat-soluble vitamin which is required to maintain normal levels of calcium and phosphate (which are required for formation and maintenance of bones, muscle contraction, nerve signalling and cell functions). While there is no national data, but many studies have shown that prevalence of vitamin D deficiency is anywhere between 55 to 90 per cent in the country. The dietary sources of vitamin D are fish, egg yolk, fortified foods and dietary supplement. Exposure to sunlight in the morning every day is also important for formation of vitamin D3 in the body. The presence of vitamins A (retinol) and D is closely related to the fat content, and so they are almost absent in most low-fat groups. Appreciable but low concentrations of vitamin A are found in fatty finfish and bivalve molluscs, whereas vitamin D is very abundant in fatty fish.

Water-soluble vitamins are well represented in all kinds of fish, with the sole exception of vitamin C (ascorbic acid), which is almost absent in all of them. The concentrations of the rest are highly variable; however, with few exceptions, they constitute a medium-to-good source of such vitamins, comparable with, or even better than, meat. Vitamin B_{12} is important for formation of red cells, energy production during carbohydrate, fat and protein metabolism, and a healthy nervous system. Some studies have shown deficiency as high as 70-100 percent in individuals. This is primarily because many Indians are vegetarians and even those who consider themselves non-vegetarians do not consume meat every day. There are no plant sources of Vitamin B_{12}. The animal sources include liver, shellfish, salmon, trout, milk and milk products. The contents of vitamin B_2 (riboflavin), B_6 (pyridoxine), niacin, biotin, and B_{12} (cobalamin) are relatively high. Indeed, 100 g of fish can contribute up to 38, 60, 50, 33, and 100%, respectively, of the total daily requirements of those vitamins. Fatty fish also provides a higher supply of many of the water-soluble vitamins (namely pyridoxine, niacin, pantothenic acid, and cobalamin) than does white fish or shellfish. Crustaceans also possess a relatively higher content of pantothenic acid, whereas bivalve molluscs have much higher concentrations of folate and cobalamin.

Minerals

Seafood is also loaded with minerals such as phosphorus, magnesium, iron, zinc, and iodine in marine fish. The first point to note is that all kinds of finfish and shellfish present a well-balanced content of most minerals, either macro minerals or trace elements, with only a few exceptions. Sodium content is low, as in other muscle and animal origin foods. However, it must be remembered that sodium is usually added to fish in most cooking practices in the form of common salt; also, surimi-based and other manufactured foods contain high amounts of added sodium. Anaemia is a big public health concern in India. The latest National Family Health Survey (NFHS-4) data showed that the prevalence of anaemia is 53 percent among adult women, and 23 percent among adult men. Nutritional anaemia can be caused due to deficiencies of micronutrients such as iron, folic acid and vitamin B_{12}, with iron deficiency being the most common cause of anaemia. Iron is an important micronutrient which is essential for various functions including the growth and differentiation of cells, transport of oxygen, immune function, cognitive function, mental and physical growth etc. So, deficiency of iron, due to either physiological or pathological reason, can affect mental and physical growth resulting in decreased learning capacity and work productivity. Meat, fish & poultry products are good sources of iron. Foods rich in vitamin C help absorption of iron. About 17 mg/day iron is required for men and 21 mg/ day for women. Fatty variety of fishes contain more iron content compared to lean verities. Calcium forms one of the important minerals required for healthy bones. Nearly 2000mg is required for meeting daily requirement by human body and the content of Ca in fish meat varies. Dietary calcium deficiency can cause secondary vitamin D deficiency. Though India as a nation is the largest producer of milk, there is profound shortage of calcium intake in the diet with all negative consequences on bone health. In fish, its content varies with variety of fishes, and it is 10 to 50mg per 100g in white or lean variety of fishes whereas it can go as high as 10 to 200mg per 100g in fatty variety of fishes. Molluscs and crustaceans also contain higher levels in the range of 50-200 and 20-200mg/100g. Small fishes when consumed with bone results in increased amount of Ca consumption. Similarly, Zinc (Zn) is another micronutrition very essential to maintain good health. Zinc deficiency causes growth retardation, loss of appetite, and impaired immune function. Weight loss, problems with wound healing, decreased ability to taste food, and lower alertness levels can also occur. The recommended daily intake (RDI) is 11 mg for adult men and 8 mg for adult women. Molluscs, crustaceans and cephalopods are good source of Zn. Iodine is essential to make thyroid hormones. These hormones control the body's metabolism and many other important functions. The body also needs thyroid hormones for proper bone and brain development during pregnancy and infancy. iodine deficiency is the most common cause of thyroid enlargement and goitre which may result in swallowing difficulties. The recommended daily intake (RDI) of iodine is 150 µg per day for most adults. Most seafood is rich in iodine and regular consumption of seafood can prevent iodine deficiency.

