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SOUTH CENTRE

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# ABSTRACT

This study on Antimicrobial Resistance (AMR) in Indian shrimp farming underscores its critical impact on public health, environmental sustainability, and economic viability. The global scenario with many export rejections on account of persistent residues of antibiotics, reiterate that antimicrobial use in aquaculture, demands urgent global attention.

In the Indian context, the shrimp industry grapples with a delicate balance between production demands and long-term shrimp health. Sustainable practices, including responsible antimicrobial use, are crucial for economic viability, given the industry's reliance on specific markets like the United States, EU and China.

Sustainable aquaculture emerges as a pivotal solution, supported by government policies and a gradual industry shift towards best practices. However, challenges persist, requiring a comprehensive approach to balance economic interests with environmental conservation. The key challenges remain the large number of small stakeholders and huge geographical spread of farms which make implementation of regulations and sharing of best practices difficult. Traceability and certification programs can play a key role in promoting responsible aquaculture, ensuring transparency and accountability in the supply chain. Technological innovations, including block chain can offer efficient solutions for traceability.

The collaborative action suggested emphasizes the role of government bodies, regulatory agencies, industry players, researchers, and consumers in addressing AMR. Clearer implementable regulatory frameworks aligned with economic and environmental priorities are essential. Looking ahead, the study envisions a future where the blue economy is sustainable not just for the industry's success but also to protect the wider environment. By enhancing domestic market presence and fostering collaboration with importing countries, the Indian industry can overcome the multiple challenges raised by AMR in shrimp aquaculture.

*Este estudio sobre la resistencia a los antimicrobianos (RAM) en la cría india de camarones subraya su impacto crítico en la salud pública, la sostenibilidad medioambiental y la viabilidad económica. La situación mundial, con numerosos rechazos de exportaciones por residuos persistentes de antibióticos, reitera que el uso de antimicrobianos en la acuicultura exige una atención mundial urgente.*

*En el contexto indio, la industria camaronera lidia con un delicado equilibrio entre las demandas de producción y la salud de los camarones a largo plazo. Las prácticas sostenibles, incluido el uso responsable de antimicrobianos, son cruciales para la viabilidad económica, dada la dependencia de la industria de mercados específicos como Estados Unidos, la UE y China.*

*La acuicultura sostenible se perfila como una solución fundamental, respaldada por las políticas gubernamentales y un cambio gradual de la industria hacia las mejores prácticas. Sin embargo, persisten retos que exigen un planteamiento global para equilibrar los intereses económicos con la conservación del medio ambiente. Los principales retos siguen siendo el gran número de pequeñas partes interesadas y la enorme dispersión geográfica de las explotaciones, que dificultan la aplicación de la normativa y el intercambio de mejores prácticas. Los programas de trazabilidad y certificación pueden desempeñar un papel clave en la promoción de una acuicultura responsable, garantizando la transparencia y la rendición de cuentas en la cadena de suministro. Las innovaciones tecnológicas, incluida la cadena de bloques, pueden ofrecer soluciones eficaces para la trazabilidad.*

*La acción colaborativa sugerida hace hincapié en el papel de los organismos gubernamentales, las agencias reguladoras, los agentes de la industria, los investigadores y los consumidores a la hora de abordar la RAM. Es esencial contar con marcos normativos más claros y aplicables, en consonancia con las prioridades económicas y medioambientales. De cara al futuro, el estudio prevé un futuro en el que la economía azul sea sostenible no sólo para el éxito de la industria, sino también para proteger el medio ambiente en general. Mejorando la presencia en el mercado nacional y fomentando la colaboración con los países importadores, la industria india puede superar los múltiples retos que plantea la RAM en la acuicultura del camarón.*

*Cette étude sur la résistance aux antimicrobiens (RAM) dans l'élevage de crevettes en Inde souligne son impact critique sur la santé publique, la durabilité environnementale et la viabilité économique. Le scénario mondial, avec de nombreux refoulements à l'exportation en raison de résidus persistants d'antibiotiques, rappelle que l'utilisation d'antimicrobiens dans l'aquaculture exige une attention urgente au niveau mondial.*

*Dans le contexte indien, l'industrie de la crevette est confrontée à un équilibre fragile entre les exigences de la production et la santé à long terme des crevettes. Les pratiques durables, y compris l'utilisation responsable des antimicrobiens, sont cruciales pour la viabilité économique, étant donné que le secteur dépend de marchés spécifiques tels que les États-Unis, l'UE et la Chine.*

*L'aquaculture durable apparaît comme une solution essentielle, soutenue par les politiques gouvernementales et l'évolution progressive du secteur vers les meilleures pratiques. Cependant, des défis persistent, nécessitant une approche globale pour équilibrer les intérêts économiques et la conservation de l'environnement. Les principaux défis restent le grand nombre de petites parties prenantes et la vaste répartition géographique des exploitations, qui rendent difficiles la mise en œuvre des réglementations et le partage des meilleures pratiques. Les programmes de traçabilité et de certification peuvent jouer un rôle clé dans la promotion d'une aquaculture responsable, en garantissant la transparence et la responsabilité dans la chaîne d'approvisionnement. Les innovations technologiques, y compris la chaîne de blocs, peuvent offrir des solutions efficaces en matière de traçabilité.*

*L'action concertée suggérée souligne le rôle des organismes gouvernementaux, des agences de réglementation, des acteurs de l'industrie, des chercheurs et des consommateurs dans la lutte contre la résistance aux antimicrobiens. Des cadres réglementaires plus clairs et applicables, alignés sur les priorités économiques et environnementales, sont essentiels. L'étude envisage un avenir où l'économie bleue sera durable, non seulement pour le succès de l'industrie, mais aussi pour la protection globale de l'environnement. En renforçant sa présence sur le marché national et en encourageant la collaboration avec les pays importateurs, l'industrie indienne peut surmonter les multiples difficultés posées par la résistance aux antimicrobiens dans l'aquaculture de la crevette.*

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# 1. Introduction

### 1.1 Fisheries and Aquaculture

Aquatic foods offer highly accessible and affordable sources of animal proteins and micronutrients, playing a vital role in the food and nutrition security of many, particularly vulnerable coastal populations. Their crucial role as suppliers of highly nutritious food, essential for physical and cognitive development, has been growing, even though less than half of public health nutrition policies currently identify their consumption as a key objectives. In addition, fisheries and aquaculture already support 58.5 million jobs in the primary sector, including part-time and occasional, and 600 million livelihoods, and the trade in aquatic products provides an important source of hard currency and income for exporting countries and regions.[1]

In the 25 years following the endorsement of the Code of Conduct for Responsible Fisheries, capture fisheries production remained stable, but aquaculture production, the controlled cultivation or farming of fish, shellfish and aquatic plants, grew by 250 per cent. This enabled the sector to meet the increase in aquatic food demand and consumption which rose to 20.5 kg per person, per year (a growth rate double that of the world population). The integration of aquatic foods in global and regional supply chains means that fisheries and aquaculture trade value is now 200 per cent greater than in 1995, and the net trade value (exports minus imports) for aquatic food products by non-high-income countries is larger than that of all other food products combined.[1] *(FAO 2022[1])*

With rising global populations and income, the demand for fish and seafood will continue, and the increases in production will have to come from aquaculture. Therefore, attention must be given to increasing the sustainability of aquaculture, including addressing environmental, food safety and public health concerns. This includes issues such as the impact on the ecosystems and wild fish and seafood, waste and wastewater dumping, and use of antibiotics and other antimicrobials in aquaculture.

