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Blue-Green Circular Farming: The Future of Climate-Resilient Aquaculture in India

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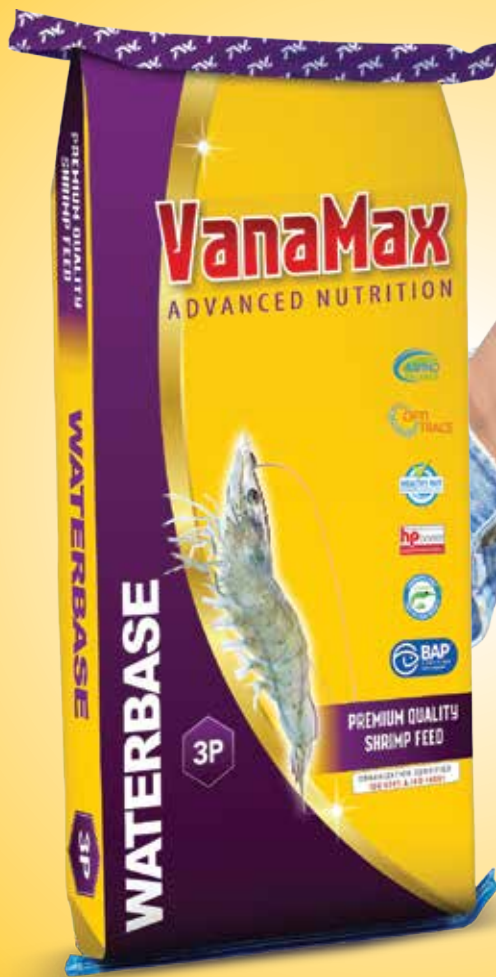
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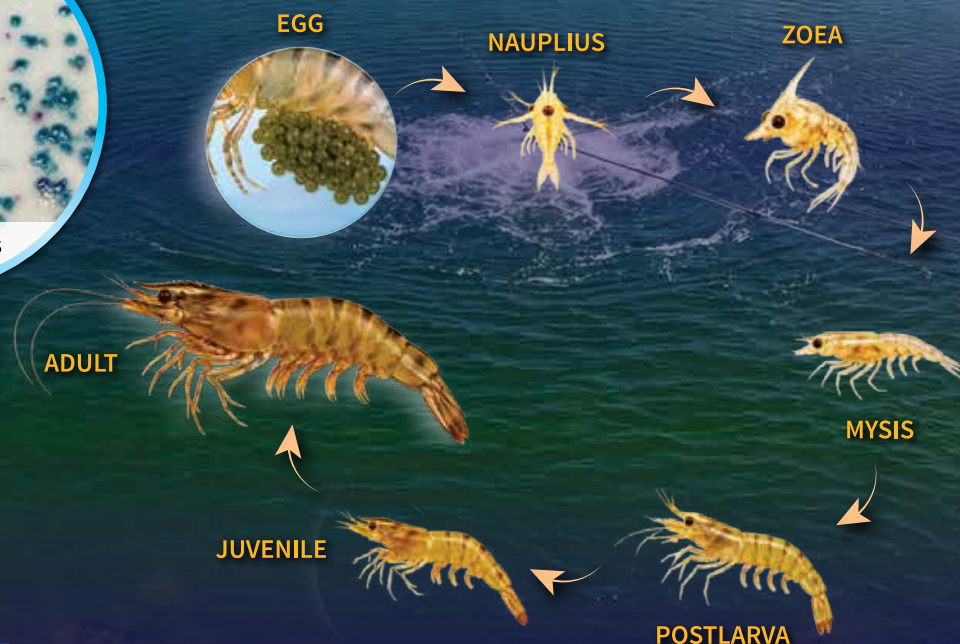
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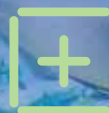
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- Editor



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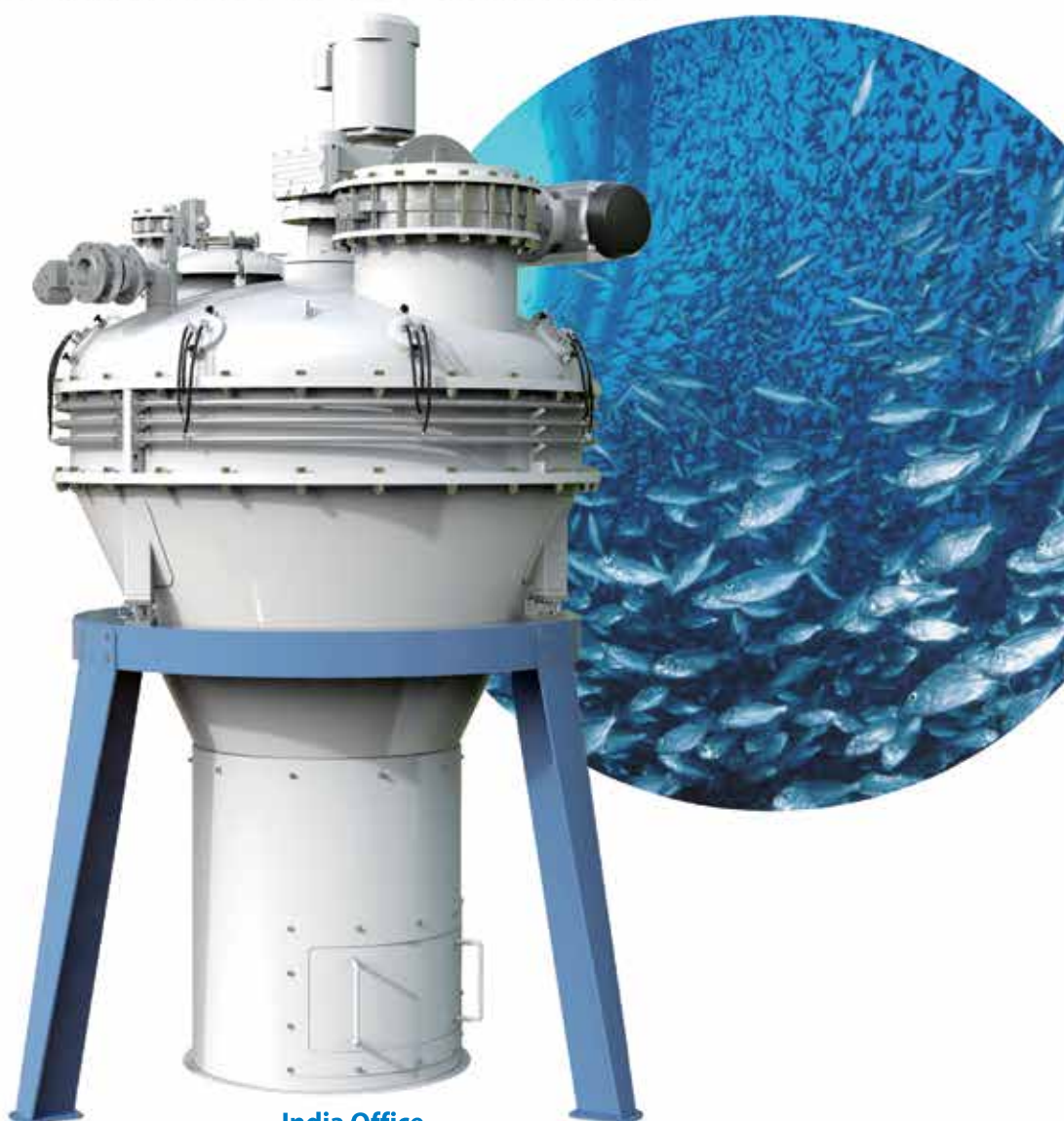
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Andhra Pradesh gives subsidised power at Rs 1.50 per unit for registered aqua farmers

India exports 19,72,018 metric tons of seafood valued at ₹ 73,890 crore (\$ 8.46 billion) in 2025-2026

The widespread and often indiscriminate use of antibiotics for disease treatment, prophylaxis, and growth promotion has accelerated the emergence of multidrug-resistant pathogens across human, animal, and environmental interfaces. This short review critically examines the current landscape of antibiotic alternatives, categorizing them into naturally occurring agents, synthetically designed antimicrobials, and biotechnology-based strategies.



Dear Readers,

The July 2026 issue of Aqua International is in your hands. In the news section, you may find news about....

India's seafood exports net US \$ 8.46 billion in 2025-26.

Volume and value rise to all-time high mark. USA, China top importers, frozen shrimp tops the list. India has exported 19,72,018 metric tons (MT) of seafood valued at ₹73,890.46 crore (\$ 8.46 billion) during the fiscal year 2025-26, which is an all-time high mark by volume and value despite global odds, according to Mr P. Jawahar, IAS, Chairman of the Marine Products Export Development Authority. The USA and China remained the primary importers of Indian seafood. Frozen shrimp remained the leading product in seafood exports, generating ₹49,037.93 crore (\$ 5,624.48 million). It accounts for 40.19% of the total quantity and 66.52% of total US dollar earnings from seafood exports. During this period, shrimp exports increased by 13.16% in ₹ value and 8.64% in \$ value.

Andhra Pradesh government announced subsidised power at Rs 1.50 per unit for registered aqua farmers. The Andhra Pradesh Agriculture Minister Mr Kinjarapu Atchannaidu highlighted that providing subsidised electricity costs the State Rs 1,100 crore annually, underscoring that the government prioritises the sector's growth over financial burden. Agriculture Minister K. Atchannaidu thanked the State Assembly for approving the Aquaculture Development Authority Amendment Bill-2025, aimed at bolstering the aquaculture sector. Speaking in the Assembly, he outlined several initiatives to support aqua farmers and enhance the industry's growth. The Minister emphasised the State government's commitment

to aquaculture sector, with Chief Minister N. Chandrababu Naidu dividing it into zones and non-zones to streamline development efforts. He announced that only registered aqua farmers will be eligible for subsidised electricity at Rs 1.50 per unit. The government is also implementing geo-tagging to identify and monitor aquaculture ponds. The aquaculture law was formulated after consultations with farmers and industry stakeholders to ensure profitability.

Nutraceuticals highlighted as natural route to healthier aquaculture. A new review argues that nutraceuticals could play an increasingly important role in helping aquaculture producers improve fish health, reduce disease pressure and limit reliance on antibiotics. As aquaculture intensifies to meet rising demand for fish protein, producers are facing growing challenges linked to disease outbreaks, environmental stress, poor water quality and antimicrobial resistance. These issues threaten productivity, profitability and the long-term sustainability of fish farming operations worldwide. A recent review authored by Dr Pratapa M G and colleagues from ICAR - Mahatma Gandhi Integrated Farming Research Institute in Bihar, India, explores how nutraceuticals can help address these challenges by supporting fish health through natural and sustainable approaches. The review examines a range of bioactive compounds that can be incorporated into aquafeeds to improve growth, immunity and disease resistance while reducing dependence on antibiotics and synthetic chemicals.

Odisha cabinet approves over ₹ 2,000 crore deep sea fishing mission. Project expected to bring in an additional 2 lakh metric tonnes of marine fish annually. The Odisha government recently approved a deep sea fishing mission with an outlay of over ₹ 2,000 crore, aiming to transform the state into a leading marine export hub, officials said. The mission was approved at a cabinet meeting

Contd on next page



Our Mission

Aqua International will strive to be the reliable source of information to aquaculture industry in India.

AI will give its opinion and suggest the industry what is needed in the interest of the stakeholders of the industry.

AI will strive to be The Forum to the Stakeholders of the industry for development and self-regulation.

AI will recognize the efforts and contribution of individuals, institutions and organizations for the development of aquaculture industry in the country through annual Awards presentation.

AI will strive to maintain quality and standards at all times.

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chaired by Chief Minister Mohan Charan Majhi. It is a flagship initiative of the Fisheries and Animal Resources Development Department to unlock the vast offshore fisheries potential of the state and accelerate blue economy-led growth, Chief Secretary Anu Garg told reporters at Bhubaneswar. The mission seeks to promote sustainable deep-sea fishing, modernise marine fisheries infrastructure, enhance seafood exports, and strengthen the fishing community's livelihoods, she said. An estimated ₹ 2,295 crore will be spent to implement the mission over 2026 - 2036, Garg said. The Chief Secretary said that it will be implemented in a phased manner through convergence of central schemes, state support, beneficiary participation, institutional finance and public-private partnership (PPP). The state will set up a dedicated Blue Economy Hub (B-Hub) to function as the mission's knowledge, innovation and coordination centre.

A 2-day Exhibition, Panel Discussion and AI Excellence Awards presentation programme titled Aquaculture Expo 2026 was held at Bhimavaram, Andhra Pradesh on 12 & 13 June 2026. There was Panel Discussion and interaction meet with the theme: Current Challenges in Aquaculture and Strategies - Tap the Potential to take Andhra Pradesh Aquaculture to the next level of Development on the occasion AI Excellence Awards were presented to 11 individuals and organisations for the excellence achieved in their profession and for the contribution to the aquaculture industry. The Deputy Speaker Mr Kanumuri Raghuramakrishna Raju along with West Godavari district collector Mrs Ch. Naga Rani inaugurated the Expo and interacted with the exhibitors and farmers.

Deputy Speaker of Andhra Pradesh Mr Kanumuri Raghuramakrishna Raju said that farmers should realize that the permits of those ponds will be cancelled in places where aqua water is released into agriculture crop canals. He was speaking at the inaugural function of Aquaculture Expo 2026 at Bhimavaram on June 12. He said that a lion's share of shrimp production is from West Godavari district. He said that the government is providing support for the development of this sector. He said that drinking water problems are arising due to non-compliance with the rules. He said that it is not right to release waste water from shrimp ponds into crop canals for agri related activity, because of which the number of cancer victims will increase.