Fish is rich in many important nutrients, including high-quality protein, iodine and various vitamins and minerals. Fatty fishes also contain omega-3 fattyacids and vitamin D. Eating at least one serving of fish per week has been linked to a reduced risk of heart attacks and strokes.

Experiences and Coping Strategies during COVID-19 Pandemic among Small-Scale Fishers in the Island Province of Guimaras, Philippines

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ABSTRACT

The paper describes the experiences and coping strategies related with the first wave of COVID-19 threat and the community quarantine policy by the small-scale fishers in the island province of Guimaras. As food producers, the small-scale fishers faced market-related problems such as low demand, low prices of catch and produce, and logistical problems. While the in-kind support (e.g., food provisions) received and adaptive measures (e.g., continued with fishing or adjusted harvest schedule; use of social media or delivery services in marketing) allowed them to get by during the pandemic, there is a need to develop more resilient fishing households. Short-term support can be in the form of cash, production inputs, marketing, and credit. Long-term support can include diversifying livelihood, providing savings and loan services, improving post-harvest handling and processing, including the marketing facilities, improving the modes of marketing, and promoting cooperatives.

Strengthening Science-Technology-Policy Interface for Effective Fisheries Management

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Science, policy, and technology formthe holy trinity of sustainable fisheries. Research and development, both from public and private sources, have contributed to the global progress. On the flip side, this has created a situation where research and knowledge generation has grown exponentially while knowledge assimilation remains linear, creating a gap in the science-policy interface. With global fisheries affected by multiple internal and external stressors bringing sustainability at the stake, a transition from the traditional top-down fisheries management to a modern ecosystem-based fisheries management would critically depend on bridging this gap. An effective policy should be based on available scientific evidence and should be under constant monitoring to deal with uncertainties. In this paper, we have stressed the need for strengthening the science-policy interface to meet the requirement for moving towards an ecosystem approach and the constraints in achieving the same. The scope of using information and communication technology (ICT) to streamline the science-policy interface is also discussed.

1. Introduction

The 1995 FAO Code of Conduct for Responsible Fisheries provides a clear direction that fisheries policies should be based on the best available scientific information. This position is further substantiated by growing uncertainties in the fisheries sector due to internal and external factors such as climate change. Another significant change that happened in the fisheries sector is the growing internationalization of the fisheries issues. We have more evidence now on the transboundary and connected nature of fisheries activities. Hence, although countries enjoy sovereignty in their territorial waters and sovereign rights in their exclusive economic zones (EEZ), they cannot unilaterally take fisheries positions that are at odds with global values and positions. Such a unilateral move may draw sanctions and penalties in the international market eroding any benefit from unilateral action. Internationalization implies that the fisheries management system should be evidence-based, responsible, and transparent. It has remolded the science-policy relationship in the fisheries production system from a unidirectional input-output system to the input-output-input feedback loop.

Science, policy and technology have a co-evolutionary symbiotic relationship. *Science* explores new knowledge methodically through observation and experimentation, while *technology* is the application of scientific knowledge for various purposes. In a true sense, technology is the ultimate outcome, which satiates the needs of the society, wherein the knowledge generated through science is a prerequisite. A recent macroeconomic example of the successful triangulation of science, technology, and policy relationship is obviously the management of the Covid-19 pandemic, wherein – the 'science' aided in understanding the virus and characterizing the receptors, vaccines developed were the 'technologies', and facilitating medical research, global cooperation, managing supply chain, etc., were in the '*policy'* domain.

Scientists and policymakers across the world have a complex interface when it comes to making decisions based on data and evidence. The researchers wish that their science should drive the policy and the policymakers on the other hand know well that their decisions need to be rooted on evidence to be successful, which emanates through a structured enquiry. Despite this seemingly simplistic positive interface between the scientists and policymakers, the outcome of the interactions indicates more scope for further strengthening. One fundamental element in strengthening the interface is that the scientists and policymakers must appreciate the roles and expectations of the other side.

2. Science-Policy Interface in the Marine Fisheries Sector

The new fish variety/breed and packages of practices concerning aquafarming to fish processing across the value chain of fisheries represent the 'technologies'. Each of these technologies was developed by integrating various elements of knowledge generated through scientific enquiry and the same were eventually transferred to the end-users through various support schemes by the policymakers.