### 1.2 Antimicrobial Resistance and Animal Food Production Including Aquaculture

Antimicrobial Resistance (AMR) occurs when bacteria, viruses, fungi and parasites no longer respond to antimicrobial medicines. As a result of drug resistance, antibiotics and other antimicrobial medicines become ineffective and infections become difficult to treat, increasing the risk of disease spread and death.[2] (WHO 2023[2])

AMR is an ancient natural process that happens over time through genetic changes in pathogens. Its emergence and spread is accelerated, mainly the misuse and overuse of antimicrobials especially antibiotics to treat, prevent or control infections in humans and animals including aquaculture animals.

AMR has led to the emergence of so-called “superbugs”, that are challenging health professionals, veterinarians, and other animal health providers due to a reduction of effective therapeutic options to prevent, control, and treat infections.[3] (WOAH 2023[3])

By reversing decades of progress, AMR is now one of the top ten threats to public health, and has become a leading cause of death globally. It is a growing threat to animal health, as well as livelihoods and food security worldwide. The spread of new resistant strains of bacteria in terrestrial and aquatic animals leads to an increase in animal suffering and losses. This in turn affects livelihoods, as 1.3 billion people rely on livestock and over 20 million people depend on aquaculture[3] for their living. (WOAH 2023)

When antibiotics spill into the environment, newer and more resistant strains of bacteria can emerge. These can in turn infect animals and humans. Responsible use of antibiotics and proper disposal of waste from relevant farming activities like aquaculture ensures that these antimicrobial chemicals stay out of the environment as much as possible and reduces the risk of development of resistant bacteria.

Food also plays an important role in the spread of AMR. The presence of AMR microorganisms in food chains is a potential route of exposure[4]. (FAO 2023[4])

Ingestion of AMR organisms via food can result in human illnesses which do not respond to available antibiotics or other treatments. Moreover, even if the microorganisms are not pathogens, they can be a reservoir of antimicrobial resistant genes within our food supply. And given the global trade in food products, they contribute to the spread of AMR as well as transmit resistance to other pathogenic organisms through AMR genes.

Antimicrobial resistant microorganisms in food are not just a major public health challenge, but also represent an economic risk. They also have the potential to affect market access, through health regulations and consumer purchasing behavior. These economic risks need to be assessed in a suitable manner due to the capacity for spread of AMR across borders[4].

The World Health Organization (WHO) describes the “One Health” approach[2] to AMR as a complex problem that requires sector-specific actions in the human health, food production, animal and environmental sectors, and a coordinated approach across sectors. One Health refers to an integrated approach that aims to achieve sustainable health outcomes for people, animals and ecosystems. It recognizes that the health of humans, animals, fishes, plants and the wider environment are closely linked and inter-dependent. The One Health approach to controlling AMR brings all stakeholders from across sectors to communicate and work together in the design and implementation of programs, policies, legislation, including research to mitigate AMR so as to attain better health and economic outcomes.

### *1.3 Shrimp Aquaculture and Global Trade*

Shrimp, members of the Decapoda order, are small marine invertebrate crustaceans that hold a significant place in the global seafood industry. They possess an elongated body with a sturdy exoskeleton and boast five pairs of legs, including two specialized claws. These versatile creatures inhabit diverse marine environments, ranging from coastal waters to estuaries and even deep oceans. All farmed shrimp are of the family Penaeidae, and from just two species —*Litopenaeus vannamei* (Pacific white shrimp), 70 per cent now called *Penaeus vannamei* and secondly *Penaeus monodon* (Indian Black tiger prawn) 20 per cent— account for roughly 90 per cent of all farmed shrimp.

Renowned for their delicate, sweet flavor and tender texture, shrimps are highly sought after ingredients in a wide array of cuisines and culinary creations worldwide. Beyond their culinary appeal, they offer a wealth of nutritional benefits. Shrimps are a rich source of protein, selenium, vitamins (including B12), phosphorous, magnesium, copper, and iron.

Consuming shrimp contributes to numerous health advantages, including enhanced bone strength and a reduced risk of heart disease. They enjoy immense popularity as one of the most favored seafood choices globally, often forming the foundation of delectable seafood-based dishes. Consequently, shrimps are harvested extensively through fishing or aquaculture methods, and their impressive nutritional profile, featuring protein, vitamins, and minerals, positions them as a wholesome and nutritious seafood selection.

Shrimp has traditionally been a key player in the aquatic commodities trade, with a significant share of production coming from intensive shrimp farming in Latin America and East and Southeast Asia. The majority of this supply finds its way to high-income markets in North America, Europe, and Japan.

The United States and Japan predominantly receive warmwater species from major producers like India, Indonesia, Thailand, and Vietnam. In contrast, the European Union (EU) imports warmwater species from Asian and Latin American sources and relies on capture fisheries in Greenland for cold water species.

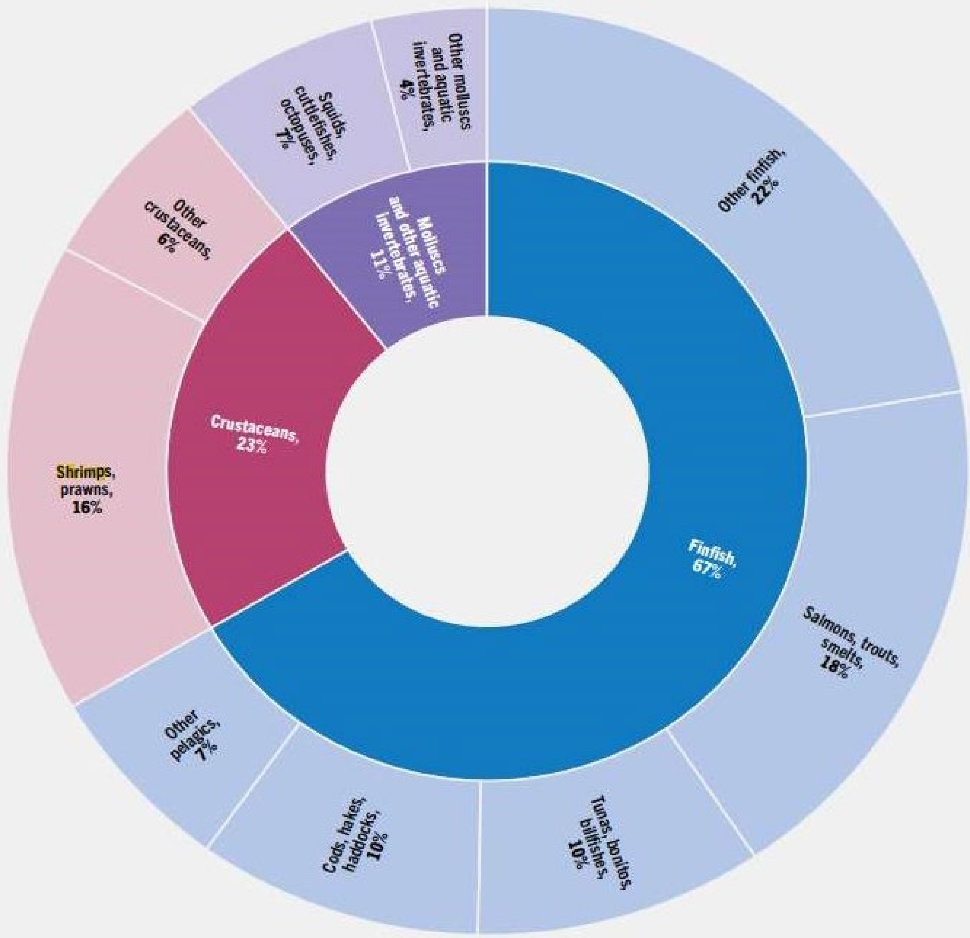
Recent trends reveal that emerging Asian economies, particularly China, are progressively absorbing more of the global shrimp supply. However, there's limited potential for a significant increase in per capita consumption in the mature traditional markets.

