N0. 261, July- September 2024 ISSN 0254-380X

MFiS

Marine Fisheries Information Service Technical & Extension Series

भाकृअनुप ICAR

सी एम एफ आर आइ CMFRI

MFiS

No. 261, July – September, 2024
ISSN 0254-380X

सी एम एफ आर आइ
CMFRI

भाकृअनुप
ICAR

Marine Fisheries Information Service Technical & Extension Series

The Marine Fisheries Information Service, Technical & Extension Series (MFIS) is a quarterly publication of ICAR-Central Marine Fisheries Research Institute disseminating latest research information on marine fisheries and mariculture in India. Research based technical articles, reporting significant new information, knowledge and understanding of marine fisheries and ecosystems as well as new concepts/technologies in marine fish nutrition, hatchery and larval rearing, fish pathology, fish health management, application of genetics in fish conservation and farming, sea farming technologies, seafood trade and fisheries governance are published. To see all issues since 1978, visit:

http://eprints.cmfri.org.in/view/subjects/MFIS.html

http://www.cmfri.org.in/publication/mfsi-t-e-series

Marine Fisheries Information Service Technical & Extension Series

Mar. Fish. Infor. Serv., T & E Ser., No. 261, 2024

Published by

Dr. Grinson George
Director
ICAR–Central Marine Fisheries Research Institute, Kochi

Green mussel, *Perna viridis*

Marine Fisheries Information Service Technical and Extension Series envisages dissemination of information on marine fishery resources based on research results to the planners, industry and fish farmers and transfer of technology from laboratory to the field.

MFIS

Marine Fisheries Information Service
Technical & Extension Series

From the Editorial Board

Warm greetings to all our esteemed readers

The Blue economy document of the Government of India envisages sustainable utilization of marine resources and resulting economic growth, fuelled by technology advancements, suitable policies and good governance keeping in mind environment and conservation aspects also. This will enable the country to march steadily towards the achievement of the UN- Sustainable Development Goal SDG 14 dealing with 'Life below Water'. Globally, India is the second and fourth largest contributor to aquaculture and capture fisheries sectors, respectively. Good Practices for farming, in open sea as well as land-based units such as Recirculatory Aquaculture Systems and hatcheries for seed production holds the key to a vibrant mariculture sector. Mapping of potential mariculture sites for seaweed and sea cage farming, establishment of mariculture parks, hatcheries and nurseries based on scientific spatial planning technologies, sustainable food value chains and climate-proofing of marine fisheries and mariculture are key focus areas for achieving the goals of a Blue Economy driven growth model. Small-scale fisheries, a significant component of the Indian marine fisheries sector, needs governance and development initiatives that will ensure the benefits reach all stakeholders. The articles in this issue of MFIS highlight contemporary research findings that concern several aspects listed above.

MFiS

Marine Fisheries Information Service
Technical & Extension Series

Contents

Brief Communications

Science Corner

Kaleidoscope

Brief Communication

Recent advances in bivalve seed production in India: Salient research findings, technologies and their social impact

M.K. Anil[1], P. Gomathi[1], M. Kavitha[2], B. Raju [1],O. Shalini[1], P.M. Krishnapriya[1], Santosh Bhendekar[3], Rajesh Kumar Pradhan[4], R, Vidya[5] and P. Laxmilatha[5]

[1]Vizhinjam Regional Centre of ICAR-Central Marine Fisheries Research Institute, Vizhinjam P.O., Thiruvananthapuram – 695 521, Kerala
[2]Tuticorin Regional Station of ICAR-Central Marine Fisheries Research Institute, Thoothukudi–628 001, Tamil Nadu
[3]Mumbai Regional Station of ICAR-Central Marine Fisheries Research Institute, Mumbai – 400 061, Maharashtra
[4]Field Centre of ICAR-Central Marine Fisheries Research Institute, Puri–752 002, Odisha
[5]ICAR-Central Marine Fisheries Research Institute, Kochi-682 018, Kerala

*E-mail: anilmk@icar.gov.in

Introduction

India, with its vast 7,516.6 km coastline, rich in native bivalve species such as mussels, oysters, and clams, holds untapped potential for aquaculture. Despite this natural advantage, the country lags far behind its Asian counterparts in bivalve production. While India produces less than 10,000 tons of mussels annually from aquaculture, countries like China, Chile, and Spain dominate global production with outputs of 903,000 MT, 369,000 MT, and 284,000 MT, respectively. India's low output is attributed to the scarcity of reliable seed supply, as the bivalve hatchery sector remains underdeveloped and the lack of awareness about the potential of this resource. Most farmers depend on erratic and limited wild-caught seed, restricting bivalve farming to specific areas such as the backwaters in Kerala.

Recognizing these constraints, the project MFD/SEED/16: Techniques for mass seed production of bivalves (2020-2024) was launched in June 2020. The initiative aimed to overcome seed supply challenges by establishing robust hatchery-based technologies for key bivalve species, including green mussels (*Perna viridis*), brown mussels (*Perna indica*), edible oysters (*Crassostrea madrasensis*), and clams (*Paphia malabarica* and *Villorita cyprinoides*). The project's scope extended beyond technical advancements to encompass the socio-economic upliftment of coastal communities, fostering sustainable livelihoods and addressing the growing domestic and export demand for bivalves. This ambitious project also explored innovative solutions such as integrated multi-trophic aquaculture (IMTA), hybrid biofloc systems, and field upweller nurseries, aiming to make bivalve farming accessible and profitable for both small-scale and large-scale farmers. By leveraging recent advancements in seed production and farming technologies, the initiative sought to develop India's capacity to lead in sustainable bivalve aquaculture. Through targeted investments and training, the project promises a brighter future for India's aquaculture sector, contributing to food security, employment generation, and environmental conservation. This project has laid the foundation for the world's first hatchery dedicated to the Asian green mussel (*Perna viridis*), locally known as *Mayilpeeli Kakka* in the south and *Kallinmel Kaya* in the north of Kerala. Set to be established in Valiyaparamba, in Kannur district of Kerala, the hatchery is currently in its final stages of completion and is being developed with the technical support of ICAR-CMFRI. This project has also enabled ICAR-CMFRI to secure a *Pradhan Mantri Matsya Sampada Yojana* (PMMSY) funded project worth ₹154 lakhs, besides two consultancy projects and MoUs with the governments of Kerala and Maharashtra.

Salient Achievements

High-density larval rearing systems

The establishment of a high-density bivalve larval-rearing system represents a transformative step in hatchery technology, benefiting mussels, oysters, pearl oysters, and clams. At its core is the cylindroconical tank, with a

High density larval rearing system

275-liter capacity, replacing traditional rectangular tanks. This innovative design supports stocking densities of 25–100 larvae per milliliter, a significant improvement over conventional systems limited to 1 larva per milliliter. The conical shape ensures uniform water circulation, preventing dead zones and promoting better growth and survival rates by providing optimal feed and oxygen availability. Each tank incorporates a cylindrical net screen, available in various mesh sizes, to retain larvae without harm while allowing efficient water exchange. This modular design enables scalability to meet production needs, enhancing resource utilization with improved food distribution and waste management. By optimizing space and maintaining a stable environment, this system addresses key challenges in bivalve aquaculture, paving the way for sustainable, high-yield hatchery operations.

Development of Micro-nursery systems

The micro-nursery system, comprising down-welling and up-welling subsystems, facilitates the settlement and metamorphosis of bivalve larvae into spat and supports further rearing to seed size suitable for farming. Designed for species such as mussels, oysters, pearl oysters, and clams, the system includes separate reservoir tanks and pumps for water circulation. In the down-welling subsystem, eyed-stage larvae are stocked at high densities for settlement and growth. Once spat reach 4 mm, they are transferred to the up-welling subsystem for further rearing. This innovative system, successfully designed and operationalized, delivers significant advancements in efficiency and scalability. Each system accommodates up to 9.6 million larvae using just two tons of water, compared to traditional systems requiring 32 tons per day for the same output. This not only enhances rearing efficiency but also minimizes water usage and labour,

Micro-nursery system for larval rearing

Cultchless spat in the downweller silos

significantly reducing costs. Its modular design supports large-scale seed production, enabling hatcheries to meet growing demands for bivalve farming.

Integration of Multi-Trophic Aquaculture (IMTA)

A groundbreaking hybrid biofloc system was developed at Vizhinjam Regional Centre, integrating bivalve nursery rearing with shrimp farming, showcasing the principles of Integrated Multi-Trophic Aquaculture (IMTA). The system features a 10,000-liter biofloc tank filled with diluted seawater (25 ppt), supported by Recirculating Aquaculture System (RAS) components such as a biological filter and protein fractionator for effective water quality management. Aeration is provided by two A3 Venturi aerators, two airoxy rings connected to a blower line, and an oxygen concentrator with a diffuser cone for emergencies. White shrimp (*L. vannamei*) are stocked at the PL10 stage, while oyster and mussel spat are placed in downweller silos or attached to ropes immersed in floc water. Nutrient-rich floc water and algae are circulated using an airlift system, supporting high survival and growth rates. The study achieved over 95% survival of bivalve spat, excellent spat growth, and a shrimp stocking density of 200/m^3. This innovative system

Mussel spat grown in hybrid biofloc system

maximizes resource efficiency by recycling waste as nutrients, reduces environmental impact, and sets a benchmark for sustainable aquaculture, combining high productivity with minimal ecological footprint.

Cultchless spat production: a landmark achievement

The production of cultchless spat of *Crassostrea madrasensis* marks a significant technological advancement in oyster

Hybrid biofloc system

farming. The process begins with the biopsy method to extract gametes, followed by standardized sperm activation to induce fertilization and produce larvae. Pediveliger larvae are then treated with epinephrine hormone, which promotes settlement as single spat while preventing attachment to tanks or cultch, resulting in unattached, cultchless spat. These single spats are subsequently transferred to a micro-nursery system for further rearing. This innovative approach achieves a 15-30% success rate in producing cultchless spat. The technology opens doors to the global market by enabling the production of single oysters, which are in high demand internationally. It represents a significant leap in technological advancement through hormone-induced settlement techniques and has been certified by ICAR, underscoring its potential to revolutionize oyster farming in India and establish it as a key player in the global oyster market.

Establishment of field upweller systems

An innovative field upwelling system was developed to support the mass nursery rearing of bivalve seed, including mussels, oysters, and clams, using natural feed sources like phytoplankton and microscopic particles from nearby water bodies. This system, designed to optimize the early growth stages of bivalves, enhances survival rates and promotes robust seed development. It features cylindrical

Field upweller system

Field upweller grown clam (*Paphia*), cultchless oyster and mussel seed

silos installed near coastal bays, estuaries or ponds, where water is pumped upward to create an upwelling effect, delivering nutrient-rich water and oxygen to the nursery. This continuous flow ensures a steady supply of natural feed, reducing the reliance on artificial diets and minimizing operational costs. The system's versatility makes it suitable for rearing various bivalve species and adaptable for both small-scale and large commercial operations. By bridging the gap between hatchery seed production and grow-out farming, this sustainable, cost-effective innovation supports the expansion of bivalve aquaculture practices.

Advances in mussel, oyster and clam hatchery techniques

The project achieved significant progress in developing hatchery techniques for clams and mussels:

Green mussels (*Perna viridis*): Larval and nursery rearing and grow-out methods were optimized, achieving high survival and growth rates in field trials.

Brown mussels (*Perna indica*): Larval and nursery rearing and grow-out methods were optimized, achieving high survival and growth rates in field trials.

Backwater oyster (*Crassostrea madrasensis*): Larval and nursery rearing and grow-out methods were optimized, achieving high survival and growth rates in field trials.

Short-Neck Clams (*Paphia malabarica*): Standardised the captive broodstock maturation of Ashtamudi Short-neck clam, by temperature manipulation and enhanced feeding. In addition to that Hormone-induced spawning protocols were also standardized, resulting in efficient seed production. Indian pearl oyster, *Pinctada fucata*: standization of mass production of pearl oysters spat seed production using micro-nursery system and field upweller system.

Deciphered the Larval cycle of invasive mussel species *Mytella strigata*: The larval cycle of the invasive mussel species *Mytella strigata* was studied in captivity, with growth monitored up to the post-settlement stage. The study revealed that *Mytella strigata* has a shorter larval cycle, taking only 13–15 days to settle as spat. In contrast, native mussel species such as *Perna indica* and *Perna viridis* require 17–21 days for settlement. This shorter larval cycle may provide *Mytella strigata* with a competitive advantage over native species, potentially influencing ecosystem dynamics and aquaculture practices.

Field demonstrations and farmer outreach

Field trials conducted in Kerala, Tamil Nadu, Maharashtra, and other regions validated the performance of hatchery-produced seeds under real-world conditions.

With Green mussels, an average production of 19.14 kg per metre rope was achieved in Ashtamudi and Neendakara, Kollam and with Brown Mussels demonstrated exceptional growth in Kanyakumari, with an average production 20.4 kg per meter rope achieved.

Socio-economic impact

The project significantly contributed to the socio-economic development of coastal communities by

Employment Generation: Created opportunities for farmers, self-help groups, and hatchery workers.

Field demonstration of hatchery-produced green mussel seed

Enhanced Livelihoods: Enabled small-scale farmers to access affordable, high-quality seed, fostering sustainable farming practices.

Empowerment: Trained farmers, and stakeholders in innovative techniques, equipping them with skills to thrive in the aquaculture industry.

Technological innovations

The project delivered several innovative technologies, including:

Photobioreactor: Designed for the high-density production of microalgae, ensuring a sustainable live feed supply for hatcheries.

Cultchless Spat Technology: Revolutionized oyster farming by enabling single-oyster production.

Capacity building

Extensive training programs and workshops were organized to disseminate knowledge and best practices:

Table 1. List of beneficiaries of technologies/ services provided under the project

List of beneficiaries of seed supplies	Bivalve species	State
Universities /Research institutes /State departments		
Mangrove cell, Maharashtra	Edible oyster seed and green mussel	Maharashtra
Kerala University of Fisheries and Ocean Studies	Green mussel seed	Kerala
ICAR-CMFRI Kochi	Edible oyster	Kerala
Mumbai Regional Station of ICAR-CMFRI	Edible oyster	Mumbai
Green mussel egg larvae and spat supplied to DBT project of ICAR-CMFRI Kochi, "De novo whole genome and transcriptome of developmental stages of *Perna viridis*"	Green mussel egg- 30 million Larvae -19.13 million Spat-0.5 million	ICAR-CMFRI, Kochi
Tuticorin Regional Station of ICAR-CMFRI	Pearl oyster, green and brown mussels	Tamil Nadu
Krishi Vigyan Kendra, Lakshadweep	Pearl oyster	Lakshadweep
TKM College of arts and science, Kollam, ZooAqua self-help group, Vellimon, Kollam (Scheduled Caste students from Dept of Zoology TKM College)	Green mussel and oysters	Kerala
Puri Field centre of ICAR-CMFRI	Oyster seed	Odisha
Farmers and hatcheries		
Tharakan Group	Cultchless oyster spat	Kerala
Saptagiri hatchery, AP	Cultchless spat	Andhra Pradesh
TKM ZooAqua self-help group, Vellimon, Kollam (Scheduled Caste students from Department of Zoology, TKM College)	Green mussel seed	Kerala
Vijayan, Kasaragod	Green mussel	Kerala

Mussel and oyster seed (cultchless and attached) supply to Maharashtra Government

Farmer Training: Covered topics such as breeding, larval rearing, and nursery techniques.