In the case of marine fisheries, one such example is the identification of an agreed period for closure of the fisheries (seasonal ban) in India. Owing to the fisheries' multiverse, identifying a common period was challenging. This was achieved through the development of multi-species breeding behavior models which were then used to negotiate amongst the stakeholders and arrive at a solution acceptable to the majority of fishers. Scientists also enjoy a positive social perception and are considered impartial, which can catalyze social negotiations in case of difficult choices (e.g., creation of an MPA).

The Potential Fishing Zone (PFZ) advisories represent a case of a happy marriage between science and technology in the marine fisheries sector. The basic knowledge generated by the ecologists, biologists, oceanographers, modelers, and remote sensing and spatial experts from across the world contributed to the development of a steadystream of automated advisory to the fishers as PFZ technology.

3. Nuances of the Science-Policy Interface

Our ability to gather, analyze, and use information regarding fish stocks, the natural systems of which they are a part, and the external factors that affect them have changed dramatically over the last few decades. It is frequently stated that incorporating this knowledge into the construction of fisheries management plans would contribute to the sustainable use of marine resources. However, relative to the rate at which new knowledge is accumulated, the assimilation of new knowledge into such systems has been slow. We look at some of the obstacles that can stymie the adoption of new knowledge, in terms of both in generating official scientific advice and of using that advice to implement fishery management measures based on the analysis as carried out by Cvitanovicr, et al., 2015:

(a) Institutional barriers: Absence of an institutional mechanism constraints the regular engagement of policymakers and scientists. Furthermore, the metrics of career progression defined by the organizations influence the priorities of the scientists.

(b) Science in-accessibility: The time gap between the data collection and its publication in a peer-reviewed research article, at times, makes the very inference irrelevant to the decision-makers in the changed circumstances. The need for a subscription to access the scientific contents compounds the issues of access to knowledge to decision-makers, which is a major obstacle to science's integration into decision-making.

(c) Knowledge exchange channels: The transfer of knowledge in linear and unidirectional knowledge transfer processes, using traditional means of communication, not factoring the recognition of the diversity of social situations among end-users and the plurality of actors involved, prevents the information from entering the decision-making process.

In this context, there is a need to appreciate the characteristics of the policy-making domain contrasting with that of the researchers.

Policymaking process is complex : Scientific results are process-driven and objective, while the decision-making is most often subjective balancing and competing for political and societal goals. This makes it imperative for the scientists to expand their channels of communication to strengthen their communication with the other stakeholders to create wider acceptance of the specific policy change, which has its roots in science.

Spatial scope: The policymakers operate within their defined spatial and technical jurisdiction, while the scientists do not. This provides an immense opportunity for the scientists to engage with various other researchers beyond the frontiers, validate their findings, and provide the best knowledge for the given spatial scope essentially matching with the interest of the policymaker.

Diverse sources of evidence available for policy makers: Studies have shown that personal knowledge and experience as well as secondary sources that are different from the scientific evidence most often guide the decision-makers, which could compromise the effectiveness of their decisions. When the policymakers look for guidance for their decisions, there are multiple sources of knowledge, which are largely grouped into three categories as under:

Independent Knowledge Generators: There are independent think tanks that generate knowledge of all shades and put it in the public domain for the potential users to pick and use; The academic institutions, universities, and Centres of Excellence which are in pursuit of pure knowledge or blue-sky research would fall under this category. This would also include independent researchers, NGOs, and private think tanks.

State-funded National Laboratories: They are largely in the 'pursuit of actionable knowledge' or agenda-based research; they undertake strategic research and generate/synthesize knowledge to directly influence state action.

Expert Opinion: The most often relied source for evidence by the policymakers for their decisions is '*expert opinion'*– which could be an individual or a group of individuals/institutions. This option is resorted to when there is no prior established knowledge and the decisions are required to be taken based on available knowledge, particularly in situations when there are multiple shades of possible solutions.

4. Strengthening Science-Policy-Technology Interface

4.1 General Strategies

It is worth noting that, after a few repeated interactions without a successful outcome, a policymaker would shift to readily available 'expert knowledge', even if it is not rigorous. As this gap would increase over time, there is a greater onus among the scientists to strengthen the science-policy interface, through conscious efforts.

(a) Nothing succeeds like success:The scientists and policymakers need to develop joint impact studies and success stories on instances of collaborative evidence-based decision making so that the partnerships would be strengthened. A Case Study on the economic, social, and ecological impact of fisheries regulation (*e.g.,* mesh size regulation) by the state based on scientific inputs from an organization, would incentivize occasions of partnerships.