Over the years, shrimp exports have seen substantial growth, though they consistently represent a stable portion of the total value of global aquatic product exports. In 1976, shrimp and prawn exports amounted to USD 1.2 billion, accounting for 15.4 percent of the value of global aquatic product exports. By 2020, this figure had risen to USD 24.7 billion, making up 16.4 percent of the total value[1].

In 2022, the total value of globally exported shrimp reached USD 24.6 billion in international sales. This marked a 28.2 percent increase from USD 19.2 billion in 2018 and a 9.8 percent rise from USD 22.4 billion in 2021. Shrimp exports are classified under the Harmonized Tariff System (HTS) codes as 0306.17, specifically for frozen seawater shrimps and 0306.17.92 for penaid shrimp.

Three major shrimp species viz. Whiteleg shrimp (52.9 MMT), Black tiger shrimp (8 MMT) and constituted 65 percent of the global crustacean production (93.87 MMT). Despite lower demand from the hotel, restaurant and catering (HORECA) sector due to COVID-19, the retail demand for fresh and frozen shrimp increased. Industry analysts fell that shrimp production moderately increased in Ecuador and Indonesia but reduced in India, Thailand, Malaysia, and Bangladesh compared to 2019.

Figure 1
**Share of Main Groups of Species in Exports of Aquatic Products by Value – 2020**




NOTE: Excluding aquatic mammals, reptiles, amphibians, turtles, algae, sponges and corals.
SOURCE: FAO.

Shrimp trade plays a very important role in international fish trade, representing about 18 percent of total world fish trade in value terms. Trade pundits describes shrimps as small in size but big on dollars. Global trade of shrimp and prawns is estimated at USD 28 billion per year, coming mostly from farms in Asia and Latin America (mainly Ecuador) producing *Penaeus vannamei*. In general, global shrimp production has been stable but serious disease outbreaks and climate vagaries have caused widespread losses to farms in many countries such as India, Vietnam, and Thailand.

### *1.4 Food Safety and Public Health Regulations*

Increasingly stringent food safety and public health regulations in major international markets imply that producers and traders must ensure that shrimp is free from substances like antibiotics and additives. Failure to do so would result in rejected shipments, brand damage[5] and even country reputation *(Globefish 2022[5])* Antibiotics and other antimicrobials are used to prevent and treat disease, and their misuse and over-use in feeding to improve productivity, has led to a rise in AMR that is a threat to animal and human health. Through consumption of shrimp, AMR genes from shrimp farms can be transferred into human pathogens.

In Asia, intensification tends to mean higher density stocking at the expense of stringent controls from farm protocols and diseases. Although there has been positive advancements in biosecurity, and now farmers are more aware of the need for greater international cooperation in biosecurity protocols, still awareness building can be improved. As more farms will adopt culture systems with a better controls, disease-free post larvae, recirculation of water, recycling of wastes, and antibiotic free production. Thailand's shrimp farming sector has experienced devastating disease outbreaks in the mid-1990s especially White Spot Disease, but it is now one of the pioneer countries to promote bio-secure and probiotic shrimp farming.

### *1.5 Frozen Shrimp Exports by Country*

Frozen seawater shrimps generated $22.7 billion in export sales during 2022, increasing via a 28.7 per cent upturn from $17.6 billion in 2018 and went up by 9.6 per cent from $20.7 billion during2021.

Below are the 10 countries that sold the highest dollar value worth of globally exported frozen seawater shrimps[1].

1. Ecuador: US$7.8 billion (34.3% of exported frozen seawater shrimps)
2. India: $4.8 billion (21.2%)
3. Vietnam: $2.3 billion (10.1%)
4. Indonesia: $1.5 billion (6.4%)
5. Argentina: $890.2 million (3.9%)
6. Thailand: $660.8 million (2.9%)
7. Spain: $379.4 million (1.7%)
8. Bangladesh: $356.2 million (1.6%)
9. China: $342.7 million (1.5%)
10. Belgium: $333.6 million (1.47%)
11. Netherlands: $302.2 million (1.34%)
12. Peru: $271.3 million (1.2%)
13. Mexico: $252.8 million (1.1%)
14. Malaysia: $233.9 million (1%)
15. Venezuela: $226.1 million (1%)

By value, the above countries shipped 90.8 percent of all frozen seawater shrimps exported in
2022. Among the above countries, the major fastest-growing exporters of frozen seawater shrimps was Ecuador (up 165.9 percent).

Those countries that posted declines in their export sales of frozen seawater shrimps were led by mainland China (down -49.7 percent from 2021).

### *1.6 Shrimp Aquaculture Industry in India*

India's shrimp farming industry has emerged as a remarkable success story, experiencing exponential growth over the past decade. During this period, the country's farmed shrimp sector has demonstrated remarkable expansion, significantly outpacing the global growth rate of 5.6 percent, albeit with annual fluctuations. This remarkable surge has firmly established

India as the world's second-largest producer of farmed shrimp.

However, despite this extraordinary trajectory of growth, India is now confronted with escalating challenges, particularly concerning export rejections attributed mainly to the presence of prohibited antibiotics in shrimp products. As of 2022, the Indian shrimp market has reached an impressive valuation of US$ 7.3 billion.

The future appears promising as it is anticipated that the market will soar to exceed US$ 15.0 billion by the year 2030[6]. This projection reflects a robust compound annual growth rate of 11 per cent, underscoring the resilience and potential of India's burgeoning shrimp industry.

### 1.6.1 Production and export details

India achieved an all-time high exports of seafood both in terms of volume and value (both US$ and Rupee) by shipping 17,35,286 MT of seafood worth Rs. 63,969.14 crore (US$ 8.09 billion) during FY 2022-23 despite the several challenges in its major export market especially USA.