Remembering fishery scientist Late Dr P. Das on his 90th birth anniversary. Dr Punyabrata Das, better known to fishery and aquaculture scientist fraternity of India as 'Dr P. Das', was a distinguished Indian fisheries scientist and expert, revered by everybody. He was the second most-prominent fishery and aquaculture scientist of India from West Bengal after Dr Hiralal Chaudhuri served continuing ten years as Director of ICAR-National Bureau of Fish Genetic Resources, Lucknow till retirement. Year 2026 happens to be his 90th birth anniversary and 4th death anniversary. Rightly stated by Dr U. K. Sarkar, Retd. Director, ICAR-NBFGR: 'Dr P. Das's personal behaviour was full of human sensibilities and values'. So gracious and pleasing was his personality, greatness incomparable.

In the Articles section, **Alternatives to Antibiotics: Biological, Synthetic and Biotechnological Strategies to address Antimicrobial Resistance (AMR)** authored by K Pani Prasad and T. Suguna discussed that Antimicrobial Resistance (AMR) represents a mounting global crisis threatening the sustainability of modern medicine, livestock production, and aquaculture. The

widespread and often indiscriminate use of antibiotics for disease treatment, prophylaxis, and growth promotion has accelerated the emergence of multidrug-resistant pathogens across human, animal, and environmental interfaces. While antimicrobial stewardship and antibiotic prudence are essential pillars of AMR mitigation, their success is fundamentally dependent on the availability of effective alternatives capable of preventing and controlling bacterial infections without promoting resistance. This short review critically examines the current landscape of antibiotic alternatives, categorizing them into naturally occurring agents, synthetically designed antimicrobials, and biotechnology-based strategies. Approaches such as bacteriophage therapy, antimicrobial peptides, bacteriocins, probiotics, fecal microbiota transplantation, phytochemicals, predatory bacteria, antibody-based therapeutics, synthetic peptide mimics, virulence inhibitors, vaccines, and genetically engineered bacteriophages and lysins are discussed with respect to their mechanisms of action, advantages, limitations, and translational readiness.

Another article titled, **Blue-Green Circular Farming: The Future of Climate-Resilient Aquaculture in India** authored by J.S.Akash, G.K.Raswin, S.Thammizhanthi, J.G.Jenisha & S.Felix said that Integrating GIFT Tilapia, Biofloc Technology and Freshwater Aquaponics for Sustainable Food Production. Blue-Green Circular Farming integrates GIFT Tilapia culture, Biofloc Technology (BFT), and freshwater aquaponics into a climate-smart aquaculture system based on IMTA principles. The model promotes efficient recycling of water and nutrients, significantly reducing waste and environmental impacts. By producing fish and plants simultaneously, it enhances productivity, profitability, and food security. The system requires less water and land than conventional farming methods, making it suitable for climate-resilient agriculture. This integrated approach offers a sustainable pathway for advancing aquaculture and supporting India's Blue Economy goals.

Another article titled, **Reproductive Strategies of Reef associated Ornamental Fishes** authored by Rekha, M. U. and T. T. Ajith Kumar says that Coral reef life demands reproductive specialization, with fish evolving diverse strategies such as egg scattering, guarding, or live brooding to increase offspring survival amidst intense predation and competition. Egg deposition with parental care is practiced by clownfish and damselfish, which lay adhesive eggs on substrates and actively guard them, increasing hatching success in predator-rich reef environments. Pelagic spawning by butterflyfish and angelfish involves releasing buoyant eggs into open water, relying on dispersal rather than protection though larval survival is often low due to complex early feeding needs. Brooding strategies like male pregnancy in seahorses and mouth brooding in cardinalfish offer high offspring protection, with males carrying or incubating eggs to shield them from predators and environmental threats. Life on coral reef is anything, but easy.

Readers are invited to send their views and comments on the news, special feature and articles published in the magazine which would be published under "Readers Column". Time to time, we shall try to update you on various aspects of Aquaculture sector. Keep reading the magazine Aqua International regularly and update yourself. Wish you all fruitful results in your efforts.

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India's seafood exports net US \$ 8.46 billion in 2025-26

- Volume and value rise to all-time high mark
- USA, China top importers, frozen shrimp tops the list



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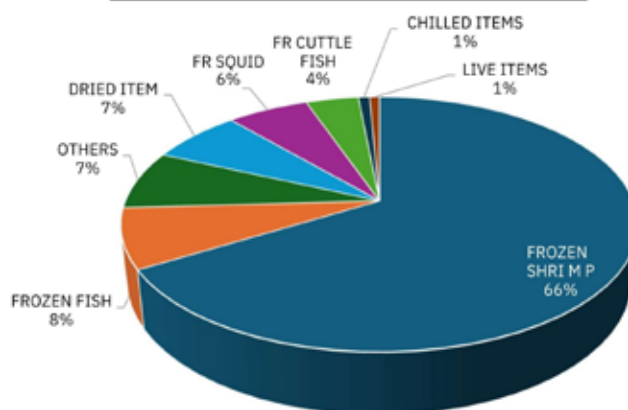
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Kochi, 01 June: India has exported 19,72,018 metric tons (MT) of seafood valued at ₹73,890.46 crore (\$ 8.46 billion) during the fiscal year 2025-26, which is an all-time high mark by volume and value despite global odds, according to Shri P Jawahar, IAS, Chairman of the Marine Products Export Development Authority (MPEDA).

The USA and China remained the primary importers of Indian seafood.

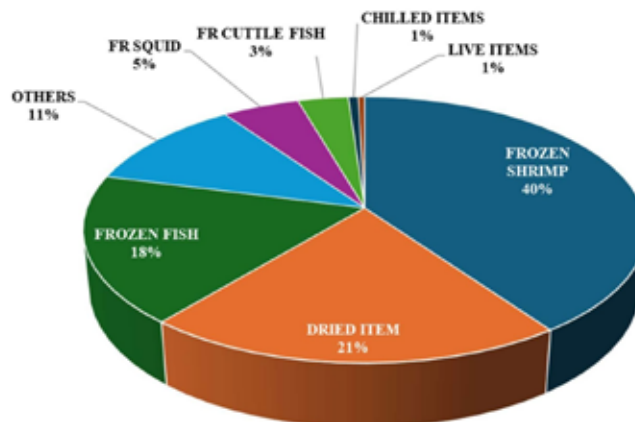
Frozen shrimp remained the leading product in seafood exports, generating ₹ 49,037.93 crore (\$ 5,624.48 million). It accounts for 40.19% of the total quantity and 66.52% of total US dollar earnings from seafood exports. During this period, shrimp exports increased by 13.16% in ₹ value and 8.64% in \$ value.

Major Item wise Export details 2025-26 (Value \$)



2 Major Item wise Export details 2025-26 (Value \$)

Major item wise export details 2025-26 (Quantity)



3 Major Item-wise exports 2025-26 (Quantity)

During the 2025-26 period, the total export of frozen shrimp was 7,92,647 MT.

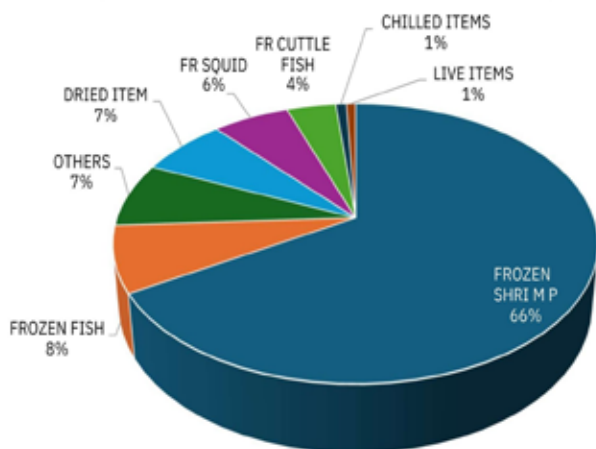
The United States, being the largest market, imported 2,56,128 MT of frozen shrimp. This was followed by China with 1,69,505 MT, the European Union with 1,35,599 MT, Southeast Asia with 83,810 MT, Japan with 40,776 MT, the Middle East with 30,478 MT, and all other countries combined, which accounted for 76,351 MT. The exports of L. vannamei and Black Tiger shrimp have shown an increase in both volume and value.

Frozen fish, the second largest exported item, generated ₹5,658.37 crore (\$ 643.70 million). Dried items, the third largest exported group, earned ₹5,079.09 crore (\$ 577.44 million) and has shown a positive export trend of 78.05% in terms of value rupees.

The export of frozen squid reached 1,02,060 MT, earning ₹4,493.80 crore (\$ 513.84 million). Meanwhile, frozen cuttlefish experienced growth in both volume and value, by 13.32% in quantity and 16.25% in \$ value, with exports totalling to 67,157 MT worth \$ 331.96 million, respectively.

The export of chilled items earned ₹ 622.31 crore (\$ 71.27 million). Export of live items showed a growth of 11.46% in value \$ terms (\$

Major Item wise Export details 2025-26 (Value\$)



4 Market Wise Exports 2025-26 (Value)



5 Market Wise Exports 2025-26 (Quantity)

62.43 million).

In terms of overseas markets, the United States remained the leading importer of Indian seafood, with imports valued at ₹ 20263.27 Crore (\$ 2,328.74 million) and a total volume of 279,193 MT. Exports to the U.S. decreased by 10.82% in rupee value, 14.22% in dollar value, and 19.51% in volume. Within the USA's seafood import basket from India, frozen shrimp had the lion's share of 93.55% in \$ value.

China emerged as the largest seafood export destination from India in terms of quantity with 4,90,369 MT worth \$

1,611.32 million. European Union continued to be the third largest destination in \$ terms, with an import of 2,97,518 MT worth \$ 1,592.09 million. This was followed by South-East Asia in value with an import of 4,51,756 MT worth \$ 1,348.97 million. Japan continued to be the fifth largest importer in value with an import of 1,05,228 MT worth \$ 452.91 million. Middle East is the sixth largest destination in value with an import of 76,743 MT worth \$ 283 million.

The top 3 ports handling seafood cargo were Vizag and JNPT, and Kochi.

Subsidised power at Rs 1.50 per unit only for registered aqua farmers, says Andhra Pradesh Agriculture Minister

The Andhra Pradesh Agriculture Minister Mr Kinjarapu Atchannaidu highlighted that providing subsidised electricity costs the State Rs 1,100 crore annually, underscoring that the government prioritises the sector's growth over financial burden.

Vijayawada: Agriculture Minister K. Atchannaidu thanked the State Assembly for approving the Aquaculture Development Authority Amendment Bill-2025, aimed at bolstering the aquaculture sector. Speaking in the Assembly, he outlined several initiatives to support aqua farmers and enhance the industry's growth.

The Minister emphasised the State government's commitment to the aquaculture sector, with Chief Minister N. Chandrababu Naidu dividing it into zones and non-zones to streamline development efforts. He announced that only registered aqua farmers will be eligible for subsidised electricity at Rs 1.50 per unit. The government is also implementing geo-tagging to identify and monitor aquaculture ponds.

Addressing queries from MLAs of Mummidivaram, Tadepalligudem and Unguturu, he revealed that the State has provided 50,000 electricity connections to aqua farmers under the subsidy scheme, with a target of reaching 64,500 connections.

He urged MLAs to raise



Minister Kinjarapu Atchannaidu during the assembly session

awareness among farmers about the importance of registration and compliance with the aquaculture bill.

The Minister highlighted that providing subsidised electricity costs the State Rs 1,100 crore annually, underscoring that the government prioritises the sector's growth over financial burden. The aquaculture law was formulated after consultations with farmers and industry stakeholders to ensure profitability, he said.

Noting that 20% of aqua farmers are yet to register, Atchannaidu announced an additional opportunity for registration with a 50% reduced late fee.

The government has also decided to extend the validity of aquaculture business operation licences from one year to five years, the Minister said.

Nutraceuticals highlighted as natural route to healthier aquaculture

A new review argues that nutraceuticals could play an increasingly important role in helping aquaculture producers improve fish health, reduce disease pressure and limit reliance on antibiotics.



Nutraceuticals refers to food or food-derived substances that provide health benefits beyond basic nutrition.

As aquaculture intensifies to meet rising demand for fish protein, producers are facing growing challenges linked to disease outbreaks, environmental stress, poor water quality and antimicrobial resistance. These issues threaten productivity, profitability and the long-term sustainability of fish farming operations worldwide.

A recent review authored by Dr Pratapa M G and colleagues from ICAR - Mahatma Gandhi Integrated Farming Research Institute in Bihar, India, explores how nutraceuticals can help address these challenges by supporting fish health through natural and sustainable approaches. The review examines a range of bioactive compounds that can be incorporated into aquafeeds to improve growth, immunity and disease resistance while reducing dependence on antibiotics and synthetic chemicals.

Nutraceuticals are food-derived or naturally sourced compounds that

provide health benefits beyond basic nutrition. In aquaculture, these include probiotics, prebiotics, amino acids, fatty acids, vitamins, seaweed extracts, herbal products and emerging nano-nutraceuticals. Interest in these functional feed ingredients has grown rapidly in recent years as the industry seeks environmentally friendly alternatives for fish health management.

Nutraceuticals support growth, immunity and disease resistance

According to the authors, these ingredients can help improve growth performance, feed utilisation, gut microbial balance, immune response and disease resistance in farmed fish and shellfish. They may also contribute to better water quality and reduced environmental impacts, making them attractive alternatives or complements to conventional disease-management approaches.