Stakeholder Engagement: Engaged government officials, researchers, and private stakeholders to promote adoption of project outcomes.

Mussel seed distribution to SCSP beneficiaries by Dr. Adeela Abdulla, Director of Fisheries, Kerala

Seed supplied to the farmers and researchers/state departments

The Bivalve seeds produced and supplied to farmers researchers in different parts of the country. The bivalve species included were the Green mussel (*Perna viridis*), Brown mussel *(Perna indica*), Edible oyster (*Crassostrea madrasensis*), Pearl oyster (*Pinctada fucata*) and Short-neck clam (*Paphia malabarica*).

Conservation efforts for the Pearl oyster in the Gulf of Mannar

To restore and revive the Pearl oyster, *Pinctada fucata* bed in the Gulf of Mannar area, hatchery produced spat (5.15 lakhs spats and 16.5 million veliger larvae) were ranched in the *paars* off Thoothukudi located on the south east coast of India.


Sea ranching of Pearl oyster seed

Table 2. Projects resulting from the success of the bivalve seed production project of ICAR-CMFRI

Project title	Project duration	Project cost (₹ in lakhs)
Funded project		
Development of Pilot-Scale Open-Sea Eco-Mussel Farms in India–A Blue Growth Project" – under the Central Sector Scheme Component of '*Pradhan Mantri Matsya Sampada Yojana* (PMMSY)	2024-25	151.21
Consultancy project (seed supply and DPR preparation)		
Preparation of DPR for Bivalve Hatchery Unit at Kasaragod, Kerala, India	2023	3.0
Bivalve seed supply for Mangrove Conservation and Livelihood Generation Funded by–Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra, Govt. of Maharashtra	2022	3.0
Bivalve seed supply for Mangrove Conservation and Livelihood Generation Funded by–Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra, Govt. of Maharashtra Project cost–₹8.21 lakhs	2023-24	8.21
	Total	165.42

Mussel hatchery coming up at Kannur with ICAR-CMFRI technology

Consultancy services to the state departments

With hands on experience of this project, ICAR-CMFRI is serving as the consultant to the state of Maharashtra, Kerala and Tamil Nadu for establishment of mussel and oyster hatcheries. The world's first hatchery dedicated to the Asian green mussel (*Perna viridis*) is nearing completion in Valiyaparamba, located in Kerala's Kannur district. This groundbreaking facility marks a significant milestone in mussel aquaculture, paving the way for sustainable seed production and enhanced farming practices.

Conclusion

The "Techniques for Mass Production of Bivalve Seed" project of ICAR-CMFRI has been a transformative initiative in India's aquaculture sector. By addressing critical challenges in seed supply and introducing innovative technologies, the project has paved the way for a thriving bivalve farming industry. It has demonstrated the potential to significantly enhance India's bivalve production, create sustainable livelihoods for coastal communities, and position the country as a competitive player in the global aquaculture market. With a strong foundation in place, the future of bivalve aquaculture in India is promising. The outcomes of this project underscore the importance of continued investment in research, technology, and farmer training to unlock the full potential of India's coastal resources. This initiative not only represents a step forward for aquaculture but also contributes to the broader goals of food security, economic growth, and environmental sustainability.

Brief Communication

Pufferfish fishery and trade in Tamil Nadu: Value addition paves way for enhanced domestic consumption

L. Remya[1*], A. R. Anuja[1], Shoba Joe Kizhakudan[1], S. Mahalingam[2], M. Midhun[2], R. Rajkumar[2], A. Rameshkumar[2], S. Joseph Jagan[2], S. Suresh[2] and M. Manojkumar[2]

[1]ICAR-Central Marine Fisheries Research Institute, Kochi-682 018, Kerala

[2]Mandapam Regional Centre of ICAR-Central Marine Fisheries Research Institute, Mandapam Camp- 623 520, Tamil Nadu

*E-mail: lremya9@gmail.com

One of the most practical solutions which addressed poorly in fishery management measures is the search of abundant, underutilized, nutritious, highly fecund, less vulnerable and low value fishes. Though highly poisonous, the skinned, gutted and beheaded (dressed/processed) Pufferfishes of coastal waters are being increasingly used for consumption by domestic consumers in India as evident from the increase in their landings at different landing centres, whereas it was previously discarded at sea itself. Tetrodotoxin (TTX) is a heat-stable potent neurotoxin that blocks sodium conductance in skeletal muscle, and poisoned victim is unable to breathe, and eventually dies from asphyxiation. TTX, in family Tetraodontidae (Pufferfish) is typically concentrated in the liver, ovaries, intestines, and skin. In most species, tetrodotoxin concentrations in the muscle are low, which is why, when properly processed, this fish is commercially exploited and safely consumed in countries such as Japan, China, Korea and USA. Unlike most of conventional fishes, puffers do not have intramuscular bone, makes them convenient to consume. In addition, this product is devoid of typical fishy odour, look like broiler piece with an apparent colour, thus popularly called as 'white chicken' among fishers and consumers. Monthly samplings and personal enquires on edible Pufferfish fishery and trade were conducted at various landing centres and villages along Tamil Nadu during 2018-23.

Monthly samplings to various Fish Landing Centres (FLC) and personal enquires using pre-tested questionnaire at dry fish units were conducted at various landing centre along Gulf of Mannar (GoM), Palk Bay (PB) and Coromandel Coast (CC) during 2018-23. Data on Pufferfish production in the area was extracted from the National Marine Fisheries Data Centre (NMFDC) ICAR-CMFRI, Kochi. Pufferfish species were identified following Sujatha and Padmavathy (2015) based on samples collected from commercial catches.

Fisher's Share in Consumer Rupee: The fisher's share in the consumer rupee calculated as the percentage of the consumer price that the fisher receives and gives an idea about the portion of the final price benefits the primary producer (fisher) was used as given below.

$$\text{Fisher's Share in Consumer Rupee} = \left(\frac{\text{Price received by fishers}}{\text{Price paid by consumer}}\right) \times 100$$

Marketing Efficiency: Marketing efficiency measures how efficiently the value chain adds costs and margins without significantly reducing the producer's share. A higher marketing efficiency indicates more equitable distribution of the consumer price. The Acharya's method for calculating marketing efficiency was used as given below.

$$\text{Marketing Efficiency} = \left(\frac{\text{Price received by fishers}}{\text{Total Marketing Costs+Margins}}\right)$$

The annual production of Pufferfish (Tetraodontidae) in Tamil Nadu during 2018 to 2023 indicate estimated catch of Pufferfish in 2019 was 1158t and highest catch followed by a steep low in 2020 (27t), probably due to COVID19 restrictions in fishing. The showed an increasing trend after the fall and reached to 1008t in 2023. Mechanised sector brought 94% of catch with multiday and single day contributing 71% of the total. Among motorised crafts,

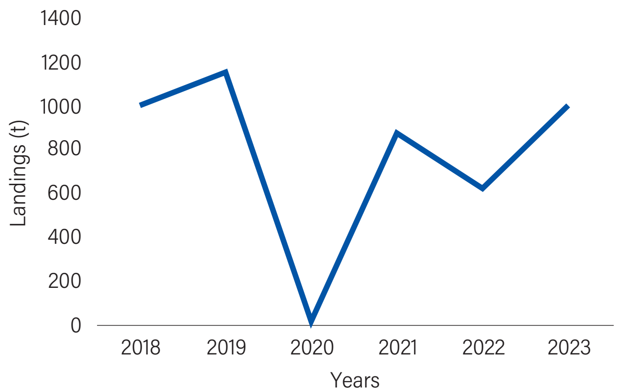


Fig. 1. Estimated landings of Pufferfish in Tamil Nadu during 2018–2023

outboard hook and line and outboard gillnet caught 44% and 33% of Pufferfish respectively.

Genus *Arothron* formed on an average of 71% of the total Pufferfish landing along Tamil Nadu (Fig. 3). The major catch came from the GoM and PB as this group is associated with inshore and reef areas. *A. immaculatus* contributing 31%, dominated among the Pufferfish species landings. *Lagocephalus* spp. especially *Lagocephalus lunaris* contributed to the bulk of Pufferfish catches in CC

The marketing channel of dry Pufferfish followed the Fisher-Collection agent- Wholesaler- Retailer- Consumer route. The total price spread which represents the difference between the price paid by the consumer and the price received by the fishers, captures the cumulative cost and margin added at each stage of the value chain. During 2018 to 2023, the price spread of the dry fish value chain has steadily increased, indicating a growth of approximately 56%. The widening spread suggests that the marketing costs and margins by intermediaries such as collection agents, wholesalers, and retailers has increased. Despite the rising consumer prices, the fisher's share in consumer rupee remains relatively low, as much of the added value benefits intermediaries indicating inefficiencies in the value chain. The fisher's share in the consumer rupee has gradually increased over the years, from 5.88% in 2018 to around 10.71% in 2023(Fig. 4). This implies that fisher's share of the consumer price is not significantly improving, indicating limited direct benefit from the higher consumer costs. The marketing efficiency improved from 6.25% in 2018 to around 12% in 2023 but the marketing efficiency of the dried Pufferfish value chain is still relatively low.

The Pufferfish is landed in the trawl and gillnet landings in Tamil Nadu, and also as trashed catch. Small dry fish units are involved in processing /dressing of Pufferfish in Tamil Nadu. People with special skill to remove head, viscera and skin of Pufferfish in a single cut were engaged for dressing

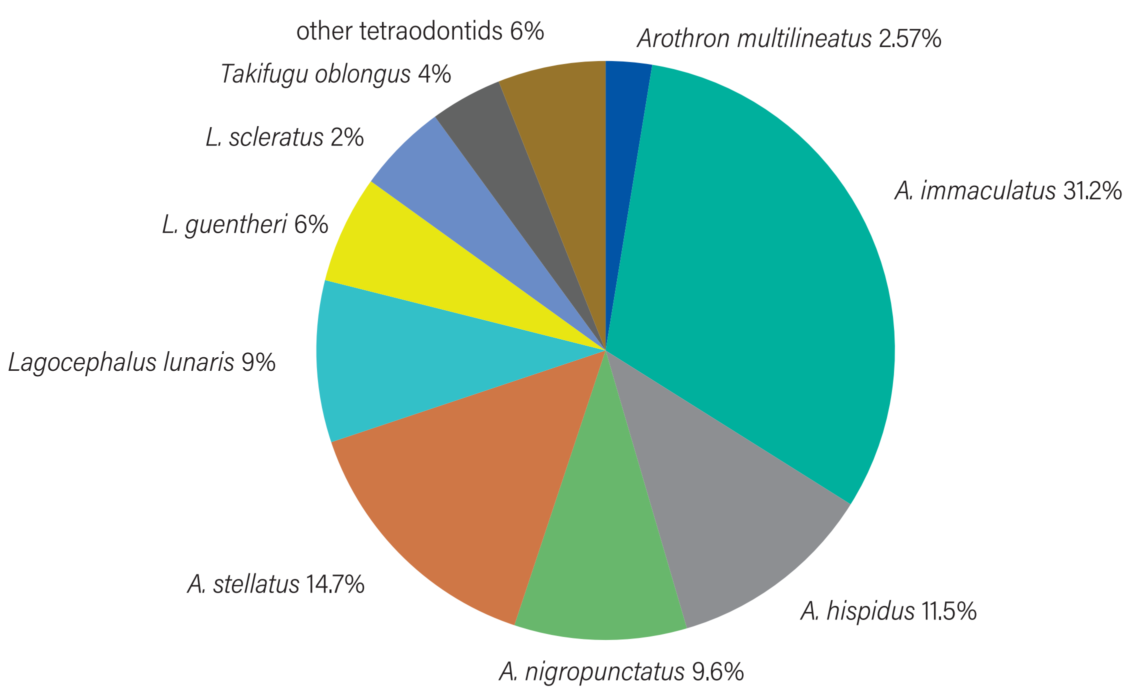


Fig. 3. Average annual species composition of Pufferfish in Tamil during 2018-23

Collection of Pufferfishes from the landing centre

Dressing of Pufferfish in dry fish unit

Dressed Pufferfish pieces

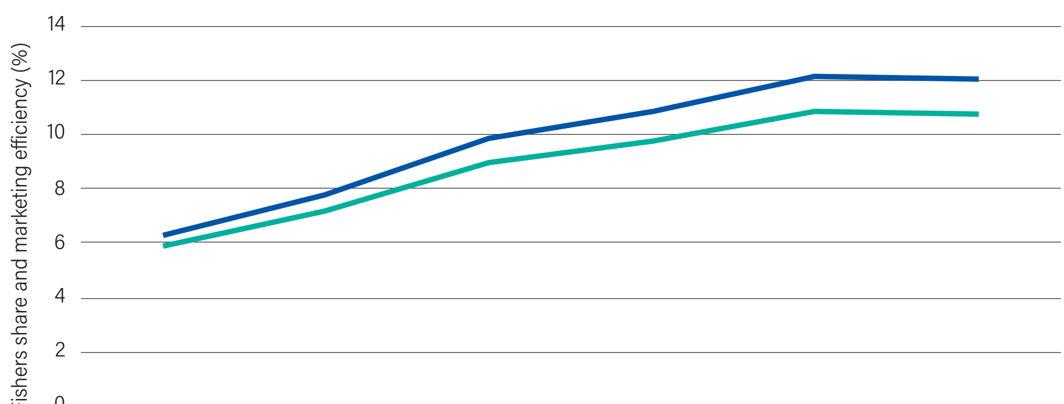
A single dressed Pufferfish

Salt curing process of Pufferfish

Cured Pufferfish

Head, skin and viscera discarded during the dressing process

Uncured slices of Pufferfish



	2018	2019	2020	2021	2022	2023
Fisher's Share (%)	5.88	7.22	9	9.77	10.8	10.71
Marketing Efficiency (%)	6.25	7.78	9.89	10.82	12.11	12

Fig. 4. Trend in fishers share in consumer rupee and marketing efficiency (%)

and curing. The wages for dressing the Pufferfishes was at the rate of ₹3 per kg fresh fish. Dressed Pufferfish from GoM and PB, especially *Arothron* species, both in salted and unsalted form, fetch good market prices (₹200 -250) and genus *Lagocephalus* ₹200 to 250 in CC of Tamil Nadu. The net weight of cured fish comes 27-35% of raw fish. While cured fish has traditionally been the preference, dressed (uncured) Pufferfish is gaining popularity, particularly in inland regions viz., Rajapalayam, Namakkal, Madurai, Coimbatore, Trichy etc. with increased consumption upto 60% higher from that of early 2000. Consumers in coastal areas are also starting to accept it more readily. This shift could be driven by changing consumer tastes, availability, or even interest in diverse seafood options. The demand dynamics for Pufferfish might continue to grow as people become more familiar with it and its culinary uses. The fatality case associated with Pufferfish in Tamil Nadu appears negligible. Almost 70-80% of the Pufferfish landings in southern Andhra Pradesh, Gujarat, Kerala and Mangalore finds are marketed to Tamil Nadu, due to the acceptance of Pufferfish by the fish consumers in Tamil Nadu. However, awareness on potential toxicity by consuming incorrectly processed Pufferfish is desirable to avoid any fatalities in future.