(b) ***Deliver in time:*** The research results would have value only when delivered in time, for it to influence policies. The time frame fixed for a scientific enquiry is mostly for the process and experimental design and not for the outcome, which will invariably be uncertain. It is worth noting that policy decisions are taken based on the best available knowledge at a given point of time, while the need for continuous enquiry is not undermined. The outputs in the form of peer-reviewed publications and the interim decision-related scientific inputs shall be shared as a discussion document, and piloting the decision may be needed on a limited scale to decide the effectiveness of the knowledge provided.

(c) **Focussed input:** The scientists generate knowledge and draw inferences based on observations and experiments. However, the data/observations which form the base for the inferences are only as good as the methods through which they are collected. Further, the data collected through the best methods would not mean the same to all scientists.

Thus, it is incumbent upon the scientists to consider all available knowledge from all sources and provide the 'single best option' for an issue at a given time, with necessary riders, as applicable, to aid in effective evidence-based policymaking.

(D) ***Deliver in the readily usable format:*** The researchers shall endeavor to provide accurate and reliable information in a readily usable format to suit the needs of the policymakers. Many of the data generated through application research can be operationalized by effectively leveraging geospatial tools and information and communication technology (ICT), including artificial intelligence and the internet of things.

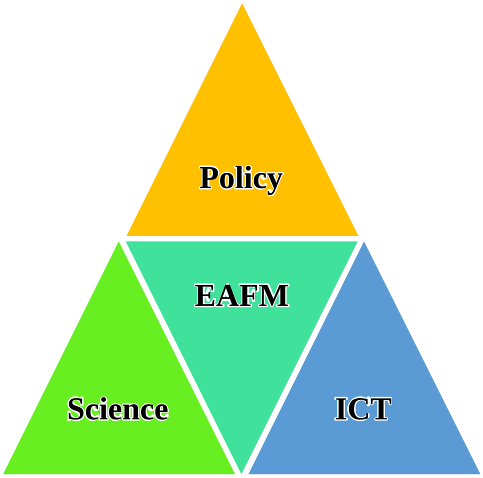
4.2 EFAM as a Tool for enhancing Science-Technology-Policy trinity

In recent years, the ecosystem approach to fisheries management has emerged as the desirable governance framework to deal with sustainability issues in fisheries. EAFM draws its strength from landmark international instruments such as the 1995 FAO Code of Conduct for Responsible Fisheries and Convention on Biological Diversity. In terms of implementation, EAFM offers a systematic procedure that ensures the interplay of science-policy and technology to arrive at the best possible solutions.

The EAFM process usually involves four overall stages: (i) developing a clear description of what is to be managed and/or assessed; (ii) identifying all the issues that need to be assessed across all components; (iii) determining, using risk analysis, which of these issues needs to be managed directly; and (iv) establishing the levels of measures that are acceptable, the management arrangements that will be used to achieve these levels, and the review processes needed to assess measures for those issues requiring management. The EAFM does not replace the traditional fisheries management system but improves it through integrating informed decision-making and evaluation at every step of implementation.

While fisheries research programmes in the region and elsewhere in the world do contribute to addressing specific gaps, a cohesive framework is not available to link research and broad policy objectives.

EAFM in this regard, provides an institutional mechanism to regularize conversation amongst the trio, viz., researchers, technologists and policy makers. A schematic diagram showing the interaction is shown below:



Science and ICT provide the grounding for EAFM while policy provides the necessary support and direction. EAFM is a bottom-up approach. Therefore, it is a prerequisite that science and ICT are remodeled to reach the masses, namely the fishers and other stakeholders. However, this cannot be achieved overnight. EAFM starts with the capacity enhancement of the scientists to enable them to communicate in a different situation from a rural setting to the highest level of urban-centric policymaking. Scientists then, in turn, help other stakeholders to build their capacity and in the process develop a shared language and goal. EAFM also provides clear direction on research needs and evaluation, which helps the policymakers to contextualize the knowledge when it is made available and appreciate its value within the system.

The use of ICT and various ICT tools such as big data analytics, data mining, digests, data-based storytelling, dashboard, and key performance indicators can play the role of an effective facilitator here. Machine learning can help scientists to automate much of their analytical information, what is otherwise, their research data or field observations, for better communication. The readily convertible translational tools provide for near-real-time translation of available knowledge into multiple vernacular languages, thus enabling their use by all stakeholders. At the same time, space technology also can be used for monitoring and predictive modelling to support policy decisions.