Probiotics and prebiotics are among the most widely used nutraceuticals in aquaculture. Probiotics consist of beneficial microorganisms that help maintain a balanced gut microbiota, improve digestion and suppress the growth of harmful bacteria. Prebiotics, on the other hand, act as substrates that stimulate the growth and activity

of beneficial microbes already present in the digestive tract. Together, they help improve nutrient absorption, strengthen immune responses and enhance resistance against bacterial and viral infections.

The review also highlights the importance of essential amino acids, vitamins and fatty acids. Amino acids such as arginine and lysine play important roles in growth and immune function, while vitamins including vitamin C and vitamin E contribute to antioxidant defence and disease resistance. Omega-3 fatty acids, particularly EPA and DHA, are recognised for their positive effects on growth performance, stress tolerance, tissue development and overall physiological health.

Seaweed-derived nutraceuticals are gaining attention as sustainable feed additives due to their rich content of bioactive compounds, minerals, vitamins and polysaccharides. Extracts from brown, red and green seaweeds have been shown to stimulate immunity, improve antioxidant status and enhance disease resistance in several aquaculture species. Herbal products such as garlic and turmeric are also increasingly explored for their antimicrobial and immunostimulatory properties.

Emerging technologies and future prospects

The review points to growing interest in nano-nutraceuticals, an emerging field that combines nutrition and nanotechnology. Nano-sized formulations such as nano-selenium and

chitosan nanoparticles may improve nutrient delivery, bioavailability and absorption efficiency. Early studies suggest that these technologies can enhance growth, antioxidant activity and disease resistance, although further validation under commercial farming conditions is still needed.

Despite their considerable promise, the authors caution that commercial adoption still faces obstacles. These include a lack of standardised dosage protocols, variations in effectiveness among species and farming systems, relatively high formulation costs and limited long-term field studies evaluating their practical application.

Nevertheless, increasing concerns over antimicrobial resistance and consumer demand for sustainably produced aquatic food is expected to drive further research and commercial adoption. Future studies should focus on developing species-specific formulations, improving cost-effectiveness and generating practical recommendations that can be readily adopted by farmers.

The review concludes that nutraceuticals are likely to become an increasingly important component of antibiotic-free and environmentally sustainable aquaculture systems. By enhancing fish health naturally and reducing the industry's reliance on conventional therapeutics, nutraceuticals offer a promising pathway towards more resilient, productive and sustainable aquaculture production in the years ahead.

Odisha cabinet approves over ₹2,000-crore deep sea fishing mission

Project expected to bring in an additional 2 lakh metric tonnes of marine Fish annually



Odisha will set up a dedicated Blue Economy Hub (B-Hub) to function as the mission's knowledge, innovation and coordination centre, the chief secretary said

Bhubaneswar: The Odisha government on Wednesday approved a deep sea fishing mission with an outlay of over ₹2,000 crore, aiming to transform the state into a leading marine export hub, officials said.

The mission was approved at a cabinet meeting chaired by Chief Minister Mohan Charan Majhi.

It is a flagship initiative of the Fisheries and Animal Resources Development Department to unlock the vast offshore fisheries potential of the state and

accelerate blue economy-led growth, Chief Secretary Anu Garg told reporters here.

The mission seeks to promote sustainable deep-sea fishing, modernise marine fisheries infrastructure, enhance seafood exports, and strengthen the fishing community's livelihoods, she said.

An estimated ₹2,295.45 crore will be spent to implement the mission over 2026-2036, Garg said.

She said it will be

implemented in a phased manner through convergence of central schemes, state support, beneficiary participation, institutional finance and public-private partnership (PPP).

The state will set up a dedicated Blue Economy Hub (B-Hub) to function as the mission's knowledge, innovation and coordination centre, the chief secretary said.

The project is expected to generate an additional 2 lakh metric tonnes of

marine fish production annually, create over 50,000 employment opportunities, substantially enhance the income of marine fishers and increase Odisha's marine exports to around ₹5,000 crore per year by 2036, the officials said.

The cabinet also approved flyovers on the road connecting Jaydev Vihar to Nandankanan in Bhubaneswar city at a cost of ₹579 crore. It is expected to be completed in two years, Garg said.

Approval was given to set up a State Data Centre 2.0 by upgrading the existing one with an investment of ₹268.44 crore.

Besides, the cabinet cleared two in-stream storage structures across the Tel river in Kesinga block of Kalahandi district, and the Ong river in Gaisilat block of Bargarh district.

Among other proposals, the cabinet approved mid-day meals to 46.6 lakh secondary school students under the Mukhyamantri Poshan Yojana (MMPY) with an outlay of ₹3,506.99 crore over the next four years, the officials said.

A humble appeal regarding the implementation of electricity subsidies for aqua farmers

Aqua farmers are enthusiastically welcoming the orders issued by the state government to continue the electricity tariff subsidy of ₹1.50 per unit. We extend our heartfelt gratitude to the state government for this farmer-friendly decision.

However, recent government orders state that the subsidy applies only to electricity service connections maintaining a power factor (PF) above 0.90.

While we appreciate the government's

objective of improving energy efficiency, many aquaculture electricity connections are currently unable to maintain a power factor above 0.90 due to various technical reasons. Consequently, this effectively replaces

previously removed restrictions with a new regulation.

Many farmers lack the necessary technical knowledge, awareness, and equipment to improve the power factor. Therefore, we believe it would be appropriate to provide farmers with the required awareness and technical assistance before strictly enforcing this regulation.

To this end, we humbly request the government

to consider the following measures:

- Conducting awareness programs for farmers regarding the importance of power factor.
- Providing technical guidance through the Electricity and Fisheries departments.
- Training farmers on the installation of capacitors, Automatic Power Factor Control (APFC) systems, and other necessary equipment.
- Allowing a suitable transition period for farmers to install the required equipment.
- Providing subsidies or financial assistance for the purchase of equipment, if necessary.

If this provision is implemented after providing farmers with adequate awareness, training, and technical assistance, the government will achieve its desired results, and farmers will not lose out on subsidy benefits.

We humbly request the government to take a favorable decision on this matter, taking into account the ground realities faced by the farmers.

UP COMING EVENT



7, 8 & 9
December 2026

SRMT Function Hall,
Kakinada, Andhra Pradesh, India

For stalls booking Contact:
Aqua International,
Hyderabad, India.
M: 96666 89554, 63010 47155
E: aquacultureexpo.nrs@gmail.com

Kunal Agro Products Engineering Nutrition for Indian Aquaculture

About Kunal Agro Products

Kunal Agro Products, a flagship unit of Naraini Exports (India) Pvt. Ltd. and a proud member of the Rathi Group, is a leading manufacturer of high-quality aqua feeds in India. From our ISO-certified, state-of-the-art plant in Wani, Yavatmal, we produce 250 MT / day of premium fish feed with complete backward integration.

Our strength lies in in-house manufacturing of Soya DOC and edible oils through group companies Aaryaveer Oil Industries and Nupur Enterprises. This gives us unmatched control



*Kunal Rathi, Director,
Kunal Agro Products*

over raw material quality, cost, and consistency – from bean to bag.

Our Promise: Make in India. Made for Farmers.

From the Managing Director's Desk – Ashok Rathi

Mr Ashok Rathi, Managing Director, Kunal Agro Products, said that the company is empowering the Indian Aquaculture with Science, Integrity & Trust. “Empowering Indian Aquaculture with Science,



*Ashok Rathi, Managing
Director, Kunal Agro Products*

Integrity & Trust”.

Vision: To be the most trusted nutrition partner for Indian aqua farmers.

Mission:

- Quality First – In-house Hi-Pro Soya DOC with up to 50% protein.
- Farmer-Centric – Feeds designed for Indian pond conditions.
- Transparent Trade – Long-term partnerships built on trust.

Every batch is tested for nutrition, digestibility and water stability.

Together, let's make Indian aquaculture globally competitive.

Director's Message – Kunal Rathi

“Quality Today, Aquaculture Tomorrow”

Key Quality Parameters:

- Raw Material Integrity
- Scientific Formulation
- Safety First – GRAVITY range certified NO Antibiotics
- Traceability

Future Projects:

- 1000-Acre Integrated Fish Farming Project
- Cold Storage &

Processing Units

- Shrimp Feed Launch

CMO's Message – Mr Ravi Chapa

“Building Reach, Ensuring Supply, Delivering Results”

- 40+ qualified technical staff.
- 8-10 warehouses across India.
- FY 2026-27 Target: 25,000 MT.
- Premium Shrimp Feed and Aqua Healthcare Products in pipeline.

Product Range

1. AQUA GOLD, AQUA SILVER, AQUA DIAMOND & AQUA+



*Ravi Chapa, CMO,
Kunal Agro Products*

Protein: 24% to 32% | Sizes: 1mm to 4mm

2. KUSHI PCF – Premium Polyculture Sinking Feed

Protein: 20% to 30%

3. GRAVITY – Premium Sinking Feed for IMC

Protein: 22% to 24%

Key Strengths:

- In-house SOYA DOC production
- Up to 50% Protein
- R&D driven for better FCR and higher yields.



AQUACULTURE PROBIOTICS EXPERT



Nuri
NET 200 g **BSL**

Probiotics
for water treatment

1. WATER QUALITY CONDITIONING

Best choice of *Bacillus* spp. that rapidly decompose uneaten feed, feces and other organic substances in pond water, keeps water quality optimal



Before



After

3. ESTABLISH BALANCED POND BACTERIA SYSTEM

Complete nutrition with vibrio and inhibit them to grow. Provide nutrition for probiotics in the pond, to establish a well-balanced farming system.

Inhibit the growth of *Vibrio* spp.



Before



After

6. INCREASE AQUACULTURE PRODUCTION

Good quality of water prevents fish/prawn infections, making high profit of production

2. HIGH ACTIVITY OF SPORES

No cultivation is needed. Easily adapt to the changes of surroundings and grow fast in freshwater or seawater culture farming, even under low oxygen environment

3. DECREASE AMMONIA CONTENT

Prevent the accumulation of toxic substances such as NH_4 , NO_3 , etc.

4. IMPROVE WATER COLOR

Improve water color regulate the algae and bacteria balance in water, turning your pond from green to clear

Eliminate undesirable algae



Before



After

Improve water color



Before



After

* COMPOSITION:

***Bacillus* spp. > 1×10^{11} cfu/kg**

(*Bacillus subtilis*, *Bacillus amyloliquefaciens*, *Bacillus licheniformis*)

Carrier (rice bran, corn gluten)

Moisture

15%

75%

10%

* STORAGE:

Keep at dry, well-ventilated condition. Avoid direct sunlight exposure and use as soon as possible once opened for best quality.

* DIRECTION OF USE:

No cultivation is needed. Apply Nuri BSL with water-soluble bag near to the working water wheel or pour into the pond evenly. Recommend apply Uni-Light PSB together with Nuri-BSL on sunny day to achieve a clear pond more efficiently.



UNI-LIGHT PSB Function:

- Decompose pond bottom
- Inhibit the growth of *Vibrio* spp.
- Purification of water quality

BSL Dosage:

Quantity	10 - 30 $\mu\text{L}/\text{m}^2$ tiger prawn or < 80 $\mu\text{L}/\text{m}^2$ Vannamei	For > 30 $\mu\text{L}/\text{m}^2$ tiger prawn or > 80 $\mu\text{L}/\text{m}^2$ Vannamei	For > 150 $\mu\text{L}/\text{m}^2$ Vannamei
7 days before stocking	800 g - 1,000 g	1,200 - 1,500 g	1,200 - 1,500 g
Day of stocking	300 g - 500 g	800 g - 1,000 g	800 g - 1,000 g
Every 7 - 10 days after stocking	300 g - 500 g	800 g - 1,000 g	800 g - 1,000 g

3 - 5 days / use 1,000g - 2,000g

***Dosages can be adjusted according to the water conditions and practices.

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✉ aquafeed@upvn.com.vn
www.uni-president.com.vn

Aquaculture development happens only when society is safe and good

If Pond Waste Water Enters Canals, Permission for those Ponds will be Revoked: Deputy Speaker

Aqua International organizes its 44th Edition Aquaculture Expo at Bhimavaram, Andhra Pradesh



Kanumuri Raghu Ramakrishna Raju, Hon'ble Deputy Speaker, Andhra Pradesh Legislative Assembly, Govt. of Andhra Pradesh and C. Nagarani, IAS, Hon'ble District Collector & Magistrate, West Godavari District, Andhra Pradesh, inaugurated 44th Aquaculture Expo 2026 at Bhimavaram on June 12. M.A. Nazeer and others are seen during the inauguration of the Expo.

Bhimavaram: A 2-days Exhibition, Panel Discussion and AI Excellence Awards presentation programme titled Aquaculture Expo 2026 was held at Bhimavaram, Andhra Pradesh on 12 & 13 June 2026. There was Panel Discussion and interaction meet with the theme: Current Challenges in

Aquaculture and Strategies - Tap the Potential to take Andhra Pradesh Aquaculture to the next level of Development.

Deputy Speaker of Andhra Pradesh Mr Kanumuri Raghuramakrishna Raju said that farmers should realize that the permits of those ponds will be cancelled in places where aqua water is released into agriculture crop canals. He was speaking at the inaugural function of Aquaculture Expo 2026 at Bhimavaram on June 12. He said that a lion's share of shrimp production is from West Godavari district. He said that the government is providing support for the development of this sector.

He said that drinking water problems are arising due to non-compliance with the rules. He said that it is not right to release waste water from shrimp ponds into crop canals for agri related activity, because of which the number of cancer victims will increase.