References

Sujatha K. and Padmavathi P., 2015. *J. Mar. Biol. Assoc. India*, 57(2): 95-104.

Brief Communication

The Grouper fishery of Andhra Pradesh, Bay of Bengal coast of India during 2017-2023

M. Muktha[1*], K. V. Akhilesh [2], Eldho Varghese[3] and V. Sreepriya[3]
[1]Visakhapatnam Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam -530 003, Andhra Pradesh
[2]Calicut Regional Station of ICAR-Central Marine Fisheries Research Institute, Kozhikode-673 005, Kerala
[3]ICAR-Central Marine Fisheries Research Institute, Kochi-682 018, Kerala

*E-mail: muktham@gmail.com

Groupers belonging to the Perciformes/Serranoidei are one of the world's most commercially important marine finfish resources, distributed mainly in tropical and subtropical waters. Groupers form the essential component of the "Live Reef Food Fish Trade" for which many species were significantly overfished (Kam *et al.,* 2024). Globally, there are 537 available species and 176 valid species of groupers (Fricke *et al.,* 2024). In India, there are at least 95 species of groupers, with 39 species from the genus *Epinephelus* (Akhilesh *et al.,* 2021). India has a minor but valuable groupers/rockcods fishery forming 1.95% of total marine landings of the country in 2023 with 69099 tonnes as indicated by the National Marine Fishery Resources Data Centre (NMFDC) of the ICAR-Central Marine Fisheries Research Institute (CMFRI-FRAEED, 2023). The estimated annual grouper landings have been sharply increasing, from the range of 12,000 to 25,000 tonnes per annum from 1995–2010 (decadal average of approximately 13,000 tonnes from 1991–2000 vs. approximately 20,000 t from 2001–2010) up to nearly 40,000 tonnes from 2011–2019 and 50,388 tonnes 2020-2023 (http://eprints.cmfri.org.in/). Andhra Pradesh contributed 1.2% to the total groupers landed in India during 2023. During 2017-2023, Andhra Pradesh had an average annual grouper landing of 588.0 with the landings showing an increasing trend across these years (Fig. 1).

Among the various coastal districts of Andhra Pradesh, the highest landings of groupers were seen in Kakinada, Konaseema and Visakhapatnam. Among the various fishing harbours in the state, Kakinada Fisheries Harbour accounting for 43% of the total landings was a major fishing hub for groupers in the region. Visakhapatnam

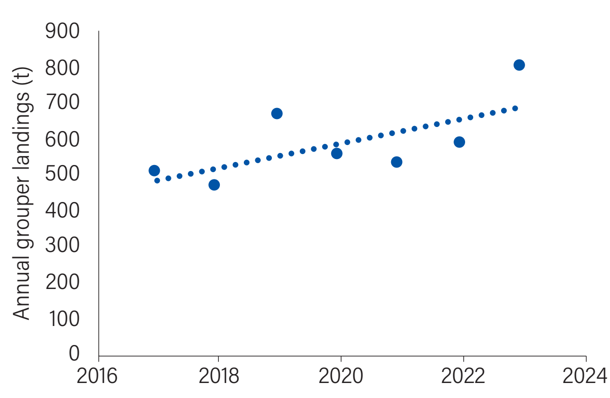


Fig.1. Annual (2017-2023) landings of Groupers in Andhra Pradesh

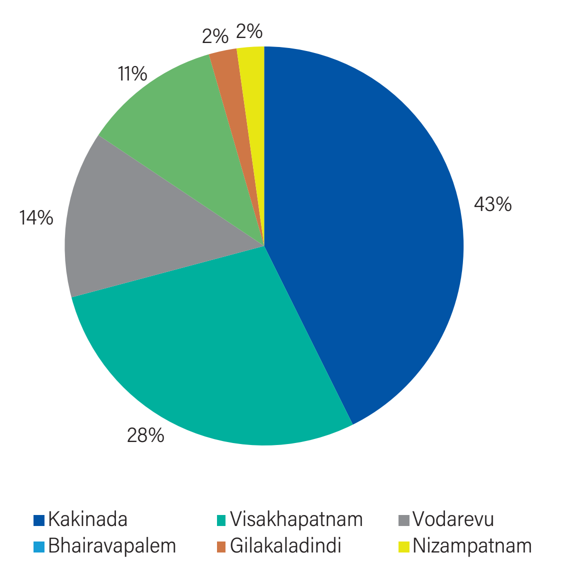


Fig. 2. Landings of groupers in different Fisheries Harbours in Andhra Pradesh

Epinephelus radiatus landed at Visakhapatnam Fisheries Harbour

followed with 28% and Bhairavapalem, with 14% of the grouper landings (Fig. 2).

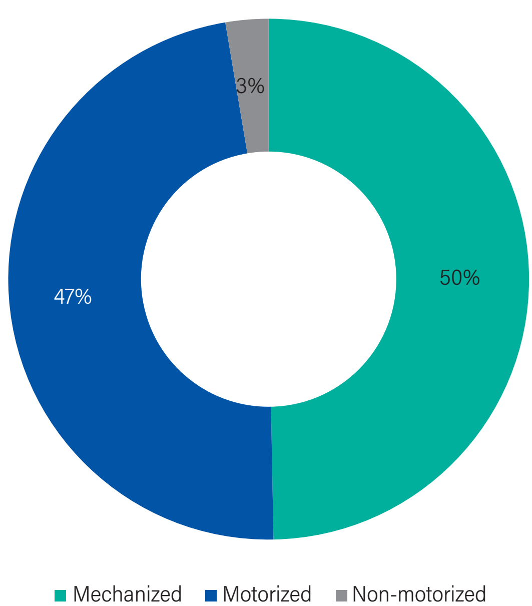


Fig. 3. Sector-wise contribution to grouper landings of Andhra Pradesh (2017-2023)

The main contribution to grouper landings in Andhra Pradesh came from the mechanized sector (50%) and the lowest was from the non-motorized sector (Fig. 3). Among the fishing gears, trawls were the largest contributors to grouper landings in Andhra Pradesh, followed by hooks and lines, gillnets and artisanal gears (Fig. 4). However, the average catch rate was quite low at 0.09 kg/hr (range: 0.05-0.12 kg/hr). The highest average catch rate was seen in hooks and lines at 2.61 kg/unit (range: 0.54-7.25 kg/unit) followed by gillnets at 0.19 kg/unit (range: 0.01-0.59 kg/unit). The average catch rate in artisanal fishing gears was 0.07 kg/unit (range: 0.02-0.2 kg/unit). Trawls, hooks and lines and gillnets (Fig. 5) showed an increasing trend in landings and catch rates of groupers during the study period.

The species composition of groupers was studied from Visakhapatnam Fishing Harbour regularly and biological studies of selected species were also undertaken. During 2023 the major grouper species landed included *Epinephelus coioides*, *E. latifasciatus*, *E. areolatus*, *E. epistictus*, *E. radiatus*, *E. malabaricus*, *Cephalopholis formosa* and *C. sonnerati*. *E. coioides* was the dominant species landed forming 76.3%

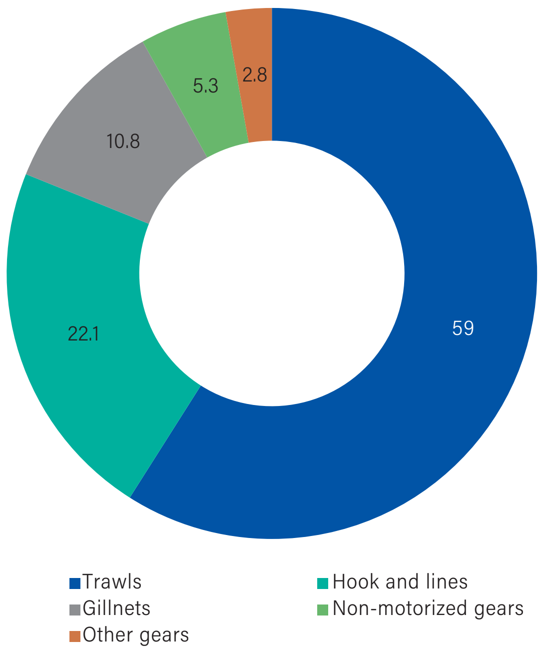


Fig. 4. Gear-wise contribution (%) to grouper landings of Andhra Pradesh (2017-2023)

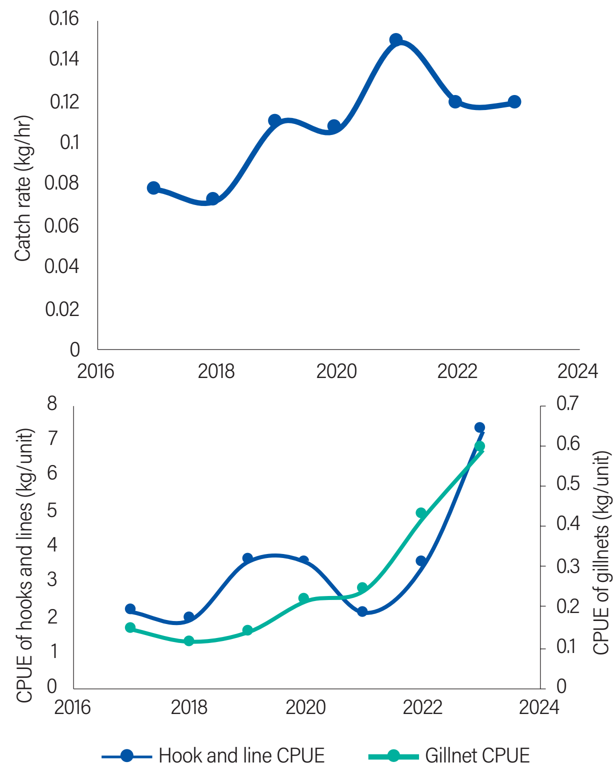


Fig.5. Catch rates in trawlers (kg/h) and Gillnet & Hooks and line (kg/unit) of Andhra Pradesh (2017 -2023)

E. coioides landed at Visakhapatnam Fisheries Harbour

Table 1. Size range of major grouper species landed at Visakhapatnam Fishing Harbour during 2023

Species	Total length range (mm)	Mean size (mm)
Epinephelus coioides	210-1030	599.6
E. latifasciatus	150-390	220.9
E. areolatus	180-320	251.7
E. epistictus	200-420	288.6
E. radiatus	220-465	296.7
Cephalopholis sonnerati	200-475	302.0
C. formosa	190-255	223.0

Groupers landed at Visakhapatnam Fisheries Harbour

of the grouper landings of the harbour. This was followed by *E. latifasciatus* (7.8%), *E. areolatus* (6.5%), *E. epistictus* (5.5%), *E. radiatus* (1.4%), *E. malabaricus* (0.1%), *Cephalopholis sonnerati* (1.6%) and *C. formosa* (0.8%). The mean sizes and size range of the grouper species landed at Visakhapatnam Fishing Harbour during 2023 is given in Table 1.

Visakhapatnam is the major grouper fishery and trade hub in north Andhra Pradesh. Though there is good demand for *E. coioides* in local markets, a substantial quantity is sent to Kolkata, Chennai, Mumbai and Kochi. The sale price at Visakhapatnam harbor for this species averages 150-300 ₹/kg which fetches upwards of 200-500 ₹/kg at the destinations. Fishes are packed whole in ice and transported to distant markets in thermocol boxes. Most of the grouper trade from Visakhapatnam relies on rail transportation with a meagre amount transported by road.

References

Fricke *et al.*, (Eds.) 2024. *Eschmeyer's Catalog of Fishes, Genera, Species, References*. https://researcharchive.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp#E pinephelidae

Yan *et al.*, 2024. *Marine Policy*, Volume 165,106200 https://doi.org/10.1016/j.marpol.2024.106200.

Akhilesh *et al.*, 2021. *Journal of the Ocean Science Foundation*, 38, 35–65.

CMFRI, FRAEED. 2024. *Marine Fish Landings in India–2023.* Technical Report. ICAR- CMFRI, Kochi

Brief Communication

Valuation of marine fish landings in India-2023

Shyam S Salim[1]*, S.S Raju[2], R. Narayana Kumar[3], P. S. Swathilekshmi[4], Swatipriyanka Sen Dash[5], Saju George[1], A.R. Anjua[1], N.R. Athira[1], Lowrane Stanley[1] and Steny Rebello[1]
[1]ICAR-Central Marine Fisheries Research Institute, Kochi-682 018, Kerala
[2]Visakhapatnam Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam -530 003, Andhra Pradesh
[3]Madras Regional Station of ICAR-Central Marine Fisheries Research Institute, Chennai-600 028, Tamil Nadu
[4]Veraval Regional Station of ICAR-Central Marine Fisheries Research Institute, Veraval – 362 269, Gujarat
[5]Field Centre of ICAR-Central Marine Fisheries Research Institute, Puri–752 002, Odisha

*E-mail: shyam.icar@gmail.com

India, being the second largest producer of fish in the world, contributes about 6.5 per cent of the global fish production. The present fish production of India is 16.24 million MT with a contribution of 4.12 million MT from marine sector and 12.12 million MT from inland sector. The Indian marine fisheries sector also contributes enormously to the economy by creating foreign exchange, food security, direct employment and income. With changing consumption pattern, emerging market forces and technological developments, the fisheries sector has assumed added importance in India and is undergoing a rapid transformation. Amidst slump in landings, the valuation of fish considerably increased on account of the realization of higher prices, movement of fish from non-consumption areas to consumption areas and augmented fish consumption. The marine fish landings exhibit wide range of volatility which might have serious impacts on the fisheries economy of the country. The pandemic COVID- 19 also had multifaceted effects on the marine fish landings as the lock down put severe restrictions and reported a reduction in the marine fish landings from different coastal states of the country. However, the demand for fish continues to increase and people prefer more of marine fish. The present study on valuation of fish, an empirical analysis analysis is an attempt to understand the valuation of fish vis-s-vis landings over the period 2023. The study was done based on the fish price realization at the point of origin (Landing Centre Prices) and point of last sales (Retail Centre Prices) for the time period sourced from FRAEED and the landings of fish were obtained from NMFDC, ICAR-CMFRI. The objectives of the study is to assess the valuation of fish landings across different states vis-à-vis different major species, its share to landings and marketing efficiency.