The following lessons can be drawn from global experience in EAFM:

1. Exposing scientists to the grassroots problems including problems in adapting 'scientific solutions'.
2. Understand the communication channel among scientists, policymakers, and other users including its diversity and inadequacy.
3. Building the capacity of scientists to communicate in a fractural system by banking on their technical expertise while appreciating traditional and system knowledge.
4. Building customized solutions for different stakeholders.
5. Contextualize research to address observable problems and thus gain the attention of the policymakers.
6. Engaging with stakeholders at every stage of research and thus alienating the technical barrier.

4.3 Using ICT to enhance the reach of science

An emerging aspect of the internationalization of fisheries is the innovative use of ICT to enhance science outreach. All stakeholders have strived to leverage the use of ICT with varying degrees of success. While at the macro level, ICT has been in use in diverse sectors, their diverse utility is gaining ground in the fisheries sector as well.

FishBase, as the most comprehensive repository of fisheries information, exemplified the use of ICT in fisheries in the global scale. It still remains the largest and most extensively accessed and cited online fisheries database on the web. Sea Around Us (www.seaaroundus.org), which reports reconstructed fisheries data along with various sustainability indicators, is another successful demonstration on the use of ICT in scale. Other such examples are Ocean Health Index, IUU Fishing Index, etc.

Apart from the direct use of ICT in production technology, more innovative uses of ICT can aid the scientistsin leveraging to reach multiple stakeholders at the same time. At the international level, FAO has developed several models for fisheries management and for science communication using ICT.

5. Conclusion

Fisheries is a sunrise sector in the region that significantly contributes to the states' economies, food, and nutritional security and ensuring gender balance, which generates millions of livelihoods in the process. To usher in the blue revolution, creating a conducive framework for knowledge exchange and technology diffusion is a necessary condition. However, at the same time, it is necessary to provide a focused direction to science and technology development so that they are in tune with the sustainable development goals and thus create a self-reinforcing mechanism to ensure achievements.

Global experience shows that while science and policy are great enablers, they have been also responsible for accentuating inequality and distorting distribution. The role of the policy is considerable in this context. The policy should provide a framework for science and technology integration so that they can contribute to the development of the masses than just a few.

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Emerging Class Structure in the Marine Fisheries Sector – A Case Study from India

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In the prevailing fisheries literature, study of revenue/profit sharing system in fisheries and its implication on fishers' welfare has received relatively little attention. Revenue or profit sharing, a dominant system of compensation in fisheries, aids in spreading of the risks. One of the major feature of the sharing system as against pure wage system is that owner and labour both take part in the decision-making process. The other aspect of sharing system is that it is not conducive to capital accumulation. However, in spite of growing uses of capital-intensive technology, the revenue/profit sharing system is prevalent in fisheries. To understand the status of fishers in India, we analysed the number of crafts, craft ownership pattern, number of fishers, etc. As there is no public data on the income of fishers, we used asset profile of fishers (education, housing, and other non-durable assets) as a proxy. Interviews were carried out with fishers to understand their role in decision-making process and concentration of ownership. Preliminary findings show that between 2005 and 2016 census years, the share of powered (mechanized and motorized) fishing crafts increased from 56% to 84%, a period during the average production recorded an increase by 23%. The population-employment ratio was observed to declinefrom 49% in 2005 to 40% in 2016 though the rate of literacy improved marginally from 56% to 60%. In terms of housing, between 2005 and 2016, share of families living in kutcha houses declined from 38% to 30% only. In absolute terms, only 15,000 families moved from kutcha to pukka houses in 10 years. The preliminary analysis of the share pattern shows signs of capitalist class structure emerging in the marine fisheries sector. Currently, the word 'fisher' is used as a collective noun in the fisheries policy and management to represent all involved in fishing sector. The study may be useful to unbundle 'fisheries' which could contribute to target the marginalized section within fishers, the issues of whom can be addressed with appropriate policy measures.

Brackishwater aquaculture: A potential option for meeting the increasing seafood demand

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Considering the current rate of population increase, scientists predicted that the world will need to double its food production by 2050. Experts say that nutrient-rich foods from aquatic environments (fisheries and aquaculture) could play a significant role. As the global demand for seafood increases every year, aquaculture is looked up to with a lot of hope and responsibility for increasing fish production, nourishing the growing population, and fulfilling several other sustainable development goals. In addition to food production, aquaculture can generate employment opportunities, support the food processing industry, offer the chance to reduce carbon emissions, and help conserve biodiversity in diversified fields across the nation.

Aquaculture currently produces 46 percent of food fish for the world, and it supplies over 60 percent of food fish, providing over 20 percent of total animal protein intake to the Asian population. India is the second largest producer of farmed fish and offers a vast potential for aquaculture development. The aquaculture sector is also confronting severe challenges, such as the impact of climate change and variability, disease outbreaks, environmental degradation, increasing input costs, anthropogenic activities and related social and economic changes, increasing intra-regional trade and public health concerns over food safety. Therefore, addressing these issues through research and development and policy formulation is of utmost necessity.