The Deputy Speaker along with West Godavari district collector Mrs Ch. Naga Rani inaugurated the Expo and interacted with the exhibitors and farmers.

There is a dilemma over the cultivation of agricultural land belonging to Bairagi Math in Pentapadu.

There are about 84 acres of agricultural land belonging to Bairagi Math in various survey numbers in Ravulaparru revenue of Ungutur mandal. The lion's share of this is being cultivated by Donthavaram farmers and some land is being cultivated by Ravulaparru farmers. Recently, there has been a



K. Raghu Ramakrishna Raju



M.A. Nazeer



Kanumuri Raghu Ramakrishna Raju, Mrs Ch. Naga Rani, Gottimukkala Gandhi Bhagawan Raju, M. Tulasi Rambabu and M.A. Nazeer lighting the Lamp during the inauguration of the Expo.

dispute over cultivation.

They want to recognize that they are there. He said that this industry is developing only when the society is good. He said that the crop canal embankment should not be used as a common embankment for shrimp production. He has been saying for a year that that waste water should not be released into the irrigation water and ordered that the regulations be implemented. Aquaculture will grow only when the people in the society are safe and healthy. He advised shrimp farmers

If waste water enters canals, permission for those ponds will be revoked. He warned that electricity will be cut off and licenses will be cancelled in places where violations occur. I have been telling aqua farmers last one year not to leave

waste water into agri canals and to follow govt. rules and advises, said Deputy Speaker Raghurama Krishna Raju.

Collector Ch Naga Rani said that every Wednesday, experts and farmers workshops are being organised at four places in the district to provide necessary support for the progress and development of Aquaculture. She said that efforts are being made to expand the work being done to control water pollution in the district.

Mrs Dr T. Suguna, Officer on Special Duty, A.P. Fisheries University; A.P. Aqua Farmers Association President Gandhi Bhagwanraju; District President M. Tulasi Rambabu, Library Chairman Juttiga Nagaraju and others participated.

Mr M.A. Nazeer, Chief Executive of the Expo and

Editor, Aqua International in his welcome address said, we have so far organised 44 exhibitions and conferences on Aquaculture sector since 1994 in different parts of the country.

The Indian aquaculture sector is rapidly transforming from a traditional, fragmented livelihood into a highly structured, tech-driven industry. The sector is getting organised and growing. The companies producing shrimp seed, feed, and shrimp processing companies have started using modernization, advanced technology and practices to produce quality products. At this stage the stakeholders like the farmers and the above mentioned segments companies should not allow conflicts which will lead to gap among them. All of them should sit together and resolve issues amicably. Looking at the situation, the Andhra Pradesh Chief Minister N. Chandra Babu Naidu has rightly organised a meeting with Union Ministers for urgent policy intervention to stabilize shrimp feed raw material prices and protect India's aquaculture challenges on 5 June 2026 at Visakhapatnam with the active participation of aquaculture farmers, said M.A. Nazeer.

I am glad to inform you that Deputy Speaker Kanumuri Raghu

Ramakrishna Raju has been putting efforts to solve aquaculture industry problems in Andhra Pradesh state, he stated.

The main objective of the Expo was to bring awareness among aquaculture farmers and other stakeholders on various products, technology, and services available to get better yield / productivity in aquaculture. The Expo was an opportunity to aquaculture farmers and other stakeholders to update their knowledge on various aspects in aquaculture. The event was also an opportunity for buyers and sellers as well in the sector.

The expo brought stakeholder of Aquaculture sector like Farmers, Scientific & Educational Institutions on Aquaculture, Govt officials, Suppliers of various products and services like Seed, Feed, Health & Nutrition Products, Aerators & Equipment, Processors & Exporters, Raw Material buying Agents, Dealers & Distributors, Commercial & Technical Professionals together on a common platform during the two days event, and the event was also useful all to meet, exchange ideas and gain knowledge on various aspects, and for better business opportunities. He thanked the Exhibitors for their participation.



A View of participants during Inauguration of the Expo

Panel Discussion and Experts Farmers Interaction Meet: Current Challenges in Aquaculture and Strategies - Tap the Potential to take Andhra Pradesh Aquaculture to the next level of Development

Panel Discussion with
the theme: 'Current
Challenges in Aquaculture

and Strategies - Tap the
Potential to take Andhra
Pradesh Aquaculture to the

next level of Development'
was held on the occasion
in which three panelists

actively interacted with the
participants on different
aspects of the industry.



Dr K. Gopal Anand, Deputy Director, Sub Regional Division, MPEDA, Bhimavaram; R. Yuvaraju, Progressive Shrimp Farmer; Lady Young Entrepreneur and M.A. Nazeer during Panel Discussion on the occasion of Aquaculture Expo 2026 held on 12 June 2026 at Bhimavaram, Andhra Pradesh.



*M.A. Nazeer presenting memento to
Dr K. Gopal Anand*



*M.A. Nazeer presenting memento to
Lady Young Entrepreneur*



*M.A. Nazeer presenting memento to
R. Yuvaraju*



*Group photo of Panelists during
Panel Discussion*



*Joshi K. Shankar, Director, Jay Jay Group of
Hatcheries making a point during Panel Discussion*



*Dr Girish Mahajan, Senior Vice President, HiMedia
Labs making a point during Panel Discussion*

M.A. Nazeer, Chief Executive, Aquaculture Expo and Editor, Aqua International presented mementos to the exhibitors as a gesture of appreciation for their participation in the Expo.





A view of Aquaculture Expo 2026 held at Bhimavaram, Andhra Pradesh on June 12 & 13





Aqua International presents AI Excellence Awards 2026 to the individuals, institutions and organisations



AI Excellence Awards 2026 Winners: Jogi Varma, M. Sakthi, Vijay Kumar and his team, Dr Rushinadha Rao Kakara, Dr Girish Mahajan, Pranav Kumar Panday, Dr K. Pani Prasad, V.R. Mansingh, PDBSN Venkateswara Rao, Kanumuri Bhasker Raju and Yuvaraju Ruddaraju along with Deputy Speaker of A.P. K. Raghu Ramakrishna Raju, Dr T. Suguna and M.A. Nazeer.

Uddaraju Kasi Viswanadha Raju, Chairman, Ananda Group receives Lifetime Achievement Award 2026



U. Jogi Varma receiving **Lifetime Achievement Award 2026** on behalf of his father Uddaraju Kasi Viswanadha Raju, Chairman, Ananda Group from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna, Officer on Special Duty, A.P. Fisheries University. M.A. Nazeer is also seen in the picture.

M. Sakthi, General Manager – Sales, The Waterbase Ltd receives Best Executive with Long Service in Aquaculture Award 2026



M. Sakthi, General Manager – Sales, The Waterbase Ltd, receiving **Best Executive with Long Service in Aquaculture Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. M.A. Nazeer is also seen in the picture.

DCM Shriram Ltd receives Best Disinfectant Manufacturer Award 2026



Vijay Kumar, Joint Manager, DCM Shriram Ltd receiving **Best Disinfectant Manufacturer Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. Representatives of DCM Shriram Ltd Distributor and M.A. Nazeer are also seen in the picture.

Dr Rushinadha Rao Kakara receives Best Technical Support in Aquaculture Award 2026



Dr Rushinadha Rao Kakara, Technical Manager, Shrimp Improvement Systems, LLC, receiving **Best Technical Support in Aquaculture Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. M.A. Nazeer is also seen in the picture.

HiMedia Laboratories Pvt Ltd receives Best Aqua Healthcare Diagnostic Solution Provider Award 2026



Dr Girish Mahajan, Senior Vice President - Microbiology Dept, HiMedia Laboratories Pvt Ltd, receiving **Best Aqua Healthcare Diagnostic Solution Provider Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. M.A. Nazeer is also seen in the picture.

Tablets (India) Limited, TIL Biosciences receives Best Soil & Water Treatment Products Manufacturer Award 2026



Pranav Kumar Pandey, Head, TIL Biosciences (Animal Health Division), receiving **Best Soil & Water Treatment Products Manufacturer Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. M.A. Nazeer is also seen in the picture.

Dr K. Pani Prasad receives Best Aquaculture Scientist Award 2026



Dr K. Pani Prasad, Professor & Research Coordinator, Andhra Pradesh Fisheries University and Former Dean (ER) & Principal Scientist, ICAR-Central Institute of Fisheries Education, Mumbai, receiving **Best Aquaculture Scientist Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. M.A. Nazeer is also seen in the picture.

V.R. Mansingh receives Best Technical Services Provider in Aquaculture Award 2026



V.R. Mansingh, General Manager, Deepak Nexgen Feeds Pvt Ltd, receiving **Best Technical Services Provider in Aquaculture Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. M.A. Nazeer is also seen in the picture.

P. Venkateswara Rao receives Best Aquaculture Technical Awareness Award 2026



P. Venkateswara Rao, Aquaculture Technical Service Professional, Godavari Aqua Global Group, receiving **Best Aquaculture Technical Awareness Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. M.A. Nazeer is also seen in the picture.

Kanumuri Bhasker Raju, SAFE Aqua, receives Best Corporate Shrimp Farmer Award 2026



Kanumuri Bhasker Raju, Managing Director, Shrimp Aqua Farms Elite (SAFE) receiving **Best Corporate Shrimp Farmer Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and Dr T. Suguna. M.A. Nazeer is also seen in the picture.

Yuvaraju Ruddarraju receives Best Shrimp Farmer Award 2026



Yuvaraju Ruddarraju receiving **Best Shrimp Farmer Award 2026** from Deputy Speaker of A.P., K. Raghu Ramakrishna Raju and M.A. Nazeer.

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POND CONDITIONER



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- Controls Body Cramp
- Pond Water Mineralization
- Shell Formation



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Suitable for all kinds of floating & sinking aquatic feed
The screw permutation is adjustable to fit different formulation
Advanced automatic touch screen control system

Model	HR165	HR118X2	HR145X2	HR168X2
Capacity(t/h)	3-5	3-6	6-10	10-15
Type	Single-screw	Twin-screw	Twin-screw	Twin-screw



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Moisture evenness $\leq 1.5\%$
Use only one-third power compared to other competitors.



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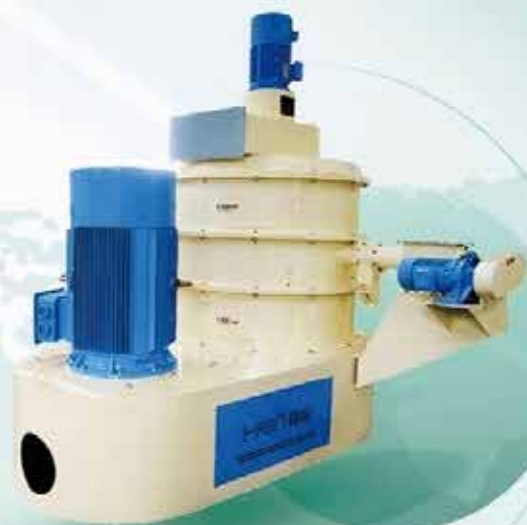
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Vertical shaft with no-screen grinding, Bearing no maintenance. The production is uniform and the fineness is adjustable. (Range from 40-200 mesh.)



Hengrun HRYTZ Series Vacuum Sprayer

Totally enclosed spraying space, Precision & Efficient spraying proportion widely ranged from 2%-30%.

Remembering fishery scientist Late Dr P. Das with reverence on 90th birth anniversary

Subrato Ghosh, Assistant Fishery Officer, Government of West Bengal
Government Fish Technological Station and Aquaculture Pathology Laboratory
Junput, Purba Medinipur – 721 450, West Bengal, Email: subratoffa@gmail.com



*Dr Das as Director,
NBFG, Lucknow*

Dr Punyabrata Das, better known to fishery and aquaculture scientist fraternity of India as 'Dr P. Das', was a distinguished Indian fisheries scientist and expert, revered by everybody. He was the second most-prominent fishery and aquaculture scientist of India from West Bengal after Dr Hiralal Chaudhuri – served continuing ten years as Director of ICAR-National Bureau of Fish Genetic Resources (NBFG), Lucknow till retirement. Year 2026 happens to be his 90th birth anniversary and 4th death anniversary. Rightly stated by Dr U. K. Sarkar, Retd. Director, ICAR-NBFG: '... Dr P. Das's personal behaviour was full of human sensibilities and values'. So gracious and pleasing was his personality, greatness uncomparable. I could come under Dr Das's likings in my life, obtained Sir's blessings, academic advice, inspiration, help, love & affection during my UG, PG and research studies in Fishery and Aquaculture. I pay homage to Sir Dr Das.

Early life and career at ICAR-CIFRI, Barrackpore

Dr Punyabrata Das (Dr P. Das) was born on 19/09/1936 in a Zamindar family in Sylhet district of Bangladesh. He came to Kolkata with his parents, other three brothers and one sister after passing School Final (Class-X) examination. He completed B.Sc. (Hons) course from Scottish Church College, Kolkata and Masters M.Sc. studies from Delhi University, New Delhi.