Valuation of fish landings

The estimate of the value of marine fish landings during 2023 at Landing Centre (LC) level was ₹60165 crores,

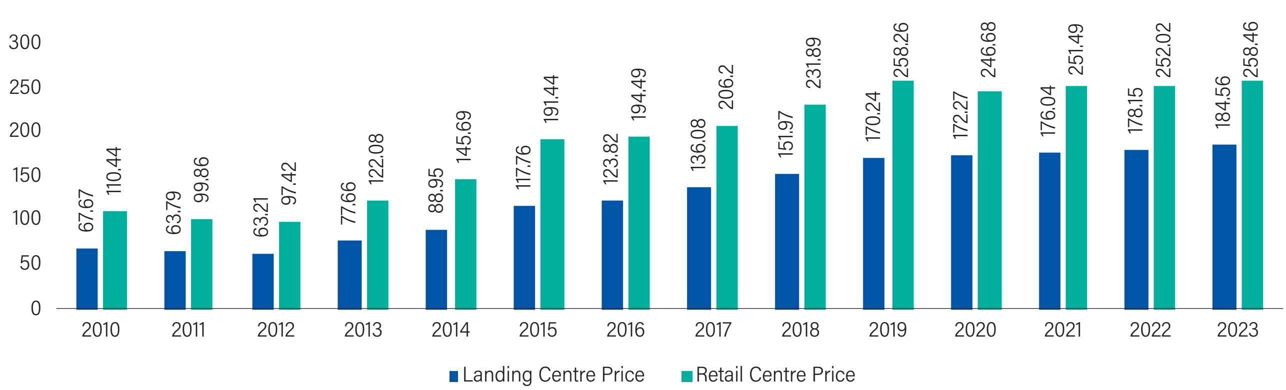


Fig. 1. Unit price at LC and RC levels (₹/kg) for the period 2010-2023

Table 1. Valuation of fish landings across states (crores)

State	LC valuation (₹ crores)			RC valuation (₹ crores)		
	2022	2023	Share (%)	2022	2023	Share (%)
West Bengal	3153	3112	5	4240	4318	5
Odisha	2521	2439	4	3388	3494	4
Andhra Pradesh	3221	3162	5	4638	4456	5
Tamil Nadu	10319	8270	14	14352	11409	14
Puducherry	771	854	1	1105	1186	1
Kerala	11053	10538	18	15146	14217	17
Karnataka	10885	9057	15	14635	12743	15
Goa	1146	1246	2	1463	1728	2
Maharashtra	3674	4309	7	4966	5917	7
Gujarat	9937	15190	25	13849	20940	25
Daman &Diu	1567	1989	3	2083	2668	3
Total	58247	60165	100	79866	83076	100

Table 2. Species wise share (%) in landings and valuation, 2023

Species	Landings (Tonnes)	Share in landings (%)	LC valuation (Rs. Crores)	Share in total value (%)	RC value (Rs. Crores)	Share in total value (%)
Oil sardine	245420	6.95	1900	3.16	3049	3.67
Lesser sardines	136878	3.88	1193	1.98	1822	2.19
Threadfin breams	207232	5.87	3119	5.18	4563	5.49
Other perches	104176	2.95	1867	3.10	2703	3.25
Ribbon fishes	269616	7.64	4329	7.19	6306	7.59
Scads	123758	3.51	2369	3.94	3285	3.95
Other carangids	109518	3.10	2200	3.66	3076	3.70
Indian mackerel	343042	9.72	5495	9.13	7512	9.04
Penaeid prawns	159201	4.51	4778	7.94	6074	7.31
Non-penaeid prawns	211260	5.98	4658	7.74	6202	7.47
Squids	105818	3.00	2245	3.73	2931	3.53

(3.29 % increase over 2022) and at Retail Centre (RC) was ₹83076 crores (4.02 % increase over 2022). The unit price per kg of fish at LC was ₹178.97 (0.74 % increase over 2022) and at RC was ₹247.62 (2.38 % increase over 2022). The marketing efficiency was 72.42 % (0.70 % decrease over 2022). The increase in the value is attributed to increase in landings during 2023.

Gujarat recorded the highest realization of prices at the landing center and retail centers registering a share of 25.00 percent and 25.00 per cent respectively over 2022. Besides, ranking second in the fish landings in the country the state of Kerala has the highest realization of prices at the retail centers registering a share of 17.00 percent and 18.00 per cent at the landing centre respectively over 2022.

Indian Mackerel accounted for the highest share of 9.72% in total marine fish landings and in value terms accounted for 9.13 % at LC level and 9.04 % at RC level (Table 2).

Price behaviour of marine fish varieties

1. Landing centre

The analysis of the landing price behavior for major species indicated a wide variation in prices across species. (Fig. 2) and across States (Table 3)

The analysis of the average RC prices for major species in India are presented in Fig. 3 and Table 4. Lobster realized

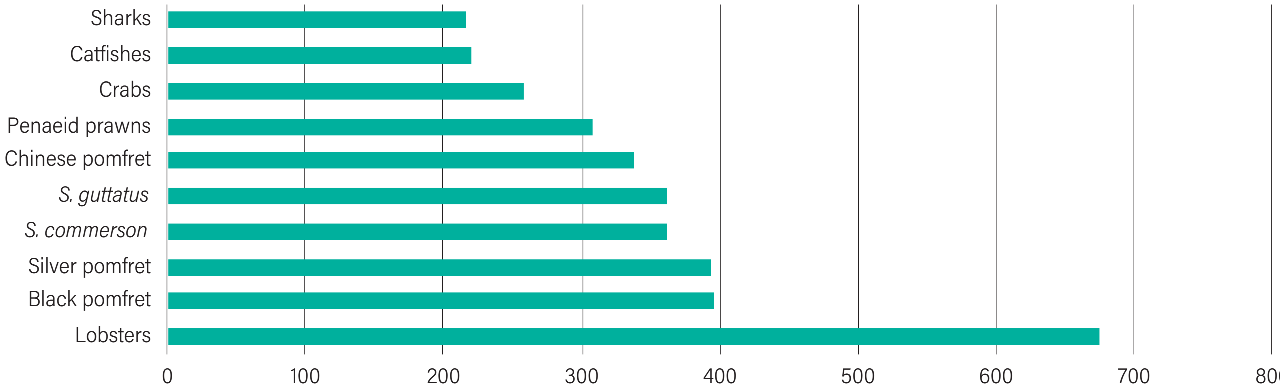


Fig. 2. Average LC price realization – All India (₹/kg)

Table 3. State-wise landing price behaviour (In ₹/kg) of major species 2023

Species	TN	GJ	KAR	KER	WB	MH	DD	OR	PU	GO	AP
Indian mackerel	127	132	125	189	141	178	165	195	126	215	172
Oil sardine	85	62	72	80	85	85	78	85	75	80	72
Ribbon fishes	159	149	138	177	151	190	223	147	182	168	165
Threadfin breams	165	162	132	172	173	224	194	219	162	190	172
Lesser sardines	87	67	84	85	78	85	115	112	72	95	117
Scads	171	195	214	178	185	230	222	185	180	200	145
Penaeid prawns	279	266	345	342	275	323	348	272	298	387	242
Non-penaeid prawns	172	219	269	220	212	238	240	185	NL	NL	168
Other carangids	183	177	227	221	158	252	230	228	210	214	202
Other perches	167	171	175	225	155	215	244	201	172	200	141

NL No landings TN- Tamil Nadu, GJ- Gujarat, KER- Kerala, KAR- Karnataka, AP- Andhra Pradesh, WB- West Bengal, MH- Maharashtra, DD- Daman & Diu, OR- Odisha PU- Puducherry, GO- Goa,

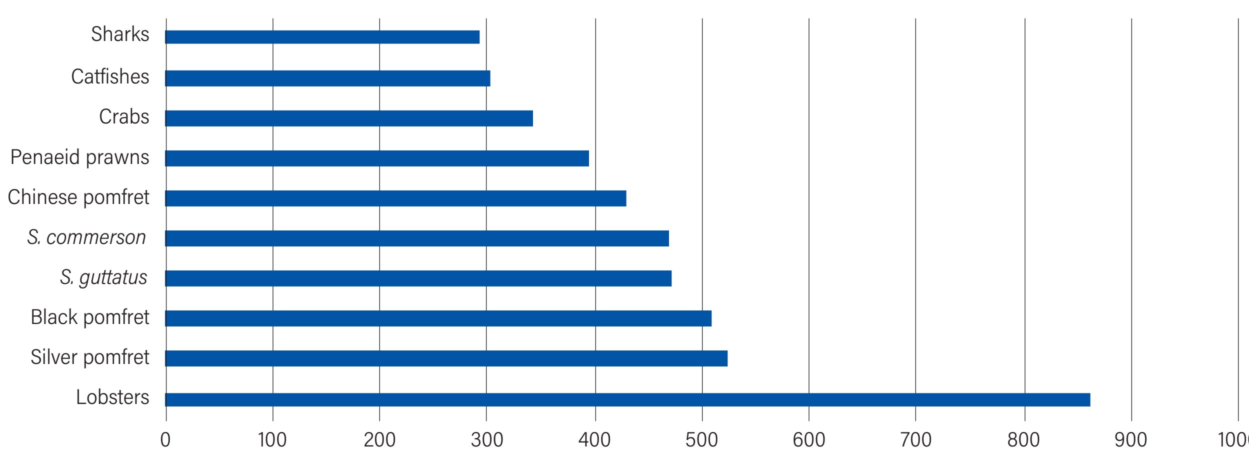


Fig. 3. Average RC price realization – All India (₹/kg)

Table 4. State-wise retail price behaviour (In ₹/kg) of major species 2023

Species	TN	GJ	KAR	KER	WB	MH	DD	OR	PU	GO	AP
Indian mackerel	181	175	168	265	179	242	242	162	179	295	224
Oil sardine	125	101	120	128	125	118	105	135	102	112	121
Ribbon fishes	220	229	214	125	212	273	280	232	247	235	222
Threadfin breams	221	252	198	239	235	297	267	298	245	342	242
Lesser sardines	132	97	125	135	115	145	153	172	102	142	185
Scads	272	289	298	235	236	292	298	253	245	333	213
Penaeid prawns	342	362	420	402	368	419	444	382	385	495	325
Non-penaeid prawns	225	289	345	325	282	330	318	262	NL	NL	232
Other carangids	252	239	292	350	219	324	323	312	292	308	282
Other perches	245	247	265	289	202	298	315	292	259	325	234

NL- No landings TN- Tamil Nadu, GJ- Gujarat, KER- Kerala, KAR- Karnataka, AP- Andhra Pradesh, WB- West Bengal, MH- Maharashtra, DD- Daman & Diu, OR-Orissa, PU- Puducherry, GO- Goa,

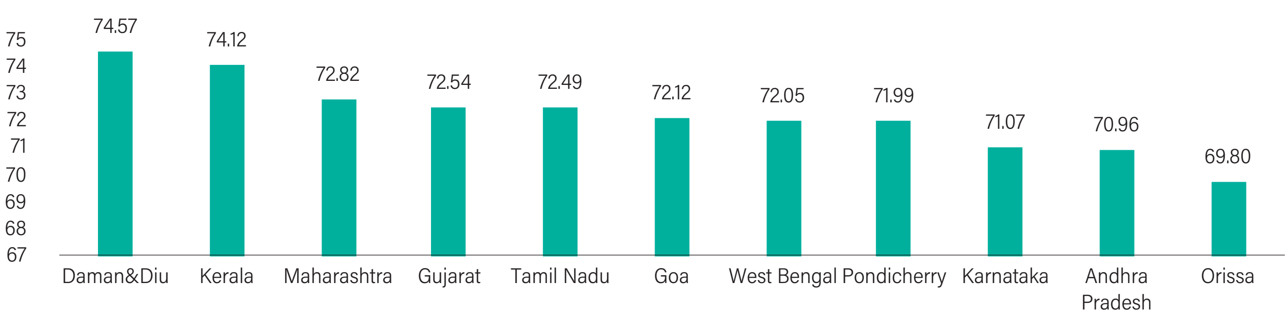


Fig. 4. Average market efficiency – All India

the highest retail price at ₹860.84 followed by silver pomfret (₹524.44).

Marketing efficiency is measured as the fishermen share of the consumer's rupee (FSCR) across the major species. The marine fish marketing efficiency across the different states in India during the period 2023 was analysed and the results indicates that Daman & Diu registered the highest (74.57 %), followed by Kerala (74.12 %) and Maharashtra (72.82%) (Fig. 4). The increase in the landings is one of the major reasons for the increased efficiency and vice versa. The marketing efficiency of the different coastal states and