Aquaculture in brackishwater

Though aquaculture is possible in all types of water resources, realizing the full potential of the oceans and inland freshwaters requires a paradigm shift to embrace a new, responsible and sustainable approach to present it as more environmentally, socially and economically effective. Brackishwaters, otherwise considered a zero-economic resource (not used in agriculture, drinking or construction), are ideal for aquaculture today and expansion in the future due to their biodiversity richness, high productivity and negligible footprint on potable water and carbon emission. As an added advantage, the high tolerance of brackishwater flora and fauna for water quality extremes makes them more appropriate for farming under controlled conditions. Therefore, in the future aquaculture development, the scope of expansion of brackishwater aquaculture is significant with the huge potential resources available for horizontal expansion in the country.

In India, brackishwater aquaculture is synonymous with shrimp farming and estimates show that only 11-12% of the potential area is utilized for farming. It is inspiring to witness the spectacular growth of this industry in India, spearheaded by the historical highest shrimp production of 8.44 lakh tonnes in 2021-22, which was only a nascent industry during the early 1990s. Besides shrimp, brackishwater has a line-up of seafood choices in its farming basket, ranging from seaweed, clams, mussels, oysters, finfishes of different feeding nature, and gastronomic values, with ready demand in both domestic and export markets. At this juncture, brackishwater aquaculture comes with many scopes and hopes due to several positivity's, catering to the country's societal and economic development.

Brackishwater resource potential

Out of a total of 3.9 million ha of the estuarine area estimated, 1.2 million hectares of coastal saline waters have been identified as potentially suitable for brackish water farming. Also, about 9 million hectares of salt-affected lands were assessed in the hot semi-arid and arid ecoregion of northern plains and central highlands in Haryana, Rajasthan, Uttar Pradesh, Maharashtra and Gujarat with surface and sub-soil saline water. In India, brackishwater aquaculture is synonymous with shrimp farming, and estimates show that only 11% of the potential area is utilized for farming, which offers tremendous scope for further expansion. To aid in national planning, management and policy decisions in brackishwater aquaculture, precise data on potential resources and their mapping is essential. CIBA initiated this task and mapped the potential areas leading aquaculture states in a phased manner.

Currently, the brackishwater farming sector in this country is centered mainly on the shrimp, almost a single species focus, due to its international market demand, short culture duration, and lucrative market price. CIBA realizes the risk of complete dependence on single species in the sector. While CIBA continues the technical support for ongoing shrimp farming, we also stress the need for the species diversification for responsible utilization of resources. Besides, brackishwater has a line-up of seafood choices in its farming basket, ranging from seaweed, shrimps, clams, mussels, oysters, finfishes of different feeding nature, and gastronomic values, with ready demand in both domestic and export markets. At this juncture, brackishwater aquaculture comes with many scopes and hope due to several positivities, catering to the country's societal and economic development. CIBA has already made commendable progress in developing seed, feed and husbandry technologies of diversified food fishes such as seabass, milkfish, pearlspot, long whiskers catfish, mud crab and five native species of shrimp.

Road map for the development of brackishwater aquaculture

Sustainable improvements in technological aspects of aquaculture will not be achieved unless they are accompanied by strong R&D, proper planning and appropriate policies that address the social and economic environment within which the aquaculture system is placed. To assist in national planning, management and policy decisions in brackishwater aquaculture, precise data on the potential resource, technological backstopping and societal linkage are crucial. In the near future, the following key elements related to brackishwater sector may be focussed with adequate policy and funding support to achieve the projected blue revolution mission.

- Promote species diversification to have more choices of finfish and shellfish in the Indian farming basket, and its genetic improvement with selected candidates for judicious utilization of resources.
- Promotion and demonstration of diversified farming systems such as cage culture, RAS, pond based farming, biofloc based farming, farming systems for inland saline soils, IMTA, poly farmingetc for better utilization of avialbale natural water resources.
- Generation of adequate technologies for hatchery production of seeds and indigenous cost-effective feeds for diversified species and demonstrate the technologies with the active participation of the stakeholder.
- Create and strengthen the marketing channels with adequate infrastructure.

- Nationwide disease surveillance and aquatic animal health management and disease control measures to control the spread of exotic disease and unexpected production losses.
- Promote cooperation of state departments, export promotion agencies, central departments & agencies, R&D institutions for joint action.