He joined ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore in the year 1958



*Dr Das with Padmavibhushan
Dr S. Z. Qasim*

as a Trainee on Inland Fisheries Management and Administration at 22 years of age. After two years, he started his professional career as a Survey Assistant at Riverine and Lacustrine Fisheries Division of ICAR-CIFRI at Allahabad in 1960. He also worked in this position at Narmada-Tapti Unit of this Division at Hoshangabad, Madhya Pradesh and in Gujarat. In 1961, he was posted at Estuarine Division of ICAR-CIFRI at Kakdwip, Dist. South 24 Parganas, West Bengal. During the period 1962-1969, Dr Das worked as Assistant Fisheries Training Superintendent at ICAR-CIFRI, Barrackpore. After qualifying UPSC exam, he worked as Superintendent of Fisheries at Goa, Daman and Diu for a brief period and got detached from ICAR-CIFRI. However, he joined as Senior Extension Officer and Head of Extension Division of ICAR-CIFRI at Barrackpore Headquarters at the All India Coordinated Research Project on Major Carp Spawn Prospecting in 1971, continued working. Dr Das's post was changed to Junior Fishery Scientist (S-1) at ICAR-CIFRI, he was the only Scientist in Extension Division around year 1976. He set up the new Division with large-scale National Demonstration Programmes, 'Lab



Dr Das giving an Invited Lecture

to Land' Programmes, publication of extension pamphlets with package of practices on new technologies in freshwater aquaculture including composite fish culture (which were supplied to All India Radio, Calcutta in 1973 for broadcasting under Farmer's programme), arranging field training programmes. Dr Das's discussion on intensive fish farming with staff of All India Radio was broadcasted in July 1973.

Dr P. Das, then S-3 at ICAR-CIFRI, Barrackpore delivered a talk on Communication media in relation to adoption of scientific fish culture to CADP (Comprehensive Area Development Corporation, Govt of West Bengal) Officials at Calcutta on 19/11/1982. On 16/07/1985, he



Dr Das with Dr P. V. Dehadrai, DDG Fisheries, ICAR

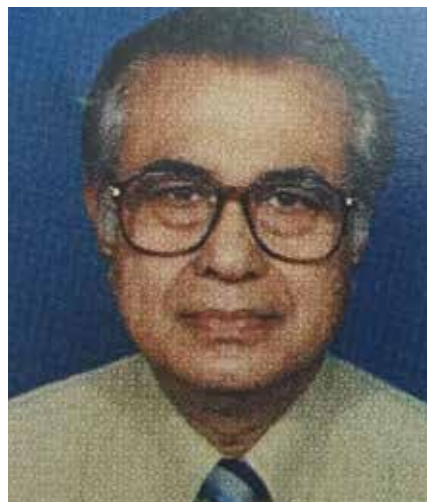
gave a Lecture in the Seminar on Fisheries Development held at Young Mens Christian Association (YMCA), Ranaghat, it was attended by over 200 fish farmers, extension personnel and Government officers. It was organized by Fish Farmers' Development Agency, Dist. Nadia, West Bengal. He participated in Seminar on Fish Culture at College of Agriculture, Viswa-Bharati, Santiniketan on 10/08/1980 – he was in S-2 in Extension Section of ICAR-CIFRI, Barrackpore in 1980. On 24/08/1982, Dr P. Das met Lt. General R. S. Dayal and other senior officers of Indian Army Headquarters - he discussed with them different fish production technologies developed at ICAR-CIFRI wrt composite fish culture and its economics. He detailed the significance of World Environment Day and the evolution of World Environment movement on 05/06/1982.

Dr Das participated and presented Paper on 'Low cost fish hatchery' in 2nd National Fish Seed Congress, organized by West Bengal Fisheries Department on 03/07/1986; in EIFAC Symposium on 'Selection, hybridization and genetic engineering in aquaculture of fish and shellfish for consumption and stocking' during 27-30/05/1986; in Symposium on 'Conservation and management of fish genetic resources of India' and presented paper on 'Predicted response to selection for faster

growth in pearl spot' on 11/04/1986. He presented the paper 'Aquaculture Research Communication' in National Workshop on Changing perspectives in extension, organized by National Institute of Rural Development, Hyderabad during 13-16/02/1984. Dr Das was relieved from ICAR-CIFRI, Barrackpore on 14/07/1986 to join as Director of ICAR-NBFGR, then at Allahabad.

Award of Doctorate of Philosophy

In 1984, Dr P. Das, who was looking after Brackishwater Fish Genetics Section of ICAR-CIFRI, Barrackpore was given the additional charge of Extension and Training Division. On 01/01/1984, Dr Das working as S-3 was promoted to next higher position upon recommendation of Agricultural Scientists Recruitment Board, New



Dr Das as Vice President of Inland Fisheries Society of India

Delhi. The Department of Zoology, University of Burdwan, West Bengal had conferred PhD degree on Sri P. Das, Scientist at ICAR-CIFRI for his thesis titled 'Studies on management and limnobiology in relation to fish production in some freshwater ponds' in July 1984. His study has led to better understanding of the complexities, certain management measures and pond limnobiology vis-a-vis fish production. The findings of Dr Das's study had immediate applicability in embanked freshwater ecosystems and thereby the aquaculture development as a whole.

Foreign visit and setting up of ICAR-NBFGR

Under initiative of the then Director of ICAR-CIFRI Dr A. V. Natarajan, Dr P. Das, Senior Fishery Scientist (S-3) was deputed through the British Council, Calcutta for a specialized training on fish genetics in United Kingdom for a period of six months from September 1983 to March 1984. He was attached to Dr B. McAndrew, Fish Geneticist of Institute of Aquaculture, University of Stirling, UK. His studies on genetics applicable to aquaculture broadly included sex manipulation, genetic engineering, fish breeding, fish hybridization, heritability estimation and selection (selective breeding) for genetic gain in cultivable fishes. He also familiarized himself with population genetics. Dr Das also visited (in his study tour) Genetics Laboratories at University College of Swansea of University of Wales and Fisheries Laboratory, Directorate



Dr Das in 1984 when Ph.D. awarded



Dr Das in a National Seminar

of Fisheries Research, Ministry of Agriculture, Fisheries and Food, Government of UK. After successful completion of the training, Dr Das received Certificate from Dr R. J. Roberts (author of well-known text book on Fish Pathology), Professor and Director, Institute of Aquaculture, University of Stirling.

This study tour ultimately helped Dr Das at a later stage in setting up the ICAR-NBFGR as founder Director – he contributed immensely in making of the institute. He joined ICAR-NBFGR as Director on 15/07/1986 with only two Senior Scientists and a few Technical Assistants. A 40 acre agricultural plot (site) was offered by Government of Uttar Pradesh for establishment of NBFGR permanently, which was 40km from Allahabad on the way to Varanasi. There was non-availability of suitable site. Then Dr Singh, Director of ICAR-Institute of Sugarcane Research at Lucknow discussed with Dr Das as first Director of ICAR-NBFGR and agreed to give about 50 acre of land to Dr Das for establishment of NBFGR. Undulating land had to be leveled. The then Director General, ICAR, New Delhi gave approval for the new site of ICAR-NBFGR at Lucknow.

In the early 1990s, Dr E. G. Silas, eminent Indian fishery and aquaculture scientist prepared a plan for establishment of a Bureau of Fish Genetic Resources at ICAR-Central Marine Fisheries Research Institute

(CMFRI), Cochin. Government of India sanctioned Rs 22.67 lakhs for setting up the Bureau in 6th Five Year Plan period as a Project with a Centre at CMFRI. The Project was initiated with Dr A. G. Jhingran as Project Director, followed by appointment of Dr P. Das as Director heading the Bureau at Allahabad. It was later shifted to its permanent campus at Lucknow and with a research unit at CMFRI campus. At ICAR-NBFGR, Dr Das led the way in setting up systems for collection, cataloguing and conservation of fish genetic resources of India, and also in promoting fish biodiversity documentation, fish stock identification and fish germplasm conservation programmes.

After retirement period

Dr P. Das retired from ICAR service on 30/09/1996 as Director, ICAR-NBFGR. Later on, he became Member of Research Advisory Committee of ICAR-CIFRI, Barrackpore; Vice President of Inland Fisheries Society of India, Barrackpore; Member, West Bengal State Agriculture Commission, Kolkata; Ex. Visiting Professor, Babasaheb Bhimrao Ambedkar University, Lucknow; Ex Fishery Consultant, West Bengal University of Animal and Fishery Sciences, Kolkata; President, Society of Nature Conservators, Muzaffarnagar; Chief Editor of Journal 'Aquacult' and hold other important positions. Dr U. Bhaumick (younger in age to Dr Das), Retd. Principal Scientist and Head, Extension Division of ICAR-CIFRI, Barrackpore did a considerable part of his PhD research under supervision

of Dr P. Das. Dr Das was honoured as Fellow of National Academy of Sciences, Allahabad; Fellow of Inland Fisheries Society of India, Barrackpore; Fellow of Association of Aquaculturists, Bhubaneswar; Fellow of Zoological Society, Kolkata; Fellow of Zoological Society of India, Bodh Gaya; Fellow of Biotech Research Society of India, Thiruvananthapuram; Fellow of Society of Nature Conservators; Fellow of Academy of Environmental Biology; Fellow of Society of Biosciences.

He was invited more than once as Guest in Fish Farmers' Day celebrations and Foundation Day celebrations of ICAR-CIFRI, Barrackpore, ICAR-CIFE Kolkata Centre, ICAR-NBFGR, Lucknow.

Dr Das was invited as Guest in the inauguration of Summer School on 'Methods of assessment of aquatic ecosystem for fish health care' at ICAR-CIFRI on 18/07/2002. He presided over the National Consultation on 'Species prioritization for ex-situ conservation and freshwater aquaculture', held at ICAR-NBFGR, Lucknow during September 2011. He Chaired Technical Session II on 'Conservation of biodiversity and small indigenous freshwater fish species' in the Workshop on Small Indigenous Fish Species: Their Role in Poverty Alleviation and Food Security, organized by ICAR-CIFRI, Barrackpore during February 2010.

Dr Das's writings (which I have with me)

Dr Das's article 'Field demonstration for fish farmers in composite fish



Dr Das seen in between Dr Vass and Dr Chaudhuri



Dr Das with his daughter-in-law

culture' was published in 1976 in Food Farming and Agriculture, Vol. 8 Issue 2. He published the article 'Communication media in relation to adoption of scientific fish culture' in Souvenir of Symposium on Harvest and Post-Harvest Technology of fishes, held in Kolkata in November 1982. The Bibliography (NBFGFR Bulletin) on 'Genetic Improvement of Fish Stock and Resource Conservation' was published by Dr Das at ICAR-NBFGFR in 1986. In year 1983, his article 'Appropriate inland aquaculture technologies for small and marginal fish farmers of Sundarbans' was published in Souvenir of Ramkrishna Ashram Krishi Vigyan Kendra, Nimpith, South 24 Parganas, West Bengal. He published 'Packages of practices for increasing carp seed production' as Aquaculture Extension Manual from ICAR-CIFRI in 1982.

In the Souvenir of 6th Indian Fisheries and Aquaculture Forum held at CIFE, Mumbai during December 2002, Dr Das's informative article 'Piscine Biodiversity Conservation with particular reference to West Bengal' was published. We are informed that after an intensive on-field study, a comprehensive list of 106 nos of threatened fish species of different aquatic ecosystems of West Bengal has been prepared under the leadership of Dr Das – the research project was undertaken by Aquatech Popularization Society, a

Kolkata-based NGO headed by Dr P. Das and funded by Department of Environment, Government of West Bengal. Dr Das's lucid Bengali article on 'Where have the fishes of rivers and canals gone?' was published in Matsya Samachar 2000 issue (publication of Retired Government Fishery Officers Association), emphasizing on the concern of depletion of fish stock in rivers. In another issue (1999) of Matsya Samachar, his Bengali article 'Transgenic Super Fish' was published, where Dr Das nicely described scientific terms and concepts like quantitative traits, gene transfer, features of transgenic fish in Bengali version. In further another issue (2002), he wrote the article 'Organic Farming Beneficial for Fish Farming'.

In Souvenir of National Seminar on 'Management challenges in fisheries of rivers and associated ecosystems – issues and strategies' organized at ICAR-CIFRI during April 2005, Dr Das wrote an important article 'Consequences of Anthropogenic Threats on Fish Gene Pools'. He nicely described about genetic variation and genetic diversity among fishes, within population variance and among population variance, genetic bottlenecks, genetic drift, inbreeding depression, strategies for fish biodiversity conservation, genetic management of endangered/severely declining fish population. In the Souvenir of National Symposium on 'Fisheries enhancement in inland waters – challenges ahead' organized at ICAR-CIFRI during April 2002, Dr Das wrote the article 'Conservation Genetics of Threatened Fishes in Open Waters'. He nicely described about aquatic resources and fish diversity, factors affecting fish biodiversity, threatened/endangered fish management, terms in fish genetics (genetic variation, population size, loss of alleles, reduction in quantitative traits, genetic drift, avoidance of inbreeding and genetic management, manifestations of inbreeding depression).

In Souvenir of International Symposium on 'Fish for nutritional and livelihood security in the 21st

century', organized at ICAR-CIFE, Mumbai during December 2001, Dr Das's article 'Genetics of Conservation and Aquaculture' was published. In addition to other important aspects, he nicely explained about genetic characterization of fishes, hybridization, sex reversal, gene banking, selective breeding/selection for faster growth, genetic engineering, gynogenesis, androgenesis, polyploidy, transgenic fish, and application of genetics in augmenting aquaculture production. In the Proceedings of Summer School on 'Fisheries management of floodplain wetlands of India' organized at ICAR-CIFRI during July-August 2003, Dr P. Das wrote the article 'Possibilities of Stock Improvement for Floodplain Wetlands'. He emphasized on genetic characterization and other aspects, hoped that sustainable Blue Revolution will be possible through application of genetics for improvement in quality of fishes used in aquaculture in the beginning of 21st century in India.