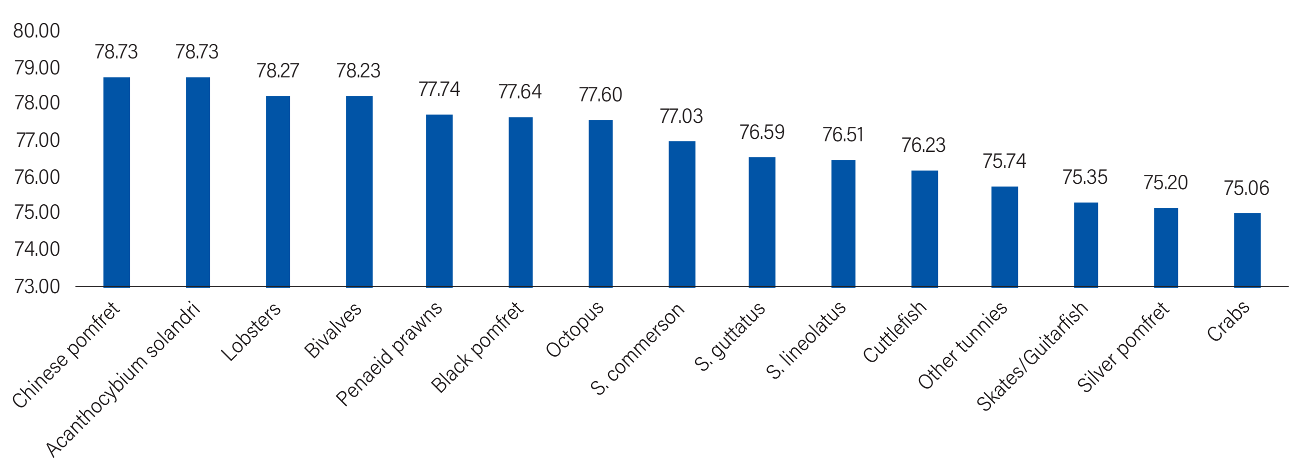


Fig. 5. Species with high marketing efficiency

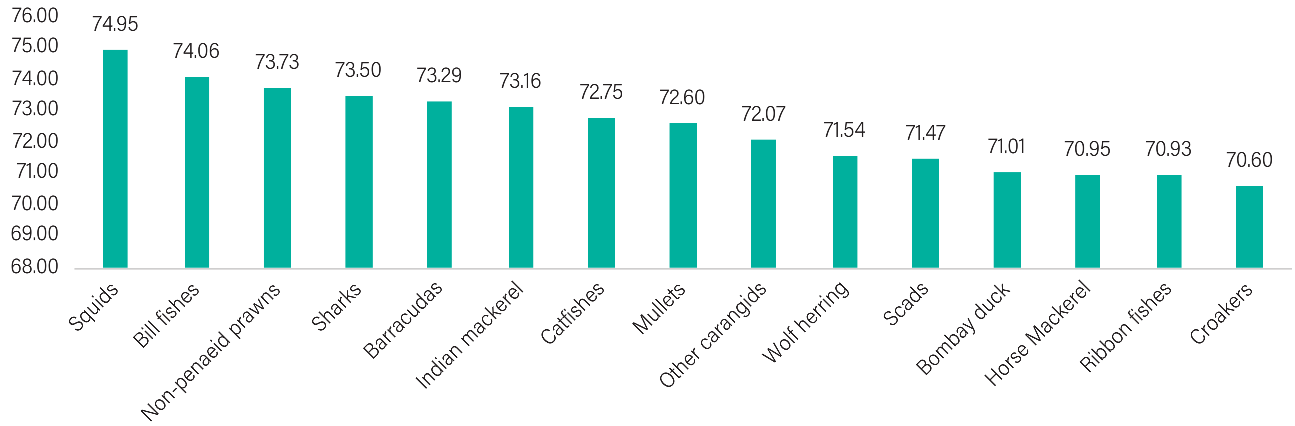


Fig. 6. Species with medium market efficiency

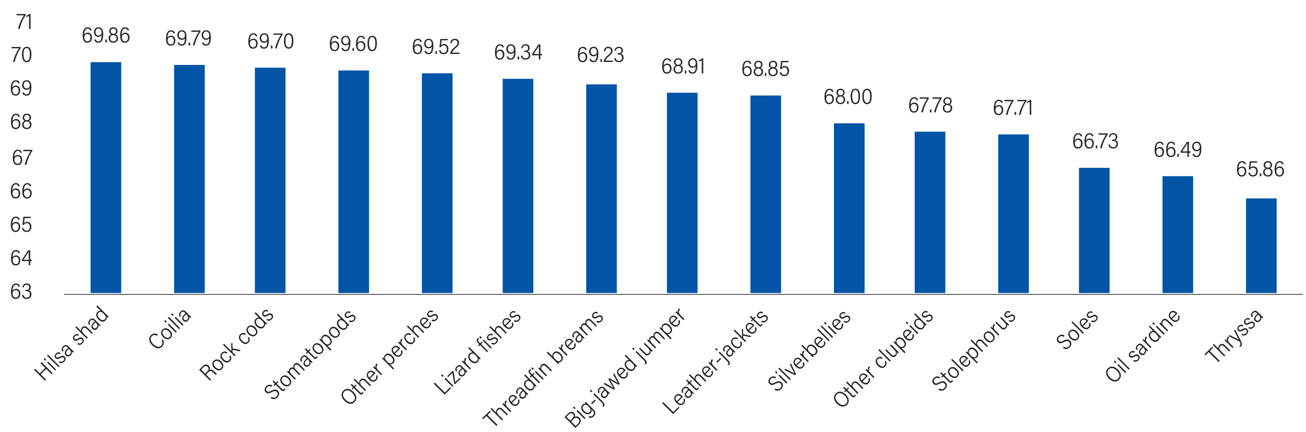


Fig. 7. Species with low market efficiency

high /medium/ low market efficient species during 2023 are clearly depicted in the figures below.

Market efficiency of species

The marketing efficiency across the major species based on the level of marketing efficiency is given in Figure 5, 6 and 7.

In general, the high value species like Chinese pomfret (78.73 %), lobster (78.27 %), bivalves (78.23 %) and penaeid prawns (77.74 %) registered higher marketing efficiencies compared to non-penaeid prawns (73.73 %), sharks (73.50 %), Indian mackerel (73.16 %) with medium marketing efficiency. The species Hilsa shad (69.86 %), Threadfin breams (69.23 %) and Oil sardine (66.49 %) registered a low marketing efficiency.

The study concluded that the valuation showed differential growth across the different coastal states. Valuation of fish has mostly increased due to the movement of fish from one state to other, which resulting in higher price realization. Price remains to be the major contributing factor for the highest revenue over the time period. The study also identified that the poor supply of fish to the domestic fish market will lead to a situation wherein the domestic consumers will be devoid of fish in the market at affordable prices. It is important to ensure the availability and affordability of high-value fishes whose consumption could be augmented by creating awareness in the country. Moreover, the efficiency of markets needs to be dealt with utmost importance. It is important to integrate domestic and international markets to ensure sustainability of fisheries trade. The different stakeholders (fishers, traders, consumers, exporters and policymakers) need to be made aware about the market and price of fishes for evolving efficient marketing systems and supporting infrastructure that would lead to better quality and prices.

Brief Communication

Restricted feeding followed by re-feeding of Indian pompano (*Trachinotus mookalee*) fingerlings: A feeding management strategy

Biji Xavier[1]*, Ritesh Ranjan[1], Sekar Megarajan[1], P. P. Suresh Babu[2], Shubhadeep Ghosh[1] and V.V.R. Suresh[3]

[1]Visakhapatnam Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam -530 003, Andhra Pradesh

[2]Karwar Regional Station of ICAR-Central Marine Fisheries Research Institute, Karwar, Uttara Kannada-581 301, Karnataka

[3]ICAR-Central Marine Fisheries Research Institute, Kochi-682 018, Kerala

*E-mail: bijicmfri@gmail.com

Introduction

Development of appropriate feeding management strategies are necessary for the optimization of feed efficiency by reducing feed wastage, deterioration of water quality and thereby ensure profitability. Different fish feeding regimes are being practiced to develop feeding protocols that are economically sustainable and cause less environmental damage by minimizing fish feed and total operational costs. Restricted feeding without growth suppression is advantageous for economic and environmental reason; result in better final product quality (Reigh *et al.,* 2006). Moreover, such feeding schedule could improve management of personnel time and water quality, with reducing feed and labour costs. A feeding strategy resulted in compensatory growth can be one of the most effective fish culture methods to overcome unfavourable environmental condition, by improving feeding activity and accelerating growth rate of fish, by reducing feed and labour costs (Cho *et al.,* 2006). The growth parameters especially low FCR can be obtained by adopting suitable feeding strategies. The amount of daily feed ration, frequency and timing of the feeding and presentation of predetermined ration are the major factors of feed management strategies which affects growth and feed conversion (De Silva and Anderson, 1995). Indian pompano (*Trachinotus mookalee*) belonging to family Carangidae is a new candidate species for mariculture in India. This fish holds immense potential for the marine finfish aquaculture sector due to its fast growth rate, easy adaptability to culture environment, fast growth rate, quick acceptance to artificial feed, pleasant appearance, good meat quality and high consumer preference and high market demand. Breeding technology for the species was developed by Visakhapatnam Regional Centre of ICAR-CMFRI in 2016 and since then seeds were consistently produced with good survival (Ritesh *et al.,* 2018). Indian pompano has been identified as potential candidate species with its excellent growth characters, reproductive potential and nutritional qualities (Sekar *et al.,* 2021). Starvation study on Indian pompano juveniles resulted with compensatory growth and significant growth performance (Xavier *et al.,* 2023). The present study aimed to investigate the effect of restricted and full-feeding regimes on growth performance, feed utilization and body composition of Indian pompano (*Trachinotus mookalee*) fingerlings.

Indian pompano (*Trachinotus mookalee*) fingerlings produced at mariculture hatchery of Visakhapatnam Regional Centre of ICAR- CMFRI was used for the feeding experiment. Two hundred and seventy fingerlings (2.0 ± 0.01gm) were distributed randomly in 9 tanks of 1000L capacity and designated as three treatments in triplicate. The fingerlings were fed with commercial diet containing 45% crude protein and 10% lipid (Growel Pvt. Ltd.). The treatments followed were: fingerlings fed with 5% of biomass (control); fingerlings fed with 3% of biomass (T_1) and fingerlings fed with 1% of biomass (T_2). After this restricted feeding period (45days), the fingerlings of each treatment (T_1& T_2) re-fed with 5% of their body weight for another 30 days along with the existing control. According to the feeding schedule, the diet was given thrice a day (10.00, 12.00 & 15.00 hrs) and water exchange was carried out daily. Water quality parameters like temperature, pH, Dissolved Oxygen, free CO_2 and alkalinity, Total Ammonia Nitrogen (TAN), nitrite nitrogen (NO_2-N) were measured through multiparameter devices (YSI, model 55-12FT, YSI Corporation, USA) and salinity was measured with a refractometer (Atago S/Mill-E, Atago Co. Ltd, Tokyo, Japan). Duration of the trial was 75days. The first phase of the experiment lasted for 45 days and tested a restricted feeding regime.

Biological parameters of fish

Growth performance was measured by weighing of the fishes at fortnightly intervals. The fishes were starved of the first ration of the feed on the sampling day. After weighing, the second ration of the feed was given according to the feeding schedule of the experimental groups.

Specific growth rate per day (SGR/Day %) was calculated according to De Silva and Anderson (1995).

Relative weight gain (%), WG= 100 × (Final weight -Initial weight)/Initial weight.

Specific growth rate (% /day), SGR= In (Final weight) – In (Initial weight) / Experimental periods in days × 100

where 'In' is the natural logarithmic value.

Feed conversion Ratio = Feed given (dry weight) / Body weight gain (wet weight)

Feed intake (% /day) = 100 × (Feed consumption (g) / (average biomass (g)) × days

On completion of the experiment, number of fish in each tank was counted and the survival rate (%) was calculated by the following formula:

Survival (%) = Total number of fish present / Total number of fish stocked×100

Fulton's condition factor ($K = W \times 100/ L^3$; where W and L are observed weight and length) was estimated to assess the condition of the individual sampled fish.

At the end of the experiment, five fish from each tank was sacrificed to study proximate composition (AOAC, 1990). Moisture content was determined by drying the fishes in an oven at 105^{0}C till constant weight. The protein content of the moist free samples were determined using the Kjeldahl method after acid digestion. The crude lipid content was determined by Soxhlet method using petroleum ether as solvent. Ash content was determined by incinerating the moisture free sample in muffle furnace at 550 $^{\circ}$C to constant weight. All analyses were performed in triplicate and statistical analysis was carried out using statistical software, SPSS 21. During the experimental period, the water quality parameters were in optimum range viz; salinity 30 ± 0.02ppt, dissolved oxygen 5.76 ± 0.03ppm; ammonia nitrogen 0.08 ± 0.002ppm; pH 7.72 ± 0.01; nitrite 0.006 ± 0.001ppm; temperature 28 ± 0.03^{0}C. There was no mortality recorded during the experimental period neither during the restricted feeding nor the re-feeding period. Initial fish body weights did not differ significantly; however, fish weights differed ($p<0.05$) among the feeding groups after 45 days of feed restriction and at the end of the experiment ($p<0.05$). Final fish weight and weight gain percentage increased in all groups by increasing feed ration from T_2–control. Control presented significantly ($p < 0.05$) highest final body weight and weight gain percentage compared with other 2 treatments during the restricted feeding period. Fingerlings of T_2 group presented a significantly ($p<0.05$) lower SGR compared with other 2 treatments, meaning that restricted ration of 1% of biomass had a severe effect on the fish growth. FCR also had similar effect as that of WG % (Table 1). During the re- feeding period the fingerlings maintained in different treatment groups, there was an improved growth performance when compared to control group irrespective of the number of feeding days. At the end of the first phase of re-feeding for 15 days (60 DOC) the growth performance of T_1 group was significantly ($p<0.05$) different from the control group and T_2 in terms of WG% (173.05±0.32). The fish weights in T_1 and T_2 groups were less than those in the control ($p<0.05$), suggesting only a partial compensation growth occurred. Whereas, during the re-feeding of fish for the consecutive 30 days followed by restricted ration, the fish in T_1 ($p<0.05$) group caught up (WG% 268.79±0.94 & SGR 1.74±0.01) with the weight of the control fish (DOC 75days). It showed complete compensation growth occurred in these fishes.

The results from analysis of condition factor of the fingerlings fed on different feeding regimes reveals that K value (Table 1) was always more than 1 irrespective of the feeding regimes. There was significantly ($p<0.05$) high K value was recorded in control (1.9±0.05) and the value was decreasing with the feeding ration during the restricted feeding. However, with the re-feeding period, the condition factor was improved in T_2 fed group, which was similar to control fed group ($p>0.05$).

Body composition analyses

Whole body composition of Indian pompano fingerlings on restriction as well as the re- feeding period is presented in Table 2. With respect to the body composition of the fish, no significant differences were found in the protein content between the different treatments. However, during the restricted feeding period, the lipid content of the fingerlings was performed a decreasing trend from control to T_2 and also inversely related to the moisture content. However, during the re-feeding period, both the control and T_1 fed group of fingerlings performed similar lipid content and which was different from T_2 fed group ($p<0.05$). Ash content was significantly increasing ($p<0.05$) with the treatments from control to T_2 during restricted feeding period with highest and lowest ash content was observed in T_2 and control fed group respectively. The ash content was significantly ($p<0.05$) reduced during the refeeding period

Table 1. Effect of feeding regime on growth and nutritive parameters (mean ±SE) of Indian pompano fingerlings during the experimental period.

Growth Parameters	Restricted feeding (DOC 45days)			Re- feeding for 15days (DOC 60days)			Re-feeding for 30days (DOC 75 days)		
	Control	T_1	T_2	Control	T_1	T_2	Control	T_1	T_2
Initial body weight(gm)	2.83±0.01	2.82±0.01	2.82±0.02	2.83±0.01	2.82±0.01	2.82±0.02	2.83±0.01	2.82±0.01	2.82±0.02
Final body weight (gm)	6.04±0.03^c	5.29±0.01^b	3.33±0.02^a	8.13±0.06^c	7.75±0.03^b	5.80±0.02^a	9.85±0.03^b	10.40±0.01^c	7.4±0.23^a
Condition factor	1.9±0.05	1.36±0.05	1.25±0.05	1.9±0.05	1.75±0.05	1.35±0.05	1.9±0.05	1.9±0.05	1.5±0.05
Average WG/fish(gm)	3.22±0.01^c	2.49±0.01^b	0.52±0.01^a	5.3±0.03^c	4.93±0.01^b	2.98±0.03^a	7.10±0.06^b	7.60±0.01^c	4.58±0.02^a
Daily feed intake	3.22±0.01^c	2.10±0.001^b	0.73±0.001^a	3.64±0.01^a	2.59±0.01^b	1.2±0.01^c	4.36±0.01^a	3.16±0.01^b	2.26±0.03^c
WG (%)	116.04±1.17^c	87.94±1.04^b	17.79±1.23^a	187.74±0.61^c	173.05±0.32^b	106.93±0.18^a	251.42±2.6^b	268.79±0.94^c	148.41±0.62^a
FCR	2.71±0.05^b	2.01±0.02^a	2.18±0.15^b	2.52±0.01^c	1.84±0.01^b	1.04±0.01^a	2.74±0.03^c	1.95±0.01^b	1.70±0.02^a
SGR	1.71±0.02^c	1.40±0.01^b	0.36^a±0.01^a	1.76±0.01^c	1.67±0.01^b	1.21±0.01^a	1.68±0.01^b	1.74±0.01^b	1.21±0.03^a

Values (Mean of triplicate ± SE) in the same column sharing different superscript letters are significantly different ($p<0.05$).T_1: Restricted feeding@ 3% biomass; T_2: Restricted feeding @ 1% biomass

Table 2. Body composition of Indian pompano fingerlings subjected to different feeding regimes during 75 days of rearing

Body composition	Restricted feeding (45 days)			Refeeding (30 days)		
	Control	T_1	T_2	Control	T_1	T_2
Moisture	67.57±0.05	68.70±0.05	69.10±0.05	67.37±0.05	69.10±0.05	69.15±0.05
Protein	18.34±0.09	18.38±0.09	18.38±0.09	18.27±0.08	18.26±0.09	18.07±0.07
Lipid	10.04±0.09^c	8.68±0.05^b	8.10±0.05^a	10.14±0.07^a	10.13±0.05^a	9.18±0.05^b
Ash	2.16±0.01^a	2.93±0.01^b	3.28±0.01^c	2.16±0.01^b	2.01±0.01^a	2.30±0.01^c

Values (Mean of triplicate±SE) in the same row sharing different superscript letters are significantly different (<0.05)

with lowest content in T_1 fed group of pompano fingerlings followed by control fed group.