This all would lead to economically viable, environmentally sustainable, socially acceptable brackishwater farming and ultimately a significant increase in the total farmed seafood production.

The role played by ICAR-CIBA

One of the national research institutes under the Indian Council of Agricultural Research (ICAR), New Delhi, ICAR-Central Institute of Brackishwater Aquaculture (CIBA), serves as the nodal agency for research and development brackishwater aquaculture in the country since the establishment in 1987. As CIBA has marked thirty five years of useful research and development in the brackishwater aquaculture sector, we are proud to steer the brackishwater aquaculture industry towards sustainability and contribute to food security and livelihood. Currently, the brackishwater sector in this country is centred on the exotic vannamei shrimp, and CIBA realizes the risk of complete dependence on single species. CIBA continues to stress the diversification of brackishwater aquaculture with different candidate species of shellfish and finfish to judiciously utilize the brackishwater resources with broad stakeholder participation.

In this direction, CIBA is at the forefront of technology development for this dynamic sector by developing customized indigenous technologies in identified thematic areas of brackishwater aquaculture. CIBA has made commendable progress in the multi-disciplinary areas of brackishwater farming covering captive seed production, feed development, farming system development, disease diagnostics and health management, genetics and stock characterization, climate-smart aquaculture, community engagements using social science tools and policy interventions through government agencies. CIBA helps the Govt agencies and policymakers to get precise data on the potential resource, technological backstopping related to seed, feed, genetics, aquatic animal health, and societal linkage, which are crucial for national planning, management, and policy decisions on brackishwater aquaculture. Cumulatively, these R&D interventions from CIBA have opened up new diversified farming initiatives and strategies to support the ongoing brackishwater farming. Fisheries being a state subject, to take the sector forward, partnership with institutions such as CIBA, State Govt, Central Govt, and other state and central agencies are imperative to construct the country's emerging blue economy. Our ultimate goal is achieving sustainable brackishwater aquaculture for food, employment, and prosperity. It is encouraging to see the tremendous support from the farmers, industry people, and government agencies for our efforts. Still, there is a long way to achieve the committed goals and changing needs.

Indian Shrimp sector 2022 – Status, Issues and means of Survival !!

Balasubramaniam V

General Secretary, Prawn Farmers Federation of India

Production Statistics of 2021

- Shrimp Production - 925,000 tons
  - 15% Higher than 2019
  - 30% higher than 2020
- PL Production - 120 billion
- Average harvest size - 70counts

Global trends

- Ecuador has over taken India
- Percentage of Global shrimp supply from Latin America is increasing and Asia is dipping
- Global demand is strong
- Pandemic disrupted the Supply chain – shipping and port clearances
- More shrimp but less value –production costs & supply chain is sucking out profits

What's New and Exciting ?

- SPF Monodon
- Very good growth
- Mixed results
- Multiple SPF Vennamei Genetic lines
- Technology

Mixed results in SPF MONODON


ISSUES

- Recognition
- Diseases
- High cost of production – meager profits
- Delays in CAA Farm registrations / renewals
- Institutional Finance
- Crop insurance
- Government Land lease
- Technical hands at field
- Domestic market penetration

How to survive and revive?

Diseases – prevention only option

- WSSV, WFD & EHP rampant
  - Practical and successful EHP prevention protocols
  - Pond, water and seed – Fundamental
  - Collective biosecurity
  - Nursery reared seeds
  - Multi Stage Farming
  - Wild Monodon seeds spreading diseases

- More robust brood-stock needed
- Genetics – SPR, SPT brood-stock needed
- Proficiency tests for shrimp health analytic labs – NO ringtest conducted for EHP yet
- Standardization of lab results
- **Proactive AQF testing – don't wait for OIE!**

High production cost – NO profits

- FEED cost have risen 30%
- ALL other input costs have risen
- High FCR due to poor growth
- High fishmeal cost
- Survivals have dropped
- Unpredictable crop outputs
- Unable to grow bigger sizes – low value
- High cost of financing

How to regain profits?