During the FY 2022-23, the export improved in quantity terms by 26.73 percent, in rupee terms by 11.08 percent, in US$ terms by 4.31 percent. In 2021-22, India had exported 13,69,264 MT of seafood worth Rs 57,586.48 crore[6] (US$ 7,759.58 million). *(Govt, of India 2023[6])*

The total production of farmed shrimp in India was estimated to be 8,43,633 MT. The overall export of frozen shrimps during 2022-23 was pegged at 7,11,099 MT. USA, the largest market, imported (2,75,662 MT) of frozen shrimp, followed by China (1,45,743 MT), European Union (95,377 MT), South East Asia (65,466 MT), Japan (40,975 MT), and the Middle East[7] (31,647 MT). *(MPEDA, Govt of India 2023[7])*

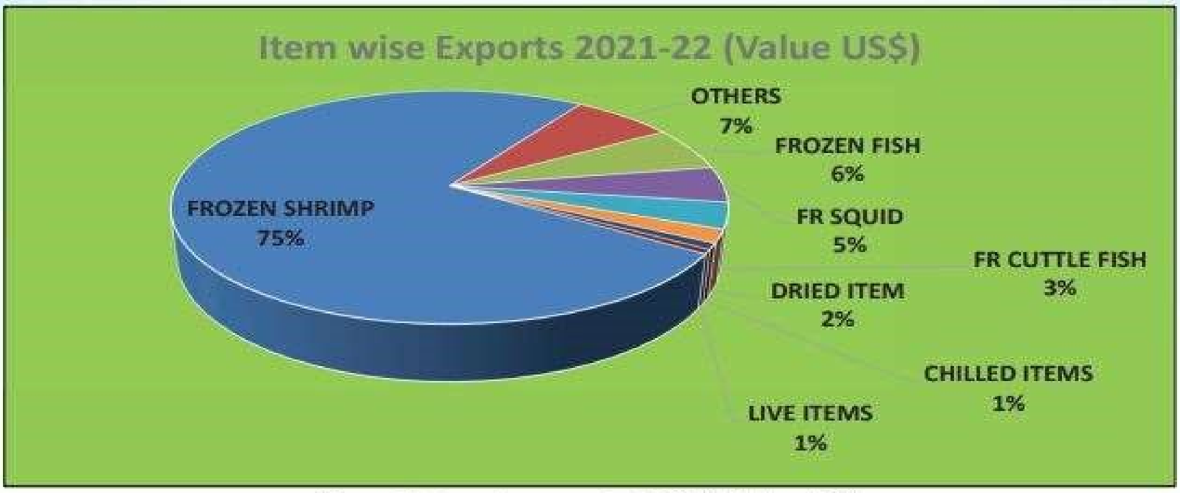



Figure 2: Item wise exports 2021-22 (Value US$)

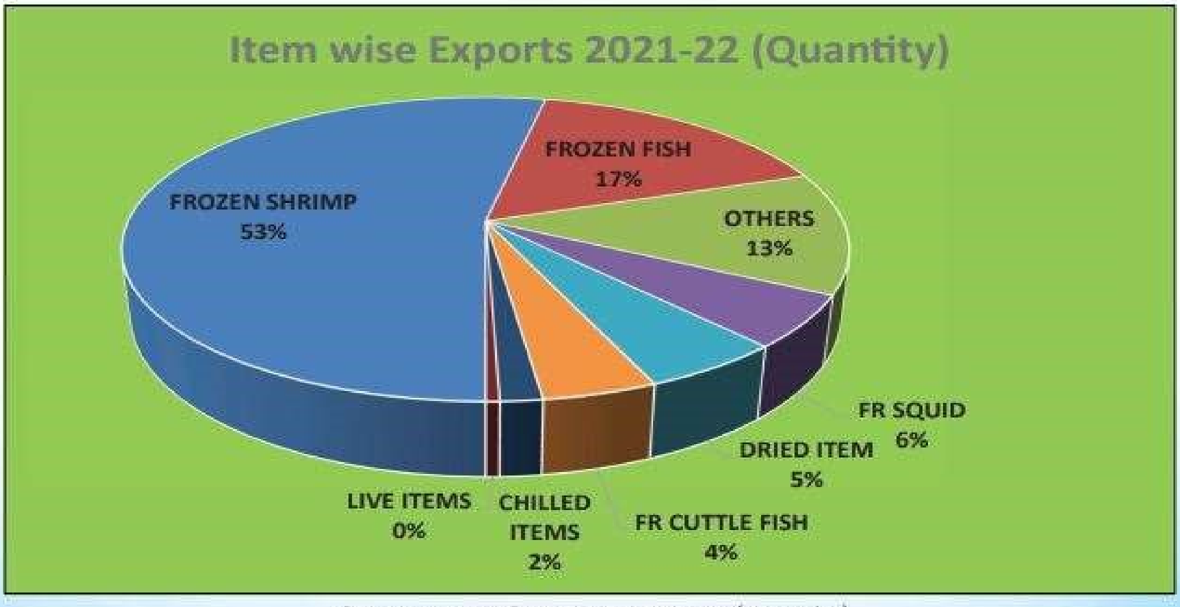



Figure 3: Item wise exports 2021-22 (Quantity)

Frozen shrimp remained the major export item in terms of both quantity and value while USA and China turned out to be the major importers from India. Frozen shrimp, which earned Rs 43,135.58 crore (US$ 5481.63 million), retained its position as the most significant item in the basket of seafood exports, accounting for a share of 40.98 percent in quantity and 67.72 percent of the total US$ earnings.

The Vannamei shrimp exports declined in 2022-23 compared to 2021-22 by 8.11 percent from US$ 5234.36 million to US$ 4809.99 million. The export of black tiger was to the tune of 31,213 MT worth Rs 2,564.71 Cr (US$ 321.23 million). Better yields per hectare, increased hatchery output, and expansion of culture areas for Vannamei shrimp can be attributed as factors contributing to this growth in production[7].