The effect of restricted feeding followed by re-feeding on growth performance, feed utilization and body composition of Indian pompano (*Trachinotus mookalee*) fingerlings were studied in the present experiment. Results demonstrated that, during the restricted feeding, the body weight of fingerlings were less compared to the normal fed group (control) of fingerlings. However, during the re-feeding period of first 15 days, fingerlings were nearing to compensation and followed by next 15 days, complete compensation was observed. Fingerlings changed from restricted to re- feeding after 45 days showed a trend toward increase in specific growth rate accompanied by increase in feed consumption. The present study also confirms the result that hyperphagia in pompano fingerlings during the refeeding period after the feed restriction. The health condition of fingerlings is not affected when following feeding regime of restricted ration followed by full feeding. Proximate composition results from our study reveals that moisture, crude protein and ash showed no significant differences among the groups. However, the body lipid content of fingerlings showed reduction during the restricted feeding period, may be due to the utilization of lipid for the protection of basal metabolism and survival during the period.

It can be concluded that the best group from our study in terms of compensatory growth, and feed utilization Indian pompano fingerlings fed with 3% of biomass for 45 days followed by full feeding for another 30 days. This feeding strategy can be practically applied in grow out culture of Indian pompano especially when cultured in high stocking density with minimum feeding for long duration followed by normal feeding for short duration which will reduce the cost of production for pompano during culture.

References

AOAC 1990. Association of Official Analytical Chemists. Official Methods of Analysis of the Association of Official Analytical Chemists, vol. 1, 14th edn. 1102 pp.

Cho *et al.*, 2006. *J World Aquac Soc.*, 37: 168– 174.

doi: 10.1111/j.1749-7345.2006.00023.x

De Silva and Anderson, 1995. Fish nutrition in aquaculture. Chapman & Hall Aquaculture Series, p. 319

Reigh *et al.*, 2006. *Aquaculture*, 254, 506–516. https://doi.org/10.1016/j.aquaculture.2005.10.043

Ritesh *et al.*, 2018. *Aquaculture*, 495. pp. 550-557.

Sekar *et al.*, 2021. *Aquaculture*, 545. pp. 1-13.

Xavier *et al.*, 2023. *Aquaculture*, 572. pp. 1-7. ISSN 1873-5622

Science Corner

Climatic Impact-Driver framework for unfolding climate change hazards along the Indian coast

Reshma Gills*, Shelton Padua, C. Ramachandran, Eldho Varghese, K. R. Ratheesh, Grinson George, Rose P. Bright, E. Vivekanandan, J. Jayasankar and A. Gopalakrishnan
ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala
* Email: reshma1818@gmail.com

ABSTRACT

Climate change, driven largely by anthropogenic activities, has led to global shifts in climate patterns, resulting in rising temperatures, frequent extreme weather events, and ecosystem disruptions. These changes pose significant threats to natural habitats, agriculture, public health, and coastal livelihoods, particularly in regions like India. This paper examines the hazard-proneness of India's coastal districts using the CIDs (Climatic Impact-Drivers) proposed in the AR-6 of the Intergovernmental Panel on Climate Change (IPCC) framework, highlighting the physical manifestations of climate risks, including cyclones, floods, heatwaves, sea level rise, and shoreline erosion. The paper emphasized the importance of localized impact assessments alongside global climate risk evaluations, revealing regional disparities shaped by localised cultural factors. By integrating scientific insights with local contexts, this analysis provides a foundation for crafting tailored, equitable adaptation and mitigation strategies to enhance resilience in the face of escalating climate threats.

Keywords: *Risk, Climatic Impact-Drivers, Hazards,*

Introduction

Climate change is a long-term shift in global or regional climate patterns, largely attributed to human activities. It manifests in rising temperatures, more frequent extreme weather events, and significant changes in ecosystems (Shivanna, 2022). This phenomenon disrupts natural habitats, affects agriculture, and poses challenges to human health and safety. The consequences are widespread, impacting everything from sea levels to biodiversity. Rising global temperatures result in melting polar ice caps and glaciers, contributing to sea-level rise, which threatens coastal communities. Extreme weather events, including more intense hurricanes, floods, and droughts, become increasingly common, disrupting ecosystems and human life (Clarke, et al., 2022). Like in every other part of the globe, climate change in India has led to increased temperatures, resulting in more frequent and intense heat waves that impact public health and agriculture (de Bont et al., 2024; Hussain et al., 2024). For example, a severe heatwave in March 2022 saw temperatures surpass 43°C, causing crop failures and fatalities (Bal et al., 2022; Ravindra et al., 2024). Precipitation pattern changes have triggered both flooding and droughts, disrupting the monsoon-dependent agricultural sector. Extreme rainfall events have become more frequent, leading to floods that damage infrastructure and displace communities, while some areas face prolonged dry spells, affecting water supplies and crop yields. The melting of Himalayan glaciers threatens long-term water security, and climate change exacerbates urban air pollution, particularly in cities like Delhi. In the same way, the livelihoods of more than 4 million population (BOBP, 2023) reliant on coastal and marine fisheries in India are under growing threat from climate change. Rising sea levels, eroding shorelines, and extreme weather events are causing significant damage to fishing infrastructure, such as boats and nets, while also increasing risks for those working at sea. Coastal communities face displacement as critical fish landing centres become submerged. Additionally, climate change is taking a toll on ocean ecosystems. Ocean warming is disrupting fish migration patterns and breeding cycles, leading to a decline in traditional fish stocks. Coral reefs, vital for marine biodiversity, are suffering from bleaching due to rising sea temperatures, resulting in habitat loss and further straining fisheries-dependent livelihoods.

According to the Intergovernmental Panel on Climate Change (IPCC) framework, climate change impact assessment and risk assessment are closely intertwined. Together, they provide a comprehensive understanding of the risks posed by climate change, informing policymakers about where and how to act (Simpson et al., 2021). By integrating these assessments, the IPCC framework enables more effective prioritization of adaptation and mitigation efforts, ensuring that strategies are tailored to reduce vulnerability and enhance resilience in the face of growing climate risks at global level. Impact assessment focuses on identifying and quantifying the effects of climate change on specific sectors like agriculture, water resources, health, or biodiversity. The IPCC uses risk assessment as a core methodology to evaluate the potential consequences of climate change on natural and human systems (IPCC, 2022). On a global scale, it helps identify overarching threats, such as rising sea levels, extreme weather events, and disruptions to critical ecosystems, enabling coordinated international efforts to mitigate these risks. However, these global trends often mask regional and local nuances, where the impacts of climate change are shaped by geographic, socio-economic, and cultural factors. Hence, though the global assessments provide valuable insights, there is increasing recognition of the importance of conducting region-specific and local-scale evaluations to address unique challenges and contexts effectively. By integrating dual perspectives both global insights and localized data, risk assessments are crucial for crafting tailored solutions that consider the specific needs and vulnerabilities of affected regions, ensuring more effective and equitable responses to climate change. Against this backdrop, this paper delves into the hazard-proneness of India's coastal districts, a critical component of the climate change risk analysis framework outlined by the Intergovernmental Panel on Climate Change (Gills et al., 2024). By focusing on hazard-proneness, the study highlights the physical manifestations of climate risks specific to Indian coastal districts. This is particularly relevant given the nation's extensive coastline of over 7,500 kilometers, where densely populated areas, economic hubs, and biodiversity hotspots intersect. The findings contribute to a deeper understanding of the risks posed by climate-induced hazards and serve as a foundation for assessing the interplay of exposure and vulnerability.

Frameworks for climate risk assessment: concept, dimensions and metrics

Concept of risk and risk assessment

The concept of risk in the IPCC framework has undergone significant refinement between its AR5 (Fifth Assessment Report) and AR6 reports (Sixth Assessment Report), reflecting the evolving understanding of climate change impacts and the need for actionable solutions. Till the AR5 Vulnerability was the central theme for the assessment and was often treated as a static condition, determined by socio-economic factors, geographic location, and the adaptive capacity of communities. This approach emphasized the identification of at-risk populations and ecosystems, laying the groundwork for understanding climate-related risks as a product of external drivers and local sensitivities. By 2022, the IPCC Sixth Assessment Report introduced a more dynamic perspective on risk and vulnerability, emphasizing the interconnectedness of human and natural systems and the concept of risk became central to the approach for evaluating and conveying the potential adverse impacts of climate change, as well as the available response options, to decision-makers. In the context of climate change, risks arise from the interaction of climate-related hazards with the exposure and vulnerability of affected human or ecological systems. The magnitude, likelihood, and dynamics of hazards, exposure, and vulnerability can vary over time and space due to socio-economic changes and human decisions, adding layers of uncertainty. Similarly, in climate change responses, risks stem from the potential failure to meet intended objectives or from trade-offs and negative side effects on other societal goals, like the Sustainable Development Goals. These risks may arise from uncertainties in the implementation, effectiveness, or outcomes of policies, investments, technologies, and system transitions (Reisinger et al., 2020). Thus, risk assessment in the new framework considers three key components: hazard (the climate-related events such as heatwaves, floods, or storms), exposure (the presence of people, assets, or ecosystems in harm's way), and vulnerability (the sensitivity and adaptive capacity of the affected systems).

Redefining hazards

Over successive IPCC assessment reports, the conceptual framework for understanding climate change and risk has evolved, leading to technical refinements in key constructs such as hazards, exposure, and vulnerability. For instance, the IPCC Fifth Assessment Report (AR5) defined hazard as *"the potential occurrence of a natural or human-induced physical event, trend, or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources."* This definition emphasized dimensions such as climate-related physical events, trends in the frequency or intensity of such events, and assumes that all hazards inherently carry the risk of harm. However, the Sixth Assessment Report (AR6) introduced a more refined perspective, clarifying that the term "hazard" should not be used generically to describe all climatic events or trends. Instead, it highlighted that not all such phenomena lead to adverse consequences for every aspect of an affected system. For instance, an increase in temperature may harm agriculture in tropical regions but extend growing seasons in colder climates. Similarly, increased rainfall can cause flooding in vulnerable areas but benefit water-scarce regions. This conceptual refinement separating the potential occurrence of a climate phenomenon from its contextual outcomes, ensures a more precise and context-sensitive understanding of hazards, focusing on their potential to cause harm based on the interplay of exposure and vulnerability. Hence it was suggested to use the concept of 'Climatic Impact-Drivers (CIDs)' to provide a more distinguished approach to understanding how climate factors directly influence human and ecological systems (Ranasinghe et al., 2021; Ruane et al., 2022). A key distinction between CIDs and hazards lies in their scope and applicability. CIDs are defined as physical climate system conditions that affect living organisms or built environments and can be beneficial, neutral, or harmful, depending on the context. Unlike traditional notions of hazards, which focus solely on adverse consequences, CIDs encompass a broader range of climate-related phenomena, such as temperature changes, rainfall variability, droughts, frost events, and extreme weather conditions. This influence can manifest in various forms, such as extreme events (like hurricanes or heatwaves), episodic occurrences (like seasonal rainfall), or even long-term average conditions (such as gradual temperature changes or shifting rainfall patterns).

According to the IPCC's AR6 (2022), Climatic Impact-Drivers (CIDs) are categorized into seven different types, each representing specific climate-related conditions that can affect human and ecological systems. These categories include dry and wet conditions, wind, snow and ice, coastal conditions, oceanic conditions, and other climate-related factors. Within each of these categories, a variety of indices can be used to quantify and describe the specific features of the climate impact-driver that are most relevant to different sectors or regions. In total, the IPCC has identified 33 distinct indices that help capture the diverse impacts of CIDs, ranging from temperature changes and precipitation patterns to extreme weather events and oceanic phenomena. These indices allow for more targeted assessments of how specific climatic drivers might affect ecosystems, economies, and communities. When experts determine that a CID is harmful to a particular system, it is often classified as a hazard. This classification is based on the severity of the CID as defined by certain indices and thresholds. For example, a heatwave or a hurricane might be considered a hazard in certain areas due to its potential to cause harm. The threshold for a Climatic Impact-Driver refers to the specific point at which the interaction between the CID and the exposed or vulnerable system leads to significant changes in impact, risk, or opportunity. These thresholds can be determined by various factors, including the magnitude, duration, frequency, timing, and spatial extent of the CID. For example, a threshold might be reached when a temperature rise surpasses a certain degree, triggering crop damage or public health issues.

CIDs relevant to coastal hazard analysis

Recent studies have highlighted several Climatic Impact-Drivers (CIDs) from the IPCC AR6 framework that are particularly relevant to the Indian context, especially concerning coastal hazards. However, there was a lack of region-specific studies detailing the CIDs pertinent to coastal areas in India. As a result, this study adopted a deductive approach to identify and select appropriate CIDs based on sector-specific research, previous studies on coastal hazards, and expert consultations and selected, five key coastal hazards having significant potential to adversely impact the coastal socio-ecosystems. These hazards include sea-level rise, flood proneness, shoreline changes, heatwaves, and cyclone proneness. To assess the CIDs associated with these coastal hazards, the study selected the appropriate CID types from the IPCC

AR6 framework. The three key CID types chosen for the assessment were coastal, heat & cold, and wind. Under each of these CID types, specific CID categories were identified and assessed using relevant threshold-based CID indices. For the coastal CID type, five categories were considered: sea level rise, coastal flood, coastal erosion, stable coastal line and accretion. These categories reflect critical coastal hazards that directly impact infrastructure, ecosystems, and human communities. These indices are calculated using data from sources like Copernicus NCCR, MoES and the Indian Meteorological Department (IMD). Similarly, extreme heat event was included under the heat & cold CID type, reflecting the growing risks posed by increasing temperatures in coastal regions (Data source; IMD). For the wind CID type, eight categories including 'Sustained Surface Winds in CS,' 'Sustained Surface Winds in SCS', 'CS Return Period', 'SCS Return Period', 'Landfall Count', 'Storm Surge', 'Probable Rainfall in SCS' and 'Probable Rainfall in CS', as these are particularly pertinent to the region's vulnerability to storms and extreme weather events (Data source; IMD). In total, 14 threshold-based CID indices were selected to quantify the intensity of these Climatic Impact-Drivers and assess the risk levels of different coastal hazards.