- Improve production efficiency
  - Focus on Seed quality
  - Nursery seeds
  - Prevent diseases
  - Reduce densities
  - Improve survivals
  - Cut costs on every input
- Grow larger sizes
- Use only certified products
- Expand the market – international & Domestic
- Branding & Marketing strategy – better marketing brings better value (Ecuador)

Delays in Farm registrations and renewals

- CAA registration is the fundamental recognition of a farm
- Must for Electricity, Financing, insurance, cooperative societies and more
- Simplification steps notified
  - Removal of SLC
  - Online applications
  - Apply to CAA directly for renewals
  - Farms up to 5 HA can be directly recommended to CAA by SDLC
  - Transfer of registration permitted
- Needed :
  - Removal of DLC & SDLC
  - Time bound issual of registrations
  - CAA to receive all application directly and process through State Fisheries
  - Life time registrations

Institutional Finance

- Nearly 90 % of farming operations is financed from private funds
- Cost of finance is very high
- Aquaculture financing is not prioritized
- Need a big push with periodic monitoring and assessment of institutional financing for shrimps farms and crop

Crop Insurance

- No practical and affordable crop insurance to cover diseases
- Crop insurance will be bring in institutional financing and stability
- Several meetings with Government officials and Insurance companies with no results

Government land leasing

- Plenty of land suitable for shrimp culture is locked with the Governments
- Most farms have some Government land within their boundaries
- Land leased to aquaculture will be a win-win option
- A transparent and practical land lease policy for aquaculture is much needed

Capacity building

- The number of technical staff in farming operations is miniscule
- Most farming is done by farmers with completely unrelated education
- Qualified technicians needed to handle the challenges in culture
- Future farming will be more technology driven and we need technical staff in farming

Domestic market

- Huge market size waiting to be explored
- Farmers are loosing Rs 70-100 on small size shrimps
- This can be pushed to the Domestic Market at higher value
- Small size shrimps are ideally suitable for Indian cuisine
- Cold chain infrastructure is needed to ensure consistency in quality and price

Wish list

- Disease tolerant Vennamei brood stock
- Augment supply of Monodon PL's
- More BMC's for Vennamei & Monodon
- Indicus domestication program
- Strong marketing / branding strategy for Indian Shrimps

Conclusion

A concerted effort from all stake holders including the Government is needed for the survival and revival of Indian Shrimp Sector.

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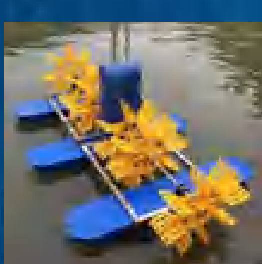

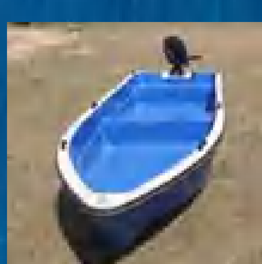


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2.கல்வி மற்றும் மாணவர்கள் மேம்பாடு தொடர்பான திட்டங்கள்

3.சுற்று சூழல் மற்றும் இயற்கை வளங்களை மேம்படுத்தும் திட்டங்கள்

4.வறுமை ஒழிப்பு மற்றும் மக்கள் துயர் துடைக்கும் திட்டங்கள்

5. பொது சுகாதாரம் மற்றும் மருத்துவ உதவி திட்டங்கள்

6.அடிப்படை வசதி மற்றும் வாழ்வாதாரங்களை பெருக்கும் திட்டங்கள்.

7.தூய்மை இந்தியா திட்டம் மூலமாக பொது சுத்தம், தனி நபர் கழிப்பறை அமைத்து கொடுப்பது ஆகிய திட்டங்கள்

8.குடிநீர் மற்றும் நீர் ஆதாரங்களை பெருக்குவது, சுத்தமான குடிநீர் வழங்கும் திட்டங்கள்

9.தானியங்கி கழிவு சுத்திகரிக்கும் இயந்திரங்கள், குப்பை அகற்றும் உபகரணம் வழங்கும் திட்டங்கள் ஆகியவை குறிப்பிடத்தக்கது.

மக்களுக்கான சக்தி, தேசத்திற்கான வளம்





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List of Exhibitors

Stall No.	Exhibitors
1	National Fisheries Development Board, Hyderabad
2	ICAR - National Bureau of Fish Genetic Resources, Lucknow
3	ICAR - Central Marine Fisheries Research Institute, Chennai
4	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
5	ICAR - Central Institute of Fisheries Education, Mumbai
6	ICAR - Central Inland Fisheries Research Institute, Barrackpore
7	Coastal Aquaculture Authority, Chennai
8	ICAR - Directorate of Coldwater Fisheries Research, Bhimtal
9	ICAR - Central Institute of Freshwater Aquaculture, Bhubaneswar
10	Marine Products Export Development Authority, Chennai
11	ICAR - Central Institute of Fisheries Technology, Cochin
12	ICAR - Central Institute of Brackishwater Aquaculture, Chennai
13	Seafood Exporters Association of India, Chennai
14	Aqgromalin, Chennai
15	Universal Technology, Chennai
16	Growel Feeds Pvt. Ltd., Andhra Pradesh
17	Bay of Bengal Programme, Chennai