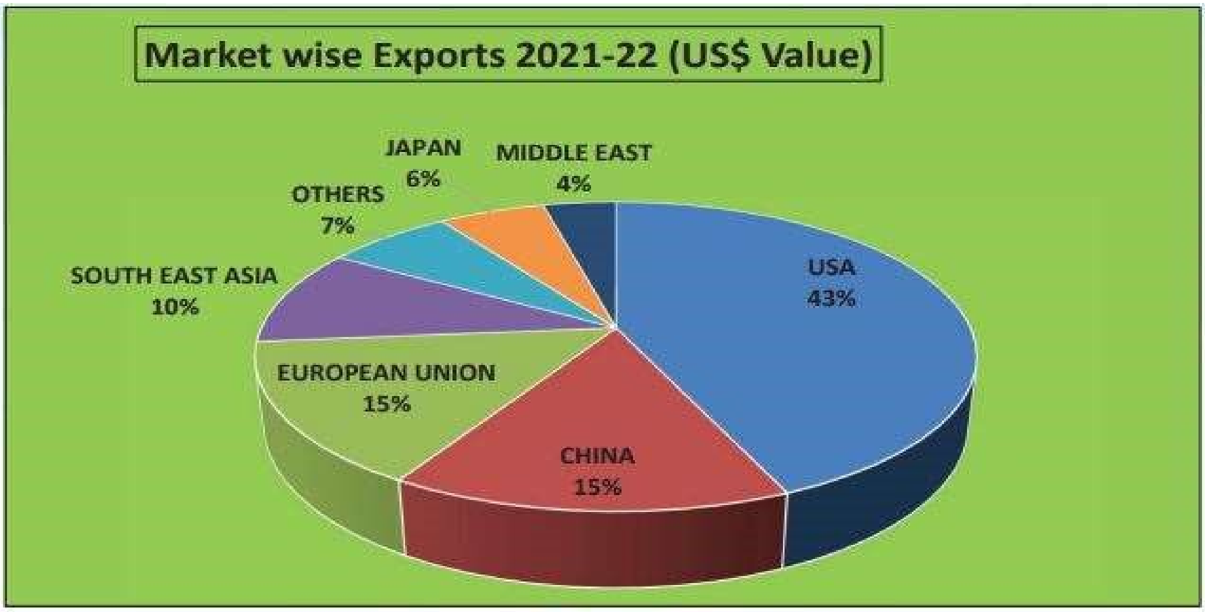



Figure 4: Market-Wise Exports 2021-22 (Value US$)

### 1.6.2 Indian market players

With the growing demand for stable and disease-free shrimp, India has become one of the largest shrimp exporters to the United States and the European Union. The Indian market has about 40 major seafood processors for Shrimp and these are mainly for exports[8].

Some of these key players include:

- Nekkanti Seafoods
- Avanti Frozen Foods Private Limited
- Devi Sea Foods Limited
- Falcon Marine Exports Ltd.
- BMR Group
- Baby Marine Eastern Exports
- Sandhya Marines
- Apex Frozen Foods Limited
- Ananda Aqua Exports Private Limited
- Crystal Sea Foods Private Limited

Trade disruptions like the recent COVID-19 pandemic can introduce a considerable degree of uncertainty into the shrimp export industry, highlighting the imperative need to cultivate a robust domestic market for shrimp products within the country. A substantial hurdle lies in the form of inadequate market infrastructure, especially when it comes to the sale of fresh shrimp, which poses significant logistical challenges.

### 1.6.3 Major States and geographical distribution

India exports marine products to more than 100 countries. The major states in the market are the coastal states which account for the 8100 km coastline and associated riverine systems, Andhra Pradesh, West Bengal, and Gujarat are the major aquaculture shrimp producing states. The state of Andhra Pradesh on India’s eastern coast is the largest and the most significant Aquaculture Shrimp producing state, in certain years, even producing up to 60 percent of India’s annual production

### *State Wise Area Utilized and Production of P. vannamei*

The commercial farming of this shrimp started after its introduction to India in 2009-10 and now is the largest cultured shrimp in terms of production and productivity. Prior to 2010, black tiger was the major species of shrimp farms. Andhra Pradesh tops in area under culture and production followed by Gujarat way behind[9]. *(source: MPEDA, Govt. of India, website[9])*

Table 1

| SL. NO. | STATE | | 2016-17 | 2017-18 | 2018-19 | 2019-20 | 2020-21 |
|---|---|---|---|---|---|---|---|
| **1** | W. Bengal | AUC | 3657 | 4127 | 5096 | 6072 | 6059 |
| | | EP | 26085 | 22191 | 29846 | 31376 | 35392 |
| **2** | Orissa | AUC | 6300 | 8862 | 5102 | 10554.8 | 10649 |
| | | EP | 25594 | 37229 | 24123 | 44007 | 43677.4 |
| **3** | Andhra Pradesh | AUC | 61391 | 62342 | 50474 | 63678 | 71921 |
| | | EP | 351137 | 456300 | 450797 | 510794 | 634672 |
| **4** | Tamil Nadu & Pondicherry | AUC | 8601 | 8849 | 6989 | 8190 | 8600 |
| | | EP | 48670 | 43622 | 47184 | 44467 | 44735 |
| **5** | Kerala | AUC | 31 | 52 | 53 | 234.74 | 157.39 |
| | | EP | 110 | 208 | 259 | 670.7 | 420.85 |
| **6** | Karnataka | AUC | 405 | 399 | 219 | 539.97 | 970.39 |
| | | EP | 1457 | 1465 | 918 | 1195.1 | 2185.84 |
| **7** | Goa | AUC | 2 | 32 | 0 | 0 | 0 |
| | | EP | 4 | 78 | 0 | 0 | 0 |
| **8** | Maharashtra | AUC | 1646 | 1291 | 916 | 1328.31 | 1183.49 |
| | | EP | 6831 | 6073 | 6567 | 5625.1 | 4252.1 |
| **9** | Gujarat | AUC | 5219 | 7542 | 6585 | 9608 | 8986 |
| | | EP | 41409 | 55161 | 58764 | 73539 | 50410 |
| | **Total** | AUC | 87252 | 93496 | 75494 | 100206 | 108526.27 |
| | | EP | 501297 | 622327 | 618678 | 711674 | 815745 |

**AUC** – Area Under Culture in hectares
**EP** – Estimated Production in tons

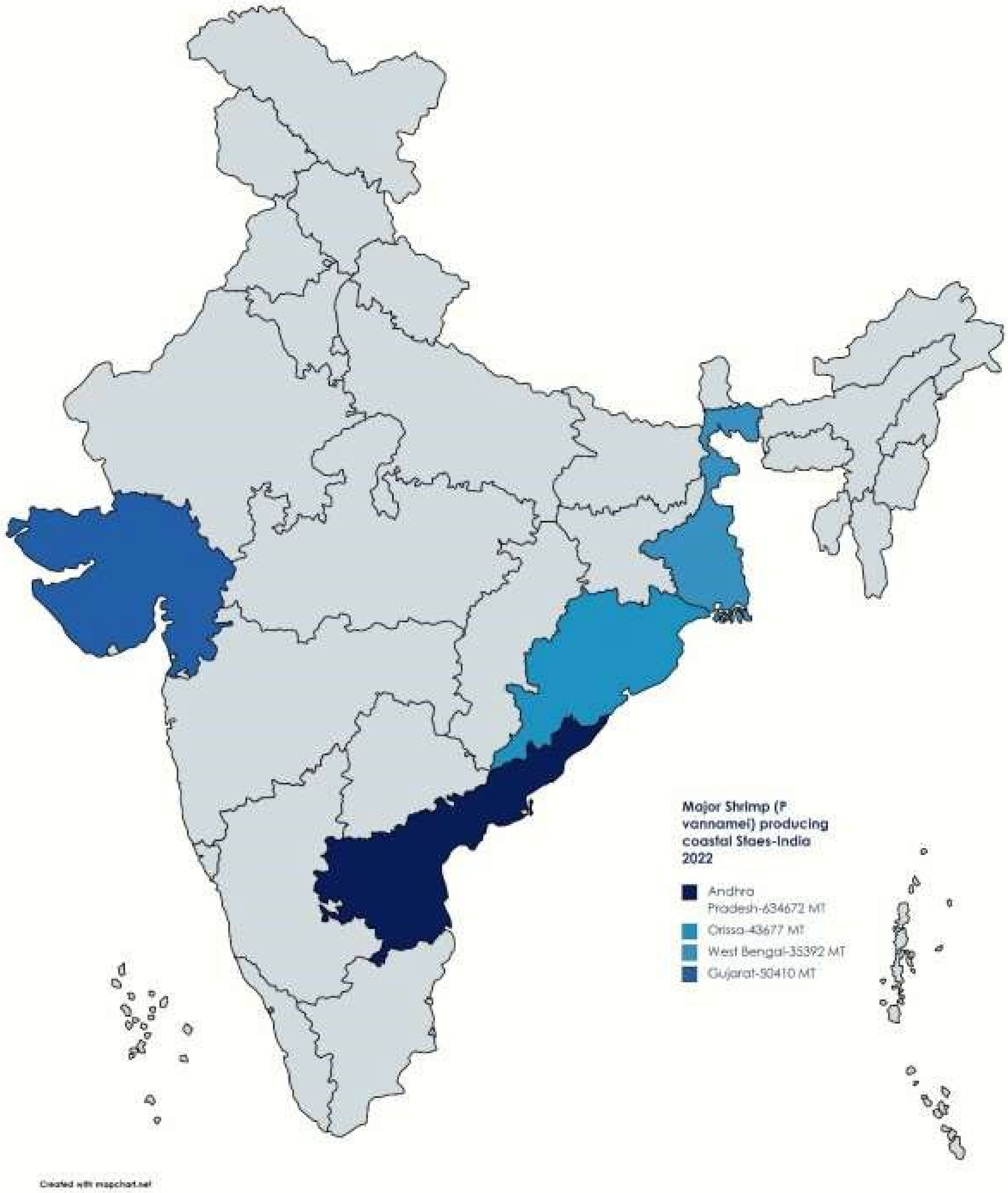
In Andhra Pradesh a single district (area), West Godavari accounts for about 30 percent of shrimp production. Some inland states are now also venturing into shrimp farming like Punjab, Uttar Pradesh and Haryana in North India, but the area is very small as these states are not having the requisite riverine systems required for penaeid shrimp and aquaculture is done in smaller ponds and tanks.