Hazard index calculation

The Hazard Indices derived from these CIDs are the Sea Level Rise Hazard Index (SLRHI), Flood Hazard Index (FHI), Heatwave Hazard Index (HWHI), Shoreline Change Hazard Index (SLCHI), and Cyclone Hazard Index. The Sea Level Rise Hazard Index (SLRHI), Flood Hazard Index (FHI), and Heatwave Hazard Index (HWHI) were developed using a quotient-based indexing method. Sea level rise data from the Copernicus database (in meters) was used to calculate the SLRHI, while the IMD data on hazard events from 1969 to 2019 informed the FHI and HWHI. District-level data for sea level rise, floods, and heatwaves were normalized using the Min-Max procedure, scaling values between 0 and 1. The state-level hazard index was derived by averaging the district-level hazard indices. The Shoreline Change Hazard Index (SLCHI) was calculated based on three important dimensions: stable, erosion and accretion, in which erosion and accretion status are quantified into high, moderate, and low levels based on the rate of change (m/year). To account for varying coastal lengths across maritime states, the data was normalized by converting the shoreline change into a proportional change, calculated by dividing the coastal length at each level by the total coastal length of the states and districts. This adjustment ensures the index reflects the intensity of shoreline change relative to the state's and district's coastal size. Experts assigned weights to different shoreline alteration levels for calculation. The three accretion levels (high, medium, and low) were given weights of 50, 33, and 17, respectively, while the erosion levels received the reverse weights. The stable level (no shoreline change) was assigned a weight of 1. The shoreline change index for each coastal district was then calculated by summing the weighted levels of shoreline change. Similarly, the Cyclone Hazard Index (CHI) calculation uses data from eight CID indices related to cyclonic activity within 50 nautical miles of coastal districts between 1961 and 2020. To standardize the data, all CID indices were normalized to a unitless range of 0 to 1. Expert opinions were used to assign weights to different CIDs to reflect the severity of cyclones. For example, longer return periods for cyclones were assigned negative weights of -2 and -4 for cyclonic storm and severe cyclonic storm return periods, respectively. Other CIDs like surface wind and maximum rainfall in a cyclonic storm were given a weight of 1, while landfall count, surface wind in a severe cyclonic storm, and maximum rainfall in a severe cyclonic storm were assigned a weight of 2. Given its significant impact, storm surge was assigned the highest weight of 5. The Cyclone Hazard Index was then calculated by summing the weighted normalized CIDs.

The Multi-Hazards Index (MHI) a composite metric that represents the relative proneness of coastal districts to multiple physical hazards included in the study was also derived. It consolidates the effects of various individual hazards, such as sea level rise, floods, cyclones, heatwaves, and shoreline changes, into a single index. To calculate the MHI, the normalized values of each individual hazard were summed and then rescaled to a uniform range of 0 to 1 (Equation 1). This approach ensures that the index provides a standardized measure of multi-hazard proneness across coastal districts, offering a clearer understanding of cumulative risk levels and enabling more informed decision-making for disaster management and climate adaptation strategies.

$$\mathrm{MHI} = \sum_{t=1}^{5} \mathrm{W_t NHI_t} \qquad \text{(Equation 1)}$$

where,

NHI_t= Normalised Hazard Index calculated for the t^{th} physical hazard considered in the study
W_t = weightage given to the t^{th} physical hazardindex (in the present study we assumed equal weightage W=1).

Hazard proneness of coastal districts and maritime states of India

The normalized hazard indices for India's coastal states and Union Territories reveal significant variations in vulnerability to multiple physical hazards, including cyclones, floods, heatwaves, shoreline changes, and sea level rise (Fig. 1). Odisha and West Bengal emerge as the most cyclone-prone, with scores of 1.00 and 0.96, respectively, while Andhra Pradesh exhibits the highest vulnerability to heatwaves (1.00). Flood risk is particularly severe in Kerala (1.00) and Andhra Pradesh (0.79). Shoreline change is a critical concern for West Bengal (1.00) and Puducherry & Karaikal (0.74), while Daman & Diu (1.00) and Gujarat (0.93) are the most affected by sea level rise. The composite Multi-Hazard Index (MHI) identifies Andhra Pradesh (1.00) as the most vulnerable overall, with significant risks across all hazard categories, followed by Odisha (0.48) and Gujarat (0.42). States like Goa (0.00) and Daman & Diu (0.08) have minimal multi-hazard exposure but still require localized interventions for specific risks. These findings highlight the need for region-specific adaptive strategies to address the diverse climate-related challenges across India's coastal regions.

District-level analysis of physical hazard severity across west coast and east coast

Among the west coast states, in Gujarat, sea level rise hazard is critically high, particularly in the districts along the Saurashtra coast and Diu. Cyclone and shoreline change hazards are relatively low, while heat wave severity is minimal. Gir Somnath and Devbhumi Dwarka report the highest HWHI in the state, with Gir Somnath also showing higher cyclone hazard severity. Maharashtra records flood hazards as its most severe concern, particularly in Mumbai City, Thane, and Ratnagiri. Cyclone and sea level rise hazards fall into moderate severity, with Palghar, Mumbai City, and Thane being the most affected. Shoreline change is most severe in Palghar, while districts like Ratnagiri and Mumbai suburban show moderate impacts. Goa experiences moderate severity for sea level rise and cyclone hazards, while shoreline change is more pronounced in North Goa compared to South Goa. The southern district faces greater risks from sea level rise and cyclones. Kerala leads in flood hazard severity. Cyclone and heat wave hazards are minimal, and Thiruvananthapuram has the highest FHI. Similarly, the states on the East Coast also showed a varying degree of proneness to different hazards. Tamil Nadu is highly prone to cyclone hazards, particularly in northern districts, with Ramanathapuram being the most vulnerable (CHI: 0.76). The state also exhibits moderate sea level rise risk, with Cuddalore and Villupuram particularly affected. Chennai experiences significant susceptibility to flooding (FHI) and heat waves (HWHI). Shoreline change is most severe in Thiruvarur and Villupuram, while Puducherry and Karaikal face minimal flood and heat wave hazards but high sea level rise risks. Heat waves and cyclones are the most severe hazards in Andhra Pradesh, with HWHI and CHI values indicating high vulnerability. Flood risks are also significant, while sea level rise and shoreline change hazards are relatively lower. West Godavari and Vizianagaram are the most affected districts by heat waves and cyclones, respectively. Cyclones present

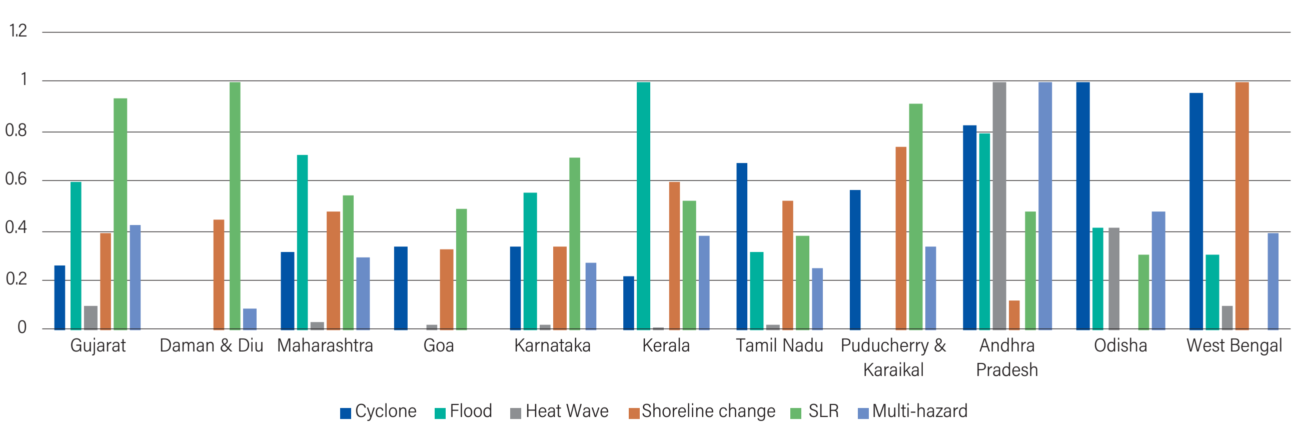


Fig.1. Hazard proneness of coastal states and Union territories of India based on normalised hazard index

extremely high severity in Odisha, with the state having faced 260 storms in the last century. Baleshwar is the most vulnerable district to cyclonic hazards. Floods and salinization are additional consequences. Shoreline change and heat wave hazards are minimal, with Bhadrak being the least prone to shoreline changes among Indian coastal districts . Similarly, Cyclones and shoreline changes are the most severe hazards in West Bengal. North 24 Parganas is highly vulnerable to shoreline erosion, while sea level rise poses the lowest risk among the hazards studied. The state demonstrates an alarming trend for erosion-driven shoreline changes, with all three coastal districts—East Midnapore, South 24 Parganas, and North 24 Parganas—being significantly affected .

The hazard atlas, derived from the multi-hazard index (Figure 2), highlights significant variability in hazard severity across coastal districts. Sindhudurg district in Maharashtra stands out with the lowest score, indicating minimal susceptibility to climate change-induced physical hazards. In contrast, Krishna district in Andhra Pradesh records the highest score, signifying its extreme vulnerability to a combination of hazards such as cyclones, floods, and heatwaves . This divergence highlights the diverse risk profiles of India's coastal regions, influenced by varying geographic, climatic, and environmental factors.

Factoring the hazards index and policy implications

The East Coast maritime states of India exhibit a higher susceptibility to climate change-induced hazards compared to their West Coast counterparts, as indicated by the multi-hazard index . This differential vulnerability is attributable to a combination of natural and anthropogenic drivers, including geomorphological characteristics, regional climatic regimes, monsoonal dynamics, and oceanographic processes. On the West Coast, key hazards such as flooding, shoreline erosion, and sea level rise dominate. The rise in sea levels, primarily driven by thermal expansion of seawater and cryospheric melting,

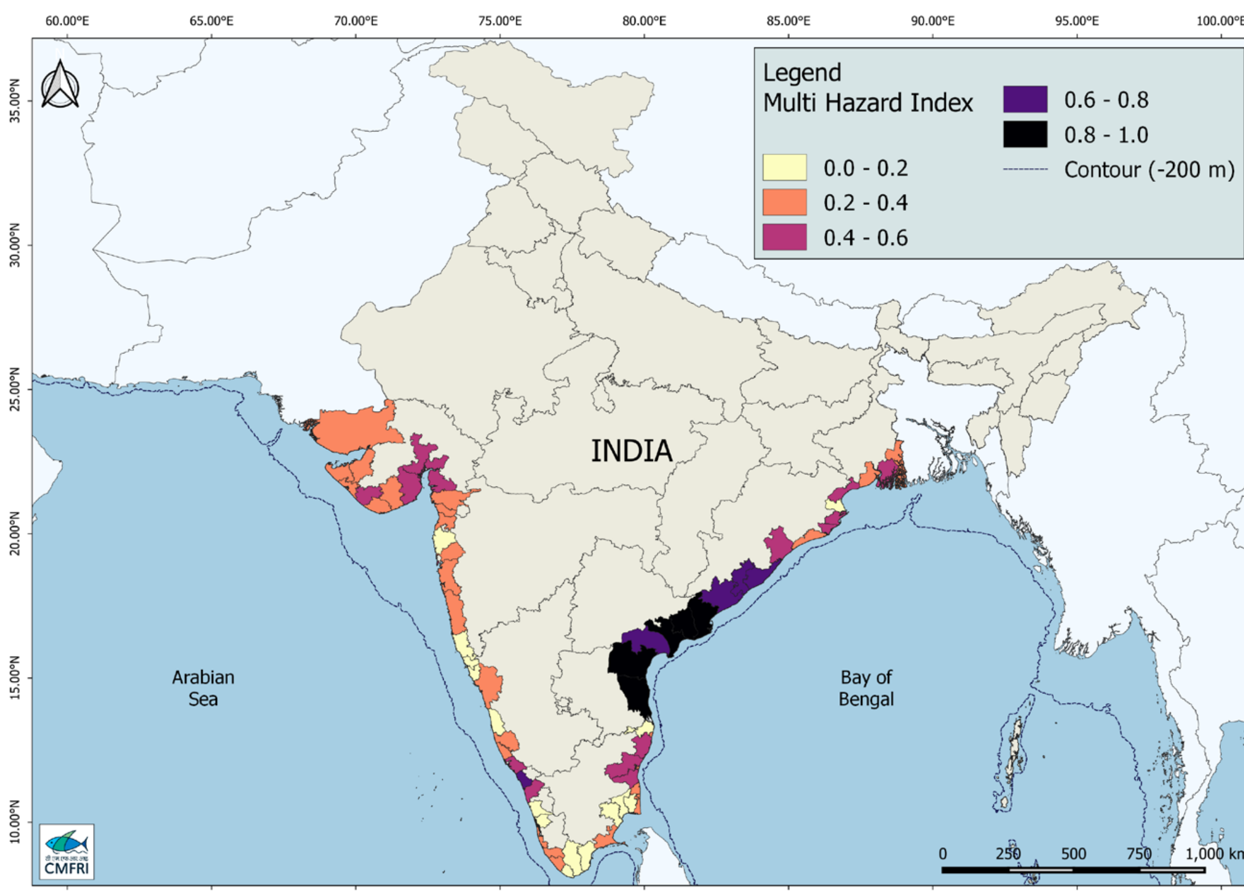


Fig. 2: Map depicting multi-hazard index across the coastal districts

exacerbates coastal flooding, particularly during extreme precipitation and cyclonic events. The region's relatively smooth coastal topography and sediment deposition from riverine systems further contribute to shoreline instability and erosion. Conversely, the East Coast experiences heightened exposure to cyclones and heatwaves, often referred to as "silent hazards," with significant shoreline erosion in states like West Bengal. The Bay of Bengal witnesses nearly fourfold higher cyclone frequency compared to the Arabian Sea, driven by elevated sea surface temperatures, El Niño-Southern Oscillation (ENSO) phenomena, and anomalous ocean-atmosphere interactions. These oceanic and atmospheric dynamics also contribute to the increased incidence of heatwaves, amplifying the region's overall vulnerability to extreme climate-related events .

The findings from the spatial analysis underscore the critical need to tailor mitigation strategies to the distinct hazard profiles of India's East and West Coasts, underpinned by the Climatic Impact-Driver (CID) framework. The East Coast's high vulnerability to cyclones and heatwaves demands scientifically driven interventions, such as enhanced atmospheric and oceanic monitoring systems, real-time cyclone forecasting, and the establishment of heat action plans tailored to local climatic conditions. Structural measures, including robust cyclone shelters and resilient building codes, should be coupled with non-structural strategies, such as community-based disaster preparedness programs. Conversely, the West Coast's challenges, primarily driven by sea level rise, shoreline erosion, and flooding, necessitate ecosystem-based solutions. These include the restoration and conservation of mangroves and coastal wetlands to act as natural buffers, alongside sustainable coastal zone management practices that limit unregulated development and reduce human interference in fragile ecosystems. Furthermore, integrating these spatial insights into coastal development policies can enable a science-based approach to infrastructure planning and land-use regulation. By incorporating real-time hazard mapping, policymakers can ensure dynamic risk assessments that account for evolving climate patterns. This approach enables prioritization of investments in high-risk districts and promotes climate-resilient infrastructure, such as elevated structures and adaptive drainage systems to mitigate urban flooding. The CID framework also highlights the importance of combining nature-based solutions with engineered interventions to address complex and compound climate risks. Strengthening disaster response mechanisms, fostering community participation, and promoting livelihoods resilient to climate stressors are essential to building adaptive capacity. By aligning policies with global frameworks, India can build a sustainable and inclusive pathway to mitigate the escalating impacts of climate change along its vulnerable coasts.