Dr Das published the paper 'Observations on four species culture of Indian major carps and silver carp' in Journal of Inland Fisheries Society of India in 1982. His paper 'Apprehensions of environmental perturbations by genetically altered fishes' was published in Souvenir of National Seminar, organized by Society of Biosciences, Environment and Health at C. C. Singh University, Meerut during 17-19/10/1997. His paper 'Diminishing Trend of Fish Species Diversity in West Bengal: A Field Study' was published in Fishing Chimes, Vol. 24 Issue 1 in 2004. During 1992 and 1994, his eight papers were published as first author with Dr K. D. Joshi on broad aspect of Conservation of fish germplasm in India; Anthropogenic stresses affecting fish germplasm resources in Ganga river; Genetics in conservation of fish germplasm resources; Mahaseer conservation.

End note

I first saw Dr P. Das in the One-day National Workshop on 'Bridging Gap for Attaining Self Sufficiency in Inland Fish Production at the Dawn

of New Millennium', organized by Retired Government Fishery Officers Association, Kolkata at Bangla Academy Sabhaghar on 22/06/2000. Then Dr Das was Director (Retd.), ICAR-NBFGR and President, Retired Government Fishery Officers Association. He took the leading role in organizing this Workshop and bringing eminent fishery scientists to deliver Talks/Lectures. I went with my teacher at Asutosh College Late Dr C. K. Majumdar to hear Talks of eminent personalities in this Workshop. It was my first-time participation in a National Seminar on Fisheries and Aquaculture in my life, I was then an on-going BSc 3rd year student in Industrial Fish and Fisheries in last month. On my request, after four days on 26/06/2000, I visited Dr Das's Flat at Indralok Estate for the first time and he gave me a hand-written participation Certificate in his Letterhead Paper with some good words in my favour. I still remember that Dr P. Das was Chairperson in the Technical Session in which I had my Oral Paper Presentation, at C. V. Kulkarni Auditorium Hall, in Sixth Indian Fisheries and Aquaculture Forum, organized at ICAR-CIFE Deemed University, Mumbai during December 2002. He congratulated me and gave advice after my Presentation.

During my participation in Tenth Indian Fisheries and Aquaculture Forum held at NBFGR, Lucknow during November 12-15, 2014, I saw the naming of the institute's Library as 'Dr P. Das Memorial Library' at Ground Floor of NBFGR building. Since, 2003, Dr Das had been invited quite regularly as Expert in Interview Board at West Bengal Public Service Commission Office, Kolkata for the posts of Assistant Director of Fisheries and District Fishery Officer under Directorate of Fisheries, Government of West Bengal. 'Dr Punyabrata Das Research Award' was started by Aquatic Biodiversity Conservation Society, Lucknow (under ICAR-NBFGR) and is given every year to selected scientist. In May 2024, Scientists of ICAR-NBFGR discovered a new species of catfish in Tissa river in Arunachal

Pradesh, it was named Glyptothorax punyabratai in honour of Dr P. Das. He participated in the World Fish Centre – ICAR-CIFRI Collaborative Project on Community-based management of rice-fish farming with adaptive learning approach.

Dr Das's wife, Smt Sukla Das was In-charge of Library and Documentation Section, ICAR-CIFRI at Barrackpore – she was Senior Library Assistant Grade-II at this institute in 1975. She obtained M.A. degree from Calcutta University in September 1978. During February 1982, she attended a week-long Management Course in conservation of documents conducted by Indian Association of Special Libraries and Information Centre, Kolkata. She died in 2020. Dr Das had one son, who is a physician. Sir's only sister lives in London. I visited Dr Das's home in Kolkata in 2000 and 2003, showed my BSc and MSc marksheets respectively to Sir

after scoring good marks. Even I sent letters to Sir and informed him after joining ICAR-CIFA, Bhubaneswar as Senior Research Fellow in November 2006 and after getting appointment in permanent service in Directorate of Fisheries, Government of West Bengal in January 2013. Truly revered and esteemed Dr Punyabrata Das died on 15/12/2022 at 86 years of age at his residence (Flat) 'A8/4 Indralok Estate, Paikpara' in north Kolkata. 'Man is mortal, but his legacy will remain immortal'. His another home (Bungalow), built later on, is at Madhyamgram, Dist. North 24 Parganas, West Bengal. I express my gratefulness and gratitude to Mrs Gita Jha, Dr P. Das's sister and Mrs Dipsikha Das, W/o Dr Sougata Das and Dr Das's daughter-in-law for providing me valuable information about Sir on my request. All compiled facts and figures presented in this write-up is genuine and trustworthy to the best of my knowledge and belief.

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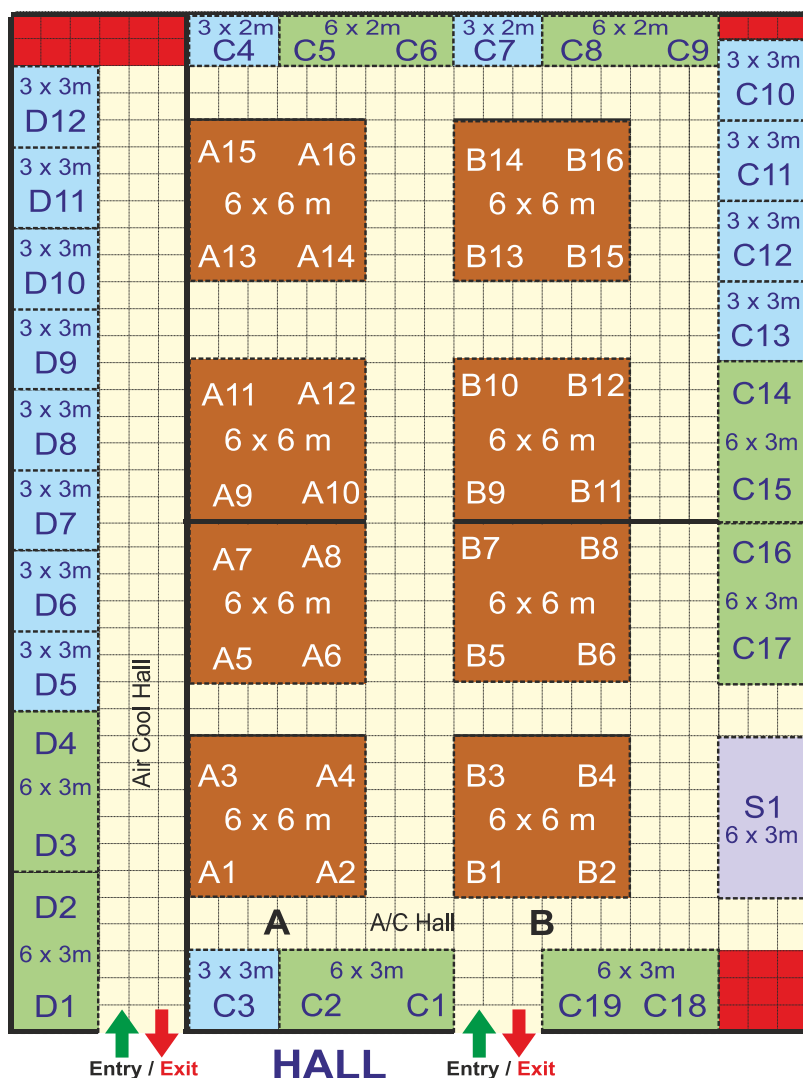


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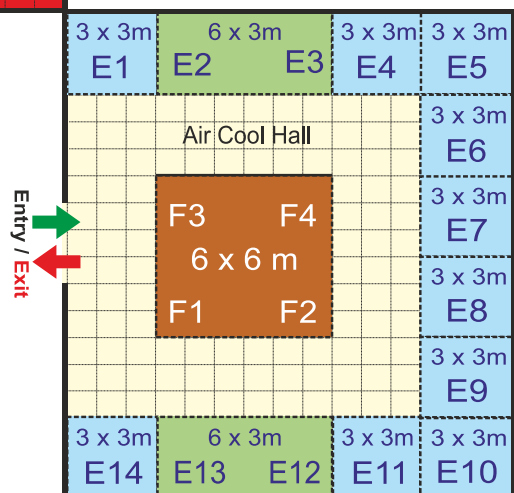
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Alternatives to Antibiotics: Biological, Synthetic and Biotechnological Strategies to address Antimicrobial Resistance (AMR)

K Pani Prasad and T. Suguna

Professor, Andhra Pradesh Fisheries University, Vijayawada – 521 137, Andhra Pradesh

Abstract

Antimicrobial resistance (AMR) represents a mounting global crisis threatening the sustainability of modern medicine, livestock production, and aquaculture. The widespread and often indiscriminate use of antibiotics for disease treatment, prophylaxis, and growth promotion has accelerated the emergence of multidrug-resistant pathogens across human, animal, and environmental interfaces. While antimicrobial stewardship and antibiotic prudence are essential pillars of AMR mitigation, their success is fundamentally dependent on the availability of effective alternatives capable of preventing and controlling bacterial infections without promoting resistance.

This short review critically examines the current landscape of antibiotic alternatives, categorizing them into naturally occurring agents, synthetically designed antimicrobials, and biotechnology-based strategies. Approaches such as bacteriophage therapy, antimicrobial peptides, bacteriocins, probiotics, fecal microbiota transplantation, phytochemicals, predatory bacteria, antibody-based therapeutics, synthetic peptide mimics, virulence inhibitors, vaccines, and genetically engineered bacteriophages and lysins are discussed with respect to their mechanisms of action, advantages, limitations, and translational readiness. Particular emphasis is placed on aquaculture and animal production systems, where antibiotic dependence remains high and ecological spill over risks are substantial.

Despite notable scientific advances,

most alternative strategies remain strain-specific, context-dependent, and economically constrained, limiting their capacity to fully replace antibiotics. The review argues that future antimicrobial strategies must move beyond one-to-one substitution and instead adopt integrated, combination-based frameworks that synergize antibiotics with targeted alternatives. Advances in biotechnology, microbiome science, and immunomodulation, supported by enabling regulatory and economic policies, will be critical for translating promising alternatives into scalable, field-ready solutions for sustainable disease management under the One Health paradigm.

Keywords: antimicrobial resistance, antibiotic alternatives, bacteriophages, antimicrobial peptides, probiotics, aquaculture health, One Health.

1. Introduction

The discovery of antibiotics revolutionized medicine and animal production, transforming once-lethal infections into manageable conditions. However, decades of excessive and inappropriate antibiotic use have driven the rapid evolution of antimicrobial resistance (AMR), rendering many first-line and even last-resort drugs ineffective. AMR is now recognized as a global health emergency with profound implications for food security, public health, and environmental sustainability.

In animal agriculture and aquaculture, antibiotics have historically been used not only for disease treatment but also for prophylaxis and growth promotion. Such practices have contributed significantly to the

selection and dissemination of resistant bacteria and resistance genes across ecosystems. The interconnectedness of humans, animals, and the environment underscores the urgency of addressing AMR through a One Health framework.

Antibiotic stewardship initiatives emphasize reduced usage, optimized dosing, and improved diagnostics. However, stewardship alone is insufficient if viable alternatives are unavailable. The concept of antibiotic prudence, while ethically and scientifically sound, becomes difficult to operationalize when animal health, livelihoods, and production efficiency are at stake. Consequently, the development of effective non-antibiotic interventions is no longer optional but essential.

This review synthesizes current knowledge on alternatives to antibiotics, evaluates their readiness for practical application, and highlights critical gaps that must be addressed to enable meaningful reductions in antibiotic dependence.

2. Classification of Antibiotic Alternatives

To enable systematic evaluation, antibiotic alternatives can be broadly grouped into three categories:

- **Naturally occurring alternatives**, derived from biological systems and ecological interactions;
- **Synthetically designed strategies**, developed through rational chemical and molecular engineering;
- **Biotechnology-based approaches**, leveraging genetic engineering, molecular biology, and immunotechnology.

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This framework reflects both the origin and functional mechanisms of the alternatives, facilitating comparison across diverse intervention strategies.

3. Naturally Occurring Alternatives

3.1 Bacteriophage Therapy

Bacteriophages are viruses that specifically infect bacteria and replicate through lytic or lysogenic cycles. Their ability to selectively target pathogenic bacteria while sparing commensal microbiota represents a fundamental advantage over broad-spectrum antibiotics. Phage therapy was widely used in parts of Eastern Europe before the antibiotic era and has recently re-emerged as a promising response to the antibiotic resistance crisis.

Phages infect bacteria by binding to specific surface receptors, injecting genetic material, and commandeering host cellular machinery to produce progeny virions. Lytic phages culminate in bacterial cell lysis, releasing new phages capable of infecting adjacent cells. This self-amplifying nature enables phages to increase in concentration at infection sites.

Despite their promise, phage therapy faces significant challenges. Bacterial resistance to phages can arise through receptor modification or CRISPR-mediated immunity. The narrow host range of most phages necessitates precise pathogen identification or the use of phage cocktails. Concerns regarding endotoxin release following bacterial lysis and immune-mediated clearance of phages also persist. Advances in phage engineering, formulation, and delivery are gradually addressing these limitations.

3.2 Antimicrobial Peptides and Host Defense Peptides

Antimicrobial peptides (AMPs) are ubiquitous components of innate immunity across plants, animals, and microorganisms. These short, cationic, amphiphilic molecules exert antimicrobial activity primarily by disrupting bacterial membranes,

leading to rapid cell death. Unlike antibiotics that target specific metabolic pathways, AMPs act on fundamental biophysical properties of bacterial membranes, making resistance development energetically costly.

In addition to direct antimicrobial activity, many AMPs function as host defense peptides (HDPs) that modulate immune responses, promote wound healing, and regulate inflammation. Emerging evidence suggests that HDPs can induce trained immunity through epigenetic reprogramming of innate immune cells, enhancing resistance to subsequent infections.

Despite extensive research, clinical translation of AMPs has been limited by issues related to proteolytic degradation, cytotoxicity, and high production costs. Nevertheless, continued innovation in peptide design and delivery systems may yet unlock their therapeutic potential.

3.3 Bacteriocins

Bacteriocins are ribosomally synthesized antimicrobial peptides produced by bacteria to inhibit closely related or competing strains. Many bacteriocins exhibit potent activity against antibiotic-resistant pathogens and possess favorable stability profiles. Their strain-specific activity offers a unique advantage in preserving beneficial microbiota.

Nisin, a well-known bacteriocin used in food preservation, exemplifies the translational potential of this class. However, broader therapeutic application has been constrained by narrow spectra of activity, regulatory complexities, and production challenges. Ongoing research into marine and aquaculture-associated bacteriocins may yield novel candidates with enhanced properties.

3.4 Modulation of Gut Microbiota

Probiotics and Prebiotics

The gut microbiota plays a central role in host nutrition, immunity, and disease resistance. Antibiotic-induced dysbiosis can predispose hosts to recurrent infections and opportunistic

pathogens. Probiotics—beneficial live microorganisms administered in adequate amounts—offer a strategy to restore microbial balance and competitively exclude pathogens.

Probiotics exert their effects through multiple mechanisms, including competitive adhesion, production of antimicrobial compounds, modulation of immune responses, and enhancement of barrier function. Their safety and suitability for long-term use make them particularly attractive for aquaculture and livestock systems.

Fecal Microbiota Transplantation

Fecal microbiota transplantation (FMT) involves transferring gut microbiota from healthy donors to diseased recipients. It has demonstrated remarkable efficacy in treating recurrent *Clostridioides difficile* infections in humans. Preliminary evidence suggests potential applications in decolonizing multidrug-resistant bacteria, although controlled studies in animals and aquaculture remain limited.

3.5 Phytochemicals and Predatory Bacteria

Plant-derived phytochemicals exhibit antimicrobial, antioxidant, and immunomodulatory properties. Their incorporation into animal diets has been associated with improved gut health and reduced pathogen load. However, variability in composition and bioavailability complicates standardization.

Predatory bacteria such as *Bdellovibrio* species prey on Gram-negative pathogens by invading and lysing prey cells. Their broad prey range, low immunogenicity, and minimal resistance induction make them intriguing candidates, although their application in aquaculture remains largely experimental.

4. Synthetically Designed Strategies

Synthetic mimics of antimicrobial peptides (SMAMPs) have been developed to overcome the limitations of natural peptides. These include peptidomimetics,

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antimicrobial polymers, and small molecules engineered to replicate amphiphilic membrane-disrupting properties. Some SMAMPs have shown the ability to resensitize resistant bacteria to conventional antibiotics.

Innate defense regulatory peptides represent another innovative approach, focusing on immunomodulation rather than direct antimicrobial activity. By enhancing host tolerance and immune competence, these peptides may reduce infection severity without exerting selective pressure on bacteria.

Gene-silencing strategies using antisense oligonucleotides aim to suppress essential bacterial genes or resistance determinants. While promising in vitro, challenges related to delivery, stability, and off-target effects have limited in vivo translation.

5. Biotechnology-Based Approaches

5.1 Genetically Engineered Phages and Lysins

Genetic engineering has expanded the therapeutic scope of bacteriophages, enabling the delivery of biofilm-degrading enzymes, resistance-sensitizing genes, and antimicrobial peptides. Phage-derived lysins—enzymes that degrade bacterial cell walls—have demonstrated rapid bactericidal activity and are progressing through clinical trials.

5.2 CRISPR-Based Antimicrobials

CRISPR-Cas systems offer unprecedented precision in targeting bacterial genomes and resistance genes. Their application in antimicrobial therapy remains experimental but holds potential for selectively eliminating resistant strains without disrupting microbial communities.

5.3 Vaccines and Antibiotic Inactivators

Vaccination remains one of the most effective strategies for reducing antibiotic use. Advances in spore-

based and autogenous vaccines have improved feasibility in aquaculture. Antibiotic inactivators, designed to protect the gut microbiome during systemic antibiotic therapy, represent a complementary strategy rather than a replacement.

6. Challenges and Future Directions

Despite significant scientific progress, most antibiotic alternatives face common challenges: limited spectrum of activity, high production costs, regulatory uncertainty, and poor commercial incentives. No single alternative can replicate the broad-spectrum efficacy of antibiotics.

Future strategies should prioritize combination therapies that integrate antibiotics with targeted alternatives, thereby enhancing efficacy while reducing resistance selection. Advances in diagnostics, microbiome profiling, and systems biology will be essential for matching interventions to specific pathogens and contexts.

7. Conclusions

Antibiotic alternatives represent a diverse and rapidly evolving field with the potential to transform antimicrobial stewardship. While complete replacement of antibiotics remains unrealistic in the near term, strategic integration of alternative approaches can substantially reduce antibiotic dependence. Coordinated efforts across science, policy, and industry are essential to translate promising innovations into practical solutions under the One Health framework.

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Blue-Green Circular Farming: The Future of Climate-Resilient Aquaculture in India

Integrating GIFT Tilapia, Biofloc Technology and Freshwater Aquaponics for Sustainable Food Production

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Highlights:

Blue-Green Circular Farming integrates GIFT Tilapia culture, Biofloc Technology (BFT), and freshwater aquaponics into a climate-smart aquaculture system based on IMTA principles. The model promotes efficient recycling of water and nutrients, significantly reducing waste and environmental impacts. By producing fish and plants simultaneously, it enhances productivity, profitability, and food security. The system requires less water and land than conventional farming methods, making it suitable for climate-resilient agriculture. This integrated approach offers a sustainable pathway for advancing aquaculture and supporting India's Blue Economy goals.

Introduction: The Need for Climate-Smart Aquaculture

India is one of the world's leading aquaculture-producing nations and plays a crucial role in meeting the growing demand for aquatic food. However, the sector faces increasing challenges arising from climate change, water scarcity, environmental degradation, rising input costs, and competition for natural resources. Traditional aquaculture systems, though productive, often depend on large quantities of water and generate nutrient-rich effluents that can affect surrounding ecosystems. As the country strives to achieve sustainable development goals and strengthen its Blue Economy, there is an urgent need for innovative farming systems that combine productivity with environmental responsibility.

In this context, the integration of

Genetically Improved Farmed Tilapia (GIFT), Biofloc Technology (BFT), and freshwater aquaponics based on Integrated Multi-Trophic Aquaculture (IMTA) principles offers a promising solution. This integrated approach, often referred to as Blue-Green Circular Farming, represents a new generation of climate-resilient food production systems that efficiently utilize water, nutrients, energy, and space while minimizing waste.

Blue-Green Circular Farming: A New Paradigm for Sustainable Food Production

The concept of Blue-Green Circular Farming is rooted in the principles of the circular economy, where resources are continuously reused, recycled, and recovered rather than discarded. In this integrated farming model, aquatic animals, beneficial microorganisms, and plants function together within a single production ecosystem. The nutrients that enter the system through fish feed are utilized multiple times before leaving the production cycle, thereby maximizing efficiency and minimizing environmental impacts.

Unlike conventional farming systems where wastes are treated as pollutants, circular farming transforms them into valuable resources. Fish waste becomes a nutrient source for microbial communities and plants, creating a productive cycle that generates multiple outputs from a single resource base. The result is a highly efficient and environmentally sustainable farming system capable of producing fish and vegetables simultaneously.

GIFT Tilapia: The Ideal Candidate for Intensive Freshwater Aquaculture

GIFT Tilapia (*Oreochromis niloticus*) has become one of the fastest-growing aquaculture species globally. Developed through selective breeding programmes, GIFT tilapia exhibits superior growth performance, efficient feed conversion, high survival rates, and remarkable adaptability to diverse environmental conditions. These traits make it particularly suitable for intensive culture systems where maximizing productivity per unit area and water volume is essential.

The species is highly tolerant of fluctuations in water quality and performs well under high stocking densities, making it an ideal candidate for integration with biofloc and aquaponic systems. Furthermore, increasing consumer demand and expanding domestic and international markets have enhanced the economic attractiveness of tilapia farming in India.

Biofloc Technology: Converting Waste into Valuable Resources

Biofloc Technology has emerged as one of the most significant innovations in sustainable aquaculture. The technology utilizes naturally occurring microbial communities to convert dissolved nitrogenous wastes into microbial biomass through the addition of suitable carbon sources. Instead of allowing ammonia and other toxic compounds to accumulate in the culture water, beneficial bacteria assimilate these nutrients and transform them into protein-rich bioflocs.



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These microbial aggregates serve multiple functions within the system. They improve water quality, reduce the need for water exchange, enhance biosecurity, and provide a supplementary natural food source for fish. Consequently, biofloc systems improve feed utilization efficiency while reducing production costs. For GIFT tilapia, which readily consumes bioflocs, the technology offers additional nutritional benefits and contributes to improved growth performance.

The reduced dependence on water exchange also makes biofloc systems particularly suitable for regions facing freshwater scarcity and increasing climate variability.

Freshwater IMTA and Aquaponics: Linking Fish and Plant Production

Integrated Multi-Trophic Aquaculture (IMTA) is traditionally associated with marine systems where species from different trophic levels are cultured together. However, in freshwater environments, aquaponics represents an effective adaptation of IMTA principles. In aquaponic systems, nutrient-rich water from fish culture tanks is directed towards hydroponic plant production units.

Vegetables, herbs, medicinal plants, and ornamental species absorb dissolved nutrients from the water, utilizing them for growth while simultaneously purifying the water. The treated water is then returned to the fish culture system, completing a highly efficient recirculating loop. This integration enables farmers to harvest both fish and crops from the same production system while conserving water and reducing nutrient losses.

Freshwater aquaponics is particularly attractive for peri-urban and urban agriculture, where limited land and water resources necessitate innovative production approaches.

Circular Economy Principles in Aquaculture:

At the heart of Blue-Green Circular Farming lies the concept of resource



Figure 1. Aquaponics integrates fish and plant production in a recirculating ecosystem where nutrients are continuously recycled.

circularity. Fish feed serves as the primary nutrient input to the system. A portion of these nutrients is converted into fish biomass, while the remainder enters the microbial pathway through fish wastes and uneaten feed. Biofloc microorganisms capture and recycle these nutrients, producing microbial protein and maintaining water quality.

The dissolved nutrients that remain in the culture water are subsequently absorbed by plants grown in aquaponic units. The plants not only generate a secondary harvest but also act as biological filters that improve water quality before recirculation. Through this continuous cycle, water, nutrients, and biological productivity are optimized, resulting in minimal waste generation and maximum resource utilization.

This integrated approach

demonstrates how aquaculture can move from a linear production model to a circular and regenerative system.

Water Conservation and Environmental Sustainability:

One of the most significant advantages of integrated GIFT Tilapia–Biofloc–Aquaponic systems is their ability to conserve water. Conventional aquaculture operations often require substantial water exchange to maintain acceptable water quality. In contrast, recirculating biofloc-aquaponic systems can operate with minimal water replacement, dramatically reducing freshwater consumption.

The system also minimizes nutrient discharge into natural water bodies. By capturing and reusing nutrients within the production cycle, environmental pollution is significantly reduced. This contributes to the protection of freshwater ecosystems and supports sustainable resource management practices.

As environmental regulations become increasingly stringent and water resources become more limited, such technologies will play an increasingly important role in ensuring the sustainability of aquaculture production.

Building Climate Resilience through Integrated Farming Systems:

Climate change poses significant challenges to aquaculture through rising temperatures, erratic rainfall patterns, prolonged droughts, floods, and increased disease risks. Integrated circular farming systems enhance resilience by reducing dependence on external water resources and creating more controlled production environments.

The recirculating nature of these systems allows farmers to maintain production even under adverse climatic conditions. The diversification of outputs through simultaneous fish and vegetable production also spreads economic risk and enhances farm-level resilience. By optimizing resource use and minimizing

environmental impacts, Blue-Green Circular Farming contributes directly to climate adaptation and mitigation efforts.

Economic Benefits and Entrepreneurship Opportunities:

The economic potential of integrated aquaculture systems extends beyond increased productivity. The simultaneous production of fish and vegetables creates multiple revenue streams from a single production unit, improving profitability and reducing market-related risks. Farmers can generate income from high-value vegetables alongside fish production, thereby enhancing overall economic returns.

Such systems are particularly attractive for small and medium-scale enterprises, youth entrepreneurs, fisheries graduates, farmer producer organizations, and women's self-help groups. Because they can be established on relatively small land holdings, they offer opportunities for income generation even in densely populated regions where land availability is limited.

As consumer demand for sustainably produced food continues to grow, integrated aquaculture enterprises are likely to gain increasing market acceptance and commercial viability.

Research, Innovation and Emerging Technologies:

The future success of Blue-Green Circular Farming will depend on continued technological innovation and scientific advancement. Emerging technologies such as artificial intelligence, Internet of Things (IoT)-based monitoring systems, automated feeding mechanisms, renewable energy integration, and precision water quality management are expected to further improve system efficiency.

Research efforts are also focusing on optimizing microbial dynamics, nutrient cycling, plant-fish interactions, carbon management strategies, and species diversification. Such innovations will facilitate the development of region-specific



Figure 2. Blue-Green Circular Farming supports resource efficiency, environmental sustainability, climate resilience, and the objectives of India's Blue Economy.

production protocols that can be adapted across India's diverse agro-climatic conditions.

Educational institutions, fisheries colleges, research centres, and incubation facilities have a critical role to play in developing and disseminating these technologies to farming communities.

The Role of Blue-Green Circular Farming in India's Blue Economy

India's Blue Economy vision emphasizes sustainable utilization of aquatic resources for economic growth, improved livelihoods, and ecosystem health. Integrated GIFT Tilapia–Biofloc–Aquaponic systems align perfectly with these objectives by promoting sustainable food production, efficient resource use, environmental stewardship, and entrepreneurship development.

The technology also contributes to national priorities related to food security, nutritional security, climate adaptation, employment generation, and sustainable rural development. As India seeks to strengthen its position as a global leader in aquaculture, such innovative farming models will become increasingly important.

Conclusion: Towards a Sustainable and Climate-Resilient

Aquaculture Sector

Blue-Green Circular Farming represents a significant evolution in freshwater aquaculture, combining the strengths of GIFT tilapia culture, Biofloc Technology, and freshwater aquaponics within a single integrated framework. By transforming waste into resources, conserving water, reducing environmental impacts, and generating multiple revenue streams, this approach offers a practical pathway towards sustainable intensification of aquaculture.

In an era marked by climate uncertainty and increasing pressure on natural resources, integrated circular farming systems provide a resilient and forward-looking solution. Their ability to produce fish and vegetables simultaneously while optimizing resource utilization makes them highly relevant for India's future food production needs.

As policymakers, researchers, educational institutions, entrepreneurs, and farmers work together to advance climate-smart aquaculture, Blue-Green Circular Farming has the potential to emerge as a cornerstone of sustainable freshwater aquaculture and a model for the future of the Blue Economy in India.

Reproductive Strategies of Reef associated Ornamental Fishes

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Highlights

- Coral reef life demands reproductive specialization, with fish evolving diverse strategies—such as egg scattering, guarding, or live brooding—to increase offspring survival amidst intense predation and competition.
- Egg deposition with parental care is practiced by clownfish and damselfish, which lay adhesive eggs on substrates and actively guard them, increasing hatching success in predator-rich reef environments.
- Pelagic spawning by butterflyfish and angelfish involves releasing buoyant eggs into open water, relying on dispersal rather than protection—though larval survival is often low due to complex early feeding needs.
- Brooding strategies like male pregnancy in seahorses and mouth brooding in cardinalfish offer high offspring protection, with males carrying or incubating eggs to shield them from predators and environmental threats.

Introduction

Life on coral reef is anything, but easy. It's a place where competition for food is intense, predators are numerous, and survival depends on strategic reproduction. Over millions of years, coral reef fishes have evolved a dazzling variety of reproductive strategies, each one finely tuned to the unique demands of reef life. Whether it's laying eggs on coral, scattering them into open waters, or even giving birth

to live young, these strategies aren't random. They reflect how different species navigate threats, secure resources, and ensure the next generation survives in a highly competitive environment. In general, reef fish reproduction can be grouped by how the species handles its eggs and young ones. And these choices reveal a lot about how they've adapted to survive in such a dynamic system.

The fishes like groupers and snappers, giants of the reef don't stick around to babysit. Instead, they produce thousands—sometimes millions—of tiny, floating eggs known as pelagic eggs. Released into the open waters around reefs, these eggs hitch a ride on currents, drifting far and wide. It's a strategy that may seem hands-off, but it works. By spreading their offspring across vast areas, these fishes increase the chances that at-least a few will find a safe place to grow. Smaller fishes, on the other hand, play a different game. Gobies, clown and damselfishes, for example, often lay their eggs on rocks, coral branches, or even bits of seaweed. These eggs stick to the surface, allowing parents to guard them closely. The approach is risky—it demands energy to find and defend a nest site, but it reduces the odds that eggs will be eaten or lost at sea. Predation is a major force, which shaping these reproductive choices.



Fig. 2. Marine Angel fish, Pomacanthus semicirculatus



Fig. 1. Clown fish, Premnas biaculeatus with eggs

Floating pelagic eggs scatter widely, making it harder for predators to gobble them all up. But demersal spawners rely on watchful parenting to ward off egg-hungry threats lurking nearby.

Interestingly, scientists believe these reproductive strategies follow a kind of evolutionary pathway. As early fishes evolved, they moved from more primitive strategies like external egg scattering to more advanced forms of parental care. This transition reflects a growing emphasis on energy efficiency and survival. Another idea, the size-advantage hypothesis, helps explain, why different fishes adopt different strategies. Smaller species are more agile and better suited to defending nesting spots in tight reef spaces. Larger fishes, on the other hand, may struggle to guard a specific site and instead opt for the strength-in-numbers approach of pelagic spawning. While theories like, resource-limitation hypothesis try to explain, why some fishes favour local nesting, they don't fully account for the complex patterns seen in those who spawn into the open ocean.

Egg Depositors

In the crowded, colorful world of coral reefs, where survival is a daily challenge, fish have evolved a stunning variety of ways to make sure the next generation thrives. One of

the most fascinating strategies is egg deposition, a method where fishes carefully place their eggs in safe spots to protect them from predators and environmental hazards. Among the masters of this approach are clown and damselfishes, both members of the Pomacentridae family and stars of the ornamental aquarium trade.

Clownfish, famously featured in the animated film *Finding Nemo*, are more than just popular pets—they're expert parents. These fish form monogamous pairs and lay sticky, elliptical eggs on flat surfaces close to their sea anemone hosts. It's a partnership built on mutualism: clownfish keep the anemone clean and safe from predators like butterflyfish, while the anemone's stinging tentacles protect the clownfish from being eaten. This unique relationship may even contribute to the clownfish's unusually long lifespan, with some individuals living up to 30 years. In the wild or in captivity, once a pair bonds, the reproductive cycle kicks into gear. The male prepares the nesting site by biting and nipping at the anemone's tentacles to expose the area, and the female lays her eggs in neat circles. The male trails her closely, fertilizing each pass. A single clutch can contain between 400 and 2,000 eggs, depending on the clownfish species (Fig. 1). Once the eggs are laid, both parents—especially the male—show dedicated parental care. They fan the eggs with their fins to keep water moving and oxygen flowing and use their mouths to remove dead or damaged eggs. This attention to detail ensures high hatching success. In most cases, the eggs hatch a few hours after sunset, synchronizing with low light to avoid predators.

Damselfishes, another group of demersal (bottom-spawning) egg layers, follow a similar script—though their habits have a flair of their own. These colorful reef dwellers deposit eggs on hard surfaces like coral or rock, and the males guard them with equal dedication. Before spawning, males and females engage in lively courtship dances, complete with chirps and grunts, especially in the early morning hours. The clutches can



Fig. 3. Seahorse, *Hippocampus kuda*

include hundreds or even thousands of eggs, and multiple clutches can be cared for by a single male at once. Like clownfish, hatching usually occurs after dark and over 90% of eggs hatch successfully if conditions are right. Damselfishes are also known for their flexible reproductive strategies. While many are protogynous hermaphrodites (starting life as females and turning into males), some species like Chromis, Pomacentrus, and Abudedefduf are gonochoristic, with fixed sexes. For breeding purposes, aquarists often place 6 - 8 juvenile fish in a 120-liter tank, observing pairs as they form. Once a bond is established, the couple is transferred to a 50-liter broodstock tank for spawning.

Egg Scatterers

Life on coral reef demands creative survival strategies—not just to stay alive, but also to successfully reproduce. While some reef fish carefully guard their eggs on rocks or corals, others take more “hands-off” approach. The egg scatterers: butterflyfishes, angelfishes (Fig. 2), and many other reef species that release their eggs into the open waters and let the currents do the rest. These fish are pelagic spawners. During spawning, males and females release eggs and sperm into the water column—often at dusk—allowing fertilization to happen mid-swim. There's no nest, no parental care, and no sticking around afterward. It may sound risky, but this strategy spreads their tiny, buoyant eggs far and wide, reducing the odds that predators will find and eat them all.

Butterflyfishes are one of the most iconic reef dwellers, known for their vibrant patterns and delicate, fluttering fins. They inhabit tropical and subtropical coral reefs and feed on coral polyps, worms, zooplankton, and algae. Like other pelagic spawners, butterflyfish eggs hatch about 24 hours after fertilization. The larvae begin feeding around day three and go through a unique tholichthys stage, a developmental phase, where the head is covered in armour-like bony plates. These are later shed as the fish mature. In species like the millet butterflyfish, mass spawning events have been observed. Early feeding on copepods has shown promise, but success remains limited.

Angelfish, including the eye-catching, blue-striped angelfish, Koran angel are protogynous hermaphrodites, meaning individuals start life as females and can become males. On the reef, males typically dominate small harems and spawn at dusk with one or more females. In captivity, a single male may mate with two females daily, just before and after sunset. Despite producing large numbers of eggs—up to one lakh per female over a season and rearing angelfish larva is difficult. The tiny hatchlings don't immediately accept common hatchery foods like brine shrimp and rotifers. Instead, they require a progression of feeds, starting with tiny ciliates like Euplotes, then enriched rotifers, copepod nauplii, and adult copepods. Even under ideal conditions, larval survival is extremely low, often under 0.2%.

Of all marine angelfish, dwarf angelfish is the most popular in the aquarium trade. These small, colorful species from the genus *Centropyge* account for over three-quarters of all angelfish imported into the U.S. They thrive in captivity and often spawn under the right conditions. In the wild and in aquaria, dwarf angelfish display fascinating social behaviours. Males maintain harems and engage in elaborate courtship dances with each female every evening. Spawning occurs at dusk, with females releasing a few hundred to a few thousand pelagic eggs—tiny, transparent spheres

with a single oil droplet to keep them afloat. Their social structure is even more intriguing. If a dominant male dies or is removed, the top-ranking female will begin to change sex—both behaviourally and physically—within a week. She becomes a fully functioning male in about 20 days, showcasing the remarkable adaptability of these reef residents.

Brooders

When it comes to ocean life, parenting can be full of surprises. While most fish scatter eggs and swim away, some species take parenting to the next level—like male pregnancy in seahorses and mouth brooding in cardinalfish. These fascinating strategies not only set these species apart but also help ensure their fragile young ones get the best possible start in life.

Seahorses (Fig. 3) aren't just charming with their curled tails and upright posture—they're also reproductive marvels. Seahorses, part of the Syngnathidae family along with pipefish and sea dragons, have unique traits like joined jaws, stretched-out bodies, and no stomachs, which means they need to eat regularly to survive. Seahorses are truly unique among fish for their remarkable parenting role reversal, the responsibility of carrying the babies falls to the males. During mating, the female transfers her unfertilized eggs into a specialized brood pouch on the male's belly. Inside this pouch, the male fertilizes the eggs and provides them with oxygen, waste removal, and even some nutrients—functions like, mammalian placenta. The pouch also protects the eggs from predators and harsh environmental conditions. Sea horses often form monogamous pairs for a breeding season, performing daily greeting rituals and synchronized dances. Courtship includes gentle weaving, tail twining, and even rising vertically through the water column. In captivity, seahorses will breed naturally, if kept in well-maintained conditions. After birth, newborns swim to the surface to gulp air, inflating their swim bladders. However, too much air intake can cause swim bladder hyperinflation, which can be deadly. Specially



Fig. 4. Banggai Cardinal fish, *Pterapogon kauderni* with Tentacle anemone,

designed tanks (like pseudo-kreisel aquaria) and proper water flow are key to preventing these early losses. Feeding young seahorses is another challenge—they must eat constantly, due to their fast metabolism and simple digestive system. Early-stage fry typically feed on rotifers and Artemia (brine shrimp), making proper nutrition essential for survival.

If male pregnancy appears unconventional, consider the even more remarkable strategy of a fish that safeguards its offspring by incubating them within its mouth. The Banggai cardinalfish (*Pterapogon kauderni*), a stunning black-and-white striped species (Fig. 4), is a mouth brooder, which is not available in Indian waters. Native to shallow Indonesian reefs, these fish form temporary mating pairs. Once eggs are fertilized, the male scoops them up and incubates them in his mouth—without eating—for up to four weeks. This unique adaptation protects the eggs from predators and environmental stressors, ensuring higher survival rates. After about 20 days of internal development, the eggs hatch, and the larvae continue to hide in the male's mouth for few more days until they're ready to swim freely and feed on their own. The young are born larger and more developed than typical reef fish fry. That means, they can start feeding immediately on standard foods like brine shrimp, without the need for tiny, specialized diets. In captivity, female Banggai cardinalfish exhibit post-mating behaviours, such as aggressively guarding their mate for a short time after egg transfer.

The male, meanwhile, is often seen adjusting the egg clutch inside his mouth, briefly exposing the eggs before sealing them away again. They've become symbolic of the need for more responsible and sustainable practices in the ornamental fish trade.

Conclusion

In the vibrant world of coral reefs, reproductive strategies among fishes are as diverse and fascinating as the ecosystems, they inhabit. From the dedicated nest-guarding of clownfish to the drifting eggs of angelfish and the extraordinary male pregnancy in seahorses, these adaptations highlight the incredible ways in marine life, which ensures the survival of the next generation. Each strategy—shaped by evolution, environment, and survival pressures—offers a glimpse into the complex life cycles beneath the waves. As interest in ornamental marine species continues to grow, understanding these natural behaviours becomes even more important—not just for scientific curiosity, but for the conservation and responsible care of these remarkable creatures.

Suggested readings

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