#### 1.6.4 Export Rejections of Indian Shrimps due to presence of Antimicrobials in 2022-23

Indian shrimps have faced rejections from importing countries mainly on account of presence of banned antimicrobials namely nitrofuran metabolites and chloramphenicol, during 2022-23, there has been four rejections of consignment from India to European Union[10] (from Belgium and the Netherlands) *(source EC website[10])*. The US FDA has refused a total of 29 entry lines of shrimp for reasons related to banned antibiotics and 10 rejections of consignments from Japan[11] (*source southern shrimp alliance website[11])*. The major antimicrobial responsible for export rejection is an antimicrobial named Nitrofuran, which after veterinary application is found as tissue/protein bound metabolite called 3Amino-2-oxazolidinone (Synonym: AOZ).

Due to the antimicrobial problem, the penetration in the Europe market, which used to account for a significant export has become low as India is not able to ensure antimicrobial-free shrimps. Along with increased testing (50 percent of all consignments) for banned antibiotics by EU and coupled with lowering of regulatory levels (ex for nitrofuran residues levels have been reduced from 1 parts per billion (ppb) to 0.5 ppb from Nov 2022) has added another dimension. So, the (EU) market share which once used to make up to 50 per cent of Indian shrimp exports (prior to Brexit) has declined over the last three-four years due to fear of exporters over rejection of consignments and availability of alternate and newer markets including China.

Figure 5
**Major shrimp (P vannamei) producing coastal states of India and production quantities in 2022**



# 2. Legislation and Regulatory Systems and Government Bodies in India for Aquaculture

India is a Federal Republic, subdivided into 28 states and 6 union territories. According to the Constitution, the state legislatures have the power to make laws and regulations with respect to a number of subject-matters, including water (i.e. water supplies, irrigation and canals, drainage and embankments, water storage and water power), land (i.e. rights in or over land and transfer of agricultural land), fisheries, as well as the preservation, protection and improvement of stock and the prevention of animal disease. Although there are many laws and regulations that may be relevant to aquaculture adopted at state level, this overview only addresses the laws and regulations adopted by the central government and broad state legislations.

## *2.1 Need for a Legislative System and Antimicrobial Resistance*

Most countries have laws or regulations addressing some aspect of antimicrobial control. Such legislation is only one part of the broad spectrum of regulatory areas with implications for AMR. Legislation on antimicrobials should ideally cover all stages of the life cycle of the antimicrobial substances – from authorization and registration of antimicrobials, and the manufacture, distribution, use and disposal of such products[12]. (FAO 2020[12])

With regard to disposal on the other hand, legislation should also pay attention to the effects of antimicrobial residues introduced into the environment and the contamination of the environment, the soil and water resources with antimicrobials, antimicrobial resistant microorganisms or resistant genes. This is important especially in aquaculture, not only for environmental protection purposes, but also to prevent human consumption of contaminated food or water, or the use of agricultural inputs potentially contaminated with antimicrobial resistant microorganisms or residues because in India a large part of the population live close to such water bodies. Current water and wastewater treatment technologies are not available to remove all Antimicrobials, and hence antimicrobial resistant microorganisms are found to be developing and spreading in multiple aquatic habitats downstream of hospitals and aquaculture activities[13]. (*Devika et all 2021*[13])

An appropriate institutional and regulatory framework and aquaculture legislation can serve as a basis for the introduction of the necessary regulatory control mechanisms (licenses, permits), good production practices and biosecurity measures that would help to improve the sanitary and phytosanitary status and reduce the need for antimicrobials in the first place.

Having a broad perspective of the legal frameworks required to address AMR not only results in a reduction in the occurrence of AMR, but also aims at improving the human, animal, and environmental health of the country, promoting the right to health and the right of people to a healthy environment.

Regulators have traditionally concentrated on selected areas and activities regarding ways to reduce AMR. This has resulted in an often well-developed national legislation on the regulatory frameworks for antimicrobials, while insufficient attention has been given to other aspects, such as the release of antimicrobials into the environment or the use of contaminated agricultural inputs. Similarly, food safety regulatory control is normally effective in monitoring the maximum residue limits (MRLs) of antimicrobials in food, as well as for setting the microbiological criteria applicable to food control, but in this exercise, countries have not paid attention to the potential resistance of the microorganisms transmitted through food. It should also be highlighted that the dynamic nature of the scientific research in this area makes it difficult to introduce effective regulatory control and monitoring mechanisms.

India has made significant strides in regulatory frameworks, particularly in aquaculture. The foundation was laid with the Environment (Protection) Act of 1986, and subsequent developments led to the enactment of the Coastal Aquaculture Authority Act in 2005.

Notably, the regulatory landscape has evolved further with the recent refinement through the Coastal Aquaculture Authority (Amendment) Bill of 2023, which explicitly prohibits the use of antimicrobials. The responsibility now lies with the authorities to effectively implement these regulations.

Executing these measures poses a formidable challenge given the vast geographical expanse and the presence of numerous small-scale farms. However, the solution may lie in leveraging technology and embracing IT tools to streamline and enhance regulatory oversight. Exploring innovative applications of technology can facilitate efficient monitoring and enforcement, ensuring compliance with the newly established regulations.

### *2.2 Coastal Aquaculture Authority Act 2005*

The Constitution of India defines the powers of the central and state governments. Agriculture, animal husbandry and fisheries are governed at the state level. Therefore, each state can draft its own policy. However, as agriculture, animal husbandry, and fisheries are of national significance, the central government assists in the development and implementation of these policies. The central government's Ministry of Agriculture and Farmers' Welfare and Ministry of Animal Husbandry & Fisheries provide broad guidelines for policies. The state governments are responsible for the implementation and administration of their policies through their departments for agriculture, animal husbandry and fisheries. Agencies of the central government directly administer central schemes and state government agencies administer state schemes. The state governments also adopt state-specific legislation (for example, on contract farming). But these legislations must be read in conjunction with one another to gain a full picture of the rules that are applicable to aquaculture.

### *2.3 Central and State Regulations*

At the national level, several pivotal laws and regulations bear relevance to aquaculture. Among them is the age-old Indian Fisheries Act (1897), which addresses the intentional killing of fish through poisoning water or the use of explosives. Additionally, the Environment (Protection) Act (1986) serves as a comprehensive umbrella act, encompassing provisions for various environmental issues.

In a landmark decision in 1996, the Indian Supreme Court made a historic ruling with profound implications for the aquaculture sector. This decision pertained to the establishment of shrimp farms in coastal areas. Notably, the Supreme Court prohibited the construction and setup of shrimp culture ponds within the Coastal Regulation Zones, generally spanning 0-200 meters from the High Tide Line, a designated “No Development Zone” where construction is strictly forbidden. The court further mandated the establishment of an authority dedicated to safeguarding ecologically fragile coastal areas, shorelines, waterfronts, and other coastal regions, specifically addressing the challenges posed by the shrimp culture industry in coastal states and union territories.

### 2.4 Case Study of Two Laws: CAA Act 2005 and its CAA Authority Amendment Bill 2023

Coastal aquaculture refers to the practice of cultivating and rearing aquatic animals, such as fish, crustaceans including shrimp, and aquatic plants, in marine or brackish water environments along the coastlines or in estuaries.

### 2.4a Coastal Aquaculture Authority Act 2005

The Coastal Aquaculture Authority Act[14] was enacted by Indian Parliament, and it came into force in December 2005. The Act was introduced for the formation of a "Coastal Aquaculture Authority" for regulating activities connected with coastal aquaculture in the coastal areas. Under this act "coastal area" meant the area declared as the Coastal Regulation Zone, "to regulate activities in the coastal area under section 3 of India's Environment Protection Act, 1986."

The Coastal Aquaculture Authority was formed for regulating coastal aquaculture activities in coastal areas, which would consist of a chairperson who is a current or former High Court Judge, a coastal aquaculture expert and members nominated by the Central Department of Ocean Development, Ministry of Environment and Forests, Ministry of Agriculture, Ministry of Commerce along with four members representing coastal states on a rotation basis and one secretary.

**What are the penalties and punishment under the Act**

Section 13 of the 2005 Act states that except for the manner provided under it, "no person shall carry on, or cause to be carried on, coastal aquaculture in coastal area or traditional coastal aquaculture in the traditional coastal aquaculture farm which lies within the Coastal Regulation Zone".

Section 14 was the only penal provision under the 2005 Act, which punished coastal aquaculture or traditional coastal aquaculture in contravention of Section 13, with imprisonment of up to 3 years or a maximum fine of Rs 1 lakh or both. However, no court could take cognizance of an offence under section 14 without a "written complaint filed by an officer of the Authority authorized in this behalf by it."

### 2.4b Coastal Aquaculture Authority (Amendment) Bill, 2023

The new Coastal Aquaculture Authority (Amendment) Bill[15] seeks to amend certain provisions of the Coastal Aquaculture Authority Act, 2005 and decriminalize offences under it for "promoting ease of doing business" and augmenting the "operational procedures of Coastal Aquaculture Authority".

Besides amending the Coastal Aquaculture Authority Act, 2005, the Bill seeks to clarify that "coastal aquaculture and activities connected therewith" shall continue to be regulated by "the Coastal Aquaculture Authority Act and no other Acts."

The 2023 Bill broadens the definition of "coastal aquaculture" or "coastal aquaculture activity" to mean "rearing and cultivation of any life stages of fish, including crustacean (shrimp), mollusks, finfish, seaweed or any other aquatic life under controlled conditions, either indoor or outdoor, in cement cisterns, ponds, etc. or otherwise in saline or brackish water in coastal areas, including activities such as production of brood stock, seed, grow out, but does not include fresh water aquaculture."

It also aims to encourage the establishment of facilities (hatcheries) in areas having direct access to seawater to produce genetically improved and disease-free broodstocks and seeds for use in coastal aquaculture[30].

**Provisions for "biosecurity" and antimicrobial usage**

The new Bill also includes new provisions for "biosecurity", which refers to measures and strategies for analyzing, managing, and preventing the risk of introducing or spreading harmful organisms like viruses and bacteria within the coastal aquaculture unit, which could lead to infectious diseases.

Moreover, the Bill under new section 12 A prohibits the use of "such pharmacologically active substance, antimicrobial agent or other material which may cause harm to human health as may be prescribed" and seeks to prevent the use of antibiotics and pharmacologically active substances, which are harmful to human health in aquaculture inputs including shrimp feed.

**Provisions for punishments and penalties under the Act**

The 2023 Bill seeks to change this by inserting Section 13A, which allows the CAA to "authorise any officer of the Authority or the State Government or the Central Government, to function as authorised officer to exercise such powers, to discharge such duties and perform such functions.".

It says that where any person carries on coastal aquaculture in contravention of any of the provisions of this Act, an officer authorized under section 13A can suspend or stop the activity for a prescribed time or impose penalties. The officer can even order the removal or demolition of any structure or the destruction of any standing crop. The officer may also suspend or cancel the registration of the offender.

**Study findings**

The Coastal Aquaculture Authority (Amendment) Bill, 2023 enhances India's aquaculture sector by clarifying regulations, promoting sustainable practices, and safeguarding the environment and upholding the "Polluter Pays Principle", while mandating aquaculture unit owners to bear the cost of any environment-related damage.

By explicitly prohibiting the use of antibiotics and pharmacologically active substances, the amendments prioritize the health of aquatic ecosystems. Improving the overall regulatory structure of aquaculture can act as a catalyst contributing to nutritious and safe food production and food security and to promoting the individual right to food and safe water. As the focus of this is also on advancing disease prevention and sustainable practices and aligns with SDG 14 (Life Below Water) and underscores India's commitment to responsible economic growth and sustainable ecological well-being.

**Other activities of Costal Aquaculture Authority on Antimicrobial Usage and Aquaculture Feed controls**

The primary objective of the Coastal Aquaculture Authority (CAA) is to regulate coastal aquaculture activities in coastal areas, ensuring sustainable development while safeguarding the coastal environment from harm. The Authority is vested with the power to establish regulations governing the construction and operation of aquaculture farms along the coast. Its responsibilities encompass inspecting farms to assess their environmental impact, registering aquaculture farms, setting standards for inputs and effluents, and addressing pollution concerns through measures like the removal or demolition of problematic coastal aquaculture farms.

A significant accomplishment by the CAA has been the registration of shrimp farms based on recommendations from State and District Level Committees. Registration with the Coastal Aquaculture Authority is mandatory for all individuals engaged in coastal aquaculture, and registrations are valid for five years, with the option of renewal. The ongoing registration process extends to new farms and those undergoing renovations for future coastal aquaculture activities.

Shrimp hatcheries focused on producing P. vannamei seed must register with the CAA and obtain approval for importing broodstock of specific pathogen-free (SPF) P. vannamei from approved suppliers. This involves submitting applications in the prescribed format and paying the designated processing fee.

As part of its regulatory measures, the CAA oversees farm and farmer registrations. Additionally, the Authority, in accordance with its functions, sets standards for all coastal aquaculture inputs, including seed, feed, growth supplements, and chemicals/medicines. The guidelines issued under CAA rules emphasize the avoidance of chemicals in shrimp ponds as feed additives, disinfectants, and antibiotics/drugs. The use of antibiotics in shrimp culture is strictly prohibited, with the prohibited substances clearly listed in the Guidelines, underscoring the commitment of CAA to maintain the health of water bodies and the organisms reared therein while upholding industry standards.

### *2.5 Marine Products Export Development Authority*

Established by a parliamentary act in 1972, the Marine Products Export Development Authority (MPEDA) operates under the auspices of the Union Ministry of Commerce and Industry. Endowed with the pivotal mandate to propel the marine products industry, with a keen focus on exports, MPEDA is proactive in developing and enhancing resources necessary for the promotion of various fishery products.

The Act empowers MPEDA to meticulously regulate the export of marine products, undertaking all requisite measures to ensure the sustained and high-quality export of seafood from the country. With the authority to self-prescribe matters crucial for the future safeguarding and augmentation of seafood exports, MPEDA conducts inspections of marine products, their raw materials, establishes standards, specifications, and provides training. Additionally, MPEDA is authorized to take all necessary steps for the effective marketing of seafood on the international stage.

Functioning as the nodal coordinating state-owned agency, MPEDA is deeply involved in fishery production and allied activities, including aquaculture. In essence, it plays a pivotal role in orchestrating and regulating the multifaceted aspects of the marine products industry, ensuring compliance with quality standards and facilitating the strategic promotion of India's seafood exports.

#### National Residue Control Program for Antimicrobials in Aquaculture

National Residue Control Program for Antimicrobials in Aquaculture, spearheaded by MPEDA, is a mandatory prerequisite for exporting to European Union countries. Operating under stringent regulations, MPEDA orchestrates this program, drawing up a meticulous sampling schedule and strategies annually. This framework aims to monitor residues of substances such as antibacterials/veterinary medicinal products and environmental contaminants.

Sampling is conducted at various critical points, including hatcheries, feed mills, aquaculture farms, and processing plants in maritime states. The samples undergo rigorous testing for the presence of antimicrobial residues, including banned antibiotics like chloramphenicol and nitrofurans, which carry a zero-tolerance policy. The commitment of MPEDA to quality assurance is fortified by its five laboratories strategically positioned across coastal states. Equipped with cutting-edge systems, including Mass Spectrometry, these labs adhere to international standards (ISO: IEC 17025), ensuring accuracy and reliability.

The results of this comprehensive monitoring, along with the subsequent year's plan, are diligently submitted to the European Union. This proactive approach not only demonstrates compliance but also guarantees a seamless export process for aquaculture products from the country, emphasizing Indian Government’s commitment to upholding the highest standards in the global seafood market.

**Pre Harvest testing for banned Antibiotics**

MPEDA has proactively established ELISA labs to conduct pre-harvest tests on farmed shrimps, certifying their freedom from banned antibiotic substances. Concurrently, the Export Inspection Council of India mandated the Pre-Harvest Test certificate for the export of all aquaculture products, irrespective of the destination country.

Notably, the Marine Products Exports Development Authority (MPEDA) has recently introduced the 'SHAPHARI' Antibiotic-free Certification scheme. This comprehensive initiative serves as an end-to-end solution, allowing MPEDA to conduct audits at various stages of aquaculture production. Aligned with FAO guidelines on aquaculture certification, “SHAPHARI” stands out from private certifications such as the Marine Stewardship Council (MSC) and Best Aquaculture Practices (BAP), which tend to be offshore processes often inaccessible to small and marginal Indian farmers due to affordability constraints.

The entire certification procedure is seamlessly executed online, mitigating human errors and ensuring heightened credibility and transparency. “SHAPHARI” comprises two integral components: certifying hatcheries for seed quality and separately approving shrimp farms that adhere to necessary good practices. The adherence to the Pre-Harvest Test certification not only ensures compliance but also positions farmers to earn MPEDA certification, further promoting the export of farmed aquatic products and emphasizing MPEDA's commitment to upholding the highest industry standards.

### *2.6 The Export Inspection Council (EIC)*

The Export Inspection Council (EIC) was established by the Government of India under Section 3 of The Export (Quality Control and Inspection) Act, 1963, with the primary objective of fostering the sound development of India's export trade through Quality Control and Inspection, and related matters. The EIC plays a pivotal role in notifying commodities that will undergo quality control and/or inspection before export, setting standards of quality for such designated commodities, and specifying the type of quality control and inspection procedures to be applied.

In addition to its advisory function, the Export Inspection Council exercises technical and administrative control over the five Export Inspection Agencies (EIAs), located in Chennai, Delhi, Kochi, Kolkata, and Mumbai. These agencies were established by the Ministry of Commerce, Government of India, to implement various measures and policies formulated by the Export Inspection Council.

The Export Inspection Council, either directly or through Export Inspection Agencies, provides services in several key areas. This includes the certification of the quality of export commodities by installing quality assurance systems in exporting units. The certification process involves two types: (1) Consignment-wise inspection, including mandatory testing of aquaculture consignments for antimicrobials, and (2) Certification of the quality of food items for export through the installation of Food Safety Management Systems in food processing units. The EIC maintains its network of accredited laboratories for testing various antibiotics used in aquaculture. Through these comprehensive measures, the Export Inspection Council contributes significantly to upholding the quality and safety standards of India's export of aquaculture products.

### *2.7 Conclusion*

In conclusion, despite the myriad laws and regulations along with various regulatory bodies operating throughout the shrimp production value chain to curb the presence of antimicrobials, a foolproof system remains elusive. Today shrimp aquaculture is the most regulated farming activity in India, with multiple regulators including environmental controls being implemented by the Costal Aquaculture Authority of India. The persistent issue of export consignments facing rejection due to the presence of these drugs continues to be a source of concern for the Indian Government, the shrimp industry, and potentially importing countries.

# 3. MAJOR STAKEHOLDERS

At the forefront are government bodies such as the Ministry of Commerce regulating exports though MPEDA & EIC, the Ministry of Fisheries, which formulates policies, regulations on SPF, diseases, farming, and the Environmental regulator the