Conclusion

This study provides critical insights into the spatial variability of climate change-induced hazards along India's coastal districts, emphasizing the differential vulnerability of the East and West Coasts under the Climatic Impact-Driver (CID) framework. The analysis reveals that the East Coast is disproportionately affected by cyclones and heatwaves, while the West Coast contends with hazards such as sea level rise, shoreline erosion, and flooding. These findings underscore the urgent need for region-specific, evidence-based adaptation strategies that address the distinct hazard profiles of these regions. The results highlight the necessity of integrating scientific knowledge with local contexts to formulate effective mitigation and adaptation policies. Policymakers must leverage this spatial analysis to prioritize investments in high-risk areas, foster community resilience, and align local efforts with global climate goals. Through such targeted approaches, India can enhance its adaptive capacity and safeguard the livelihoods and ecosystems of its coastal regions from escalating climate threats.

Suggested Reading

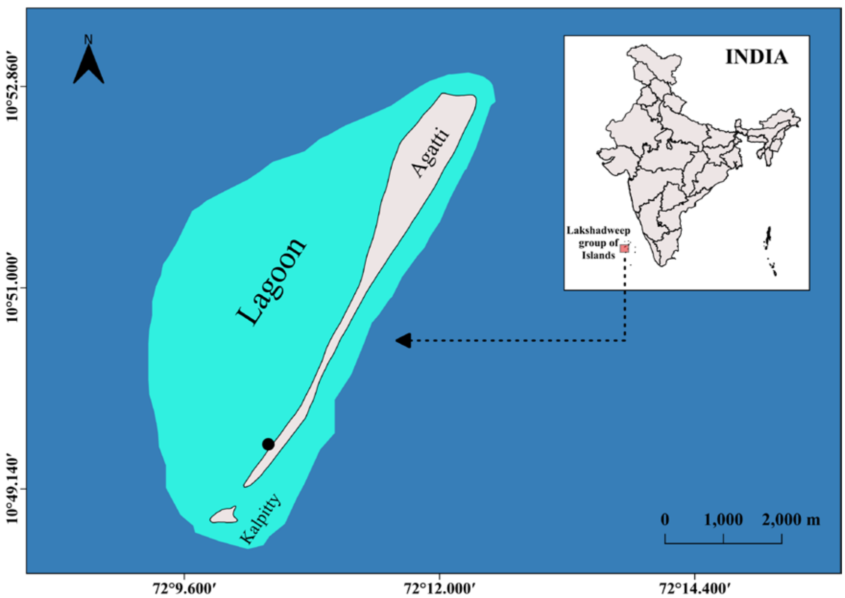
IPCC, 2022: Summary for Policymakers. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3–33,. doi:10.1017/9781009325844.001

Reisinger et al., 2020. The concept of risk in the IPCC Sixth Assessment Report: A summary of cross-working group discussions. Intergovernmental Panel on Climate Change, 15, p.130.

Source

Reshma Gills, Shelton Padua, C. Ramachandran, Eldho Varghese, K. R. Ratheesh, Grinson George, Rose P. Bright, E. Vivekanandan, J. Jayasankar and A. Gopalakrishnan. 2024. Climate change hazards along the Indian coastal districts: spatial analysis on a Climatic Impact-Driver framework. *Current Science*, 127 (4): 461 - 474

Mass stranding of Purpleback flying squid in Agatti Island, Lakshadweep



Location (closed circle) of mass stranding of *Sthenoteuthis oualaniensis* on the southwestern beach of Agatti Island in the Arabian Sea

Photographs of *Sthenoteuthis oualaniensis* strandings in the Agatti Island of the Arabian Sea. A: live squids in close proximity to the shore, B: Stranded squids on the shoreline. Photos are screen captures from the video and hence in low quality.

The "flying squids" of the family Ommastrephidae (suborder Oegopsida) make up over 50% of the global cephalopod species that are commercially exploited. Among this, the purpleback flying squid *Sthenoteuthis oualaniensis* (Lesson, 1830) is the dominant squid in the oceanic waters of the Arabian Sea and is reported to have a complicated population structure (viz. middle-sized, dwarf, and giant forms) (Jeena *et al.* 2023). Purpleback flying squid is referred to by the sobriquet 'Master of the Arabian Sea' due to its abundance, large size, fast growth, and dominance in the higher trophic niche and the mean abundance of this species in the Indian EEZ portion of the Arabian Sea was estimated to be 4.21 tonnes/km^2 (Mohamed *et al.* 2018).

On June 9, 2022, on the southwestern shore of Agatti Island, Lakshadweep, India, local fishermen sighted mass beaching of hundreds of squids in the morning. This article is based on a short video of this episode that the authors were able to view despite not being able to obtain a sample of the squids. Many squids stranded on the beach (estimated at ~3000) were subsequently identified as *Sthenoteuthis oualaniensis* (Ommastrephidae). The approximate size of the individuals ranged from 8 to 12 cm in dorsal mantle length (DML), indicating that they are sub-adults. Eyewitnesses informed that this is the first instance of squid stranding in the area. These squids that were stranded, swam directly to the shore and were beached by the ebbing tide. They were alive while they were stranded. Most of the stranded squids were gathered by residents for consumption, mostly being preserved by pickling and utilized as bait for tuna fishing.

It is reported that the maximum biomass of *S. oualaniensis* in the Indian EEZ is between 11°N and 72°E (Mohamed *et al.,* 2018), which is close to Agatti Island. Additionally, it has been indicated that the spawning grounds of *S. oualaniensis* might be in the southeastern Arabian Sea around the Lakshadweep Archipelago (09˚04´N–15˚04´N, 73˚44´E–75˚36´E) with high abundances of paralarvae (38–270 number/1000 m^3) and juveniles (1,201–3,003,003 number/km^2) observed during January–April, and October (Sajikumar *et al.,* 2018). Mass stranding events of marine whales have been reported in Indian tropical waters (Regunathan *et al.,* 2013; Jeyabaskaran *et al.,* 2018). Mass strandings of various ommastrephid squid species such as jumbo squid *Dosidicus gigas* (Ibanez *et al.,* 2023) from the eastern Pacific Ocean and seven-star flying squid *Martialia hyadesi* from Macquarie Island (O'Sullivan *et al.,* 1983) and New Island, Falkland Island (Nolan *et al.,* 1998) and Shortfin squid, *Illex illecebrosus* from Cape Cod Bay, North Atlantic Ocean, have been attributed to a wide variety of circumstances, such as oceanographic anomalies (temporal shifts in frontal zones), post-spawning mortality, human disturbance, and toxins from harmful algal blooms. However, there is no previous evidence for the mass stranding of squid in tropical Indian waters. Earlier reports hypothesized post-spawning mortality, high temperatures, toxins from harmful algal blooms (extremely potent brain toxins), and human disturbances, as reasons for the mass stranding of squids. However, in this study, no conclusive evidence supported these hypotheses. It is fairly well established that the purpleback flying squid does not die after spawning (Harman *et al.,* 1989). It is proposed that despite being an oceanic form, its presence in the shallow lagoon of Agatti Atoll may have been chased by a predator into the lagoon and subsequently onto the beach. During earlier cruises in the region, we observed instances of this species fleeing predators by gliding and landing on the vessel deck after being chased by tunas and other larger pelagic predators. Therefore, the current beaching could be due to a predator attack. Moving forward, researchers should be vigilant for such occurrences in the future to gain a better understanding of this unusual behaviour of squids.

K. K. Sajikumar*, Geetha Sasikumar, P. Laxmilatha, K.P.S. Koya and P. Pranav | ICAR-Central Marine Fisheries Research Institute, Kochi

Carcass of Indo-Pacific finless porpoise reported

A petrified carcass of the mammal was found ashore at Attupuram (Companykadavu) region of Thrissur district, Kerala, southwest coast of India on 22nd June 2023. Based on field observations, the animal was identified to be a porpoise, noted for their absence of a dorsal fin and by a ridge with circular small bump-like structure down the middle of the back. From this morphometric characteristic, the species was confirmed as Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) from the family Phocoenidae. The measurements of a stranded Indo-Pacific finless porpoise are as follows: snout to notch of tail fluke 156 cm, snout to ear 23 cm, snout to eye 13 cm, blowhole length 6 cm, blowhole width 4 cm, snout to centre of anus 96 cm, total length 158 cm, and total weight approximately 60 kg

M. A. Jishnudev*, Paulose Jacob Peter, T. G. Kishor, Akhil Babu, R. Ratheesh Kumar and J. Jayasankar | ICAR-Central Marine Fisheries Research Institute, Kochi.

Landings of Tiger shark along north Andhra Pradesh coast

Female tiger shark landed at Visakhapatnam Fisheries Harbour

Male Tiger shark landed at Pudimadaka landing centre

The Tiger shark of the genus *Galeocerdo* is reportedly represented by a single species *Galeocerdo cuvier* (Peron & Leasueur, 1822) belonging to the family Carcharhinidae. The species is a circumglobal large predator with reports of attacking humans as well. The name 'Tiger shark' is derived from the dark stripes down its body, which resemble the pattern of a Tiger; however, the patterns fade as the shark matures. This species can grow up to a maximum length of 750 cm, reaches maturity at 300 cm (Lm) (approximately 7–10 years) and has a maximum published weight of

Tiger shark landed at Chinthapalli landing centre

Table 1. Data of Tiger Shark landings

Observation record	Total Length (cm)	Total Weight (kg)	Sex	Gear	Location of landing
6-11-2018	152	20	M	Hook and line	Poodimadaka
22-01-2020	129	13	F	Hook and line	Chinthapalli
08-03-2021	202.5	55	F	Trawl*	Visakhapatnam FH
30-10-2021	246	65	M	Trawl*	Visakhapatnam FH
29-11-2021	238	70	M	Trawl*	Visakhapatnam FH
29-12-2021	213	50	F	Trawl*	Visakhapatnam FH
29-12-2021	347	150	M	Trawl*	Visakhapatnam FH
29-12-2021	261	100	F	Trawl*	Visakhapatnam FH
22-07-2022	250	85	F	Trawl*	Visakhapatnam FH
12-09-2022	203	45	F	Trawl*	Visakhapatnam FH
23-09-2022	285	70	F	Trawl*	Visakhapatnam FH
10-10-2022	219	45	M	Trawl*	Visakhapatnam FH
10-10-2022	237	66	F	Trawl*	Visakhapatnam FH
02-01-2023	210	45	M	Trawl*	Visakhapatnam FH
06-04-2023	225	66	M	Trawl*	Visakhapatnam FH
28-04-2023	115	5.5	M	Hook and line	Manchineelapeta

* Though landed by trawlers, the animals might have been caught by hooks and lines operated off a trawler most of the time

Male tiger shark landed at Manchineelapeta, Srikakulam district

807.4 kg. The maximum reported age for the species is 50 years. The IUCN lists the Tiger shark as 'Nearly Threatened' throughout its range. Along north Andhra Pradesh, Tiger sharks occur as bycatch in trawl and gillnet fisheries and as non-specific targeted catch in hooks and lines. Tiger sharks formed 9-40% of sharks landed at Visakhapatnam Fishing Harbour during 2018-2023.

On 5th July 2024, a single female Tiger shark was landed as bycatch by a multiday trawler at Visakhapatnam Fishing Harbour. On enquiry, fishermen reported that the animal was caught from a distance of 70 nautical miles northeast of Visakhapatnam Fishing Harbour, at a depth around 100 m. The animal had a total length of 356 cm and an approximate weight of 200 kg. The animal was mature, with a loose vent, indicating an earlier release of pups from the animal. This was the largest sized Tiger shark to be landed along north Andhra Pradesh during the last five years. A compilation of information on Tiger sharks landed in north Andhra Pradesh from 2018 to 2024 and for Visakhapatnam Fisheries Harbour, where only those above 200 cm TL have been mentioned is given below.

M. Muktha*, Jincy Cherian, K. Renuka, V. Ashok Maharshi, P. Pattnaik, Ch. Moshe, R.V.D. Prabhakar, T. Nageswara Rao, Sujitha Thomas and Shoba Joe Kizhakudan | Visakhapatnam Regional Centre of Central Marine Fisheries Research Institute

Report of two tuskfishes from Tamil Nadu coast

Wrasses are reef associated fishes and wrasses under genus *Choerodon* Bleeker 1847 are commonly called as tuskfishes due to peculiar canine teeth in front of mouth. Four tuskfishes are reported from India viz., Orange-dotted tuskfish *Choerodon anchorago* (Bloch, 1791), Robust tuskfish, *Choerodon robustus* Günther, 1862, Bluetooth Tuskfish, *Choerodon typus* (Bleeker 1856), and Purple eyebrowed tuskfish Choerodon *zamboangae* (Seale & Bean 1907). Present report is on two rarely observed tuskfishes from Tamil Nadu coast recorded during 2021-2023 period.

On 12th March 2022, seven specimens of *Choerodon typus* (9-12 cm TL), were observed in the trawl bycatch landed at Chennai Fisheries Harbour (Kasimedu). This species is found in the Indo-West Pacific region, rare in the Indian Ocean region however beyond the Malay Peninsula it is currently known only from Chennai (Tamil Nadu) and Myanmar (Gomon, 2017). The species was first documented and photographed by Dr. Randall from Chennai in 1975 and a report based on collections in 2008 and 2011 from Chennai was published by Misra and Saren, 2016.

On 18th August 2021, two specimens of *Choerodon robustus* was observed and photographed at Jeppiaar Fishing Harbour, Muttom. Though a widely distributed species known from Red Sea to Japan, the reports from India are rare. Eight fishes were also recorded at Threspuram Landing Centre on 27th October 2022. Similarly, 36 fishes were recorded on 12th April 2023 which were caught in bottom set gillnets (58-60 mm mesh size) operated at at a depth of 36-40 m and landed in the fish landing centre at Inigo Nagar, Thoothukudi.

L. Remya*, K.V. Akhilesh, N. S. Sruthi, R. Vinothkumar and Shoba Joe Kizhakudan |
Mandapam Regional Centre of ICAR-Central Marine Fisheries Research Institute

Choerodon typus from Chennai

Choerodon robustus from Muttom

सी एम एफ आर आइ
CMFRI

भाकृअनुप
ICAR

Indian Council of Agricultural Research
Central Marine Fisheries Research Institute

Post Box No.1603, Ernakulam North P.O., Kochi-682 018, Kerala, India.
Phone: +91 484 2394357, 2394867 Fax: +91 484 2394909
E-mail: director.cmfri@icar.gov.in **www.cmfri.org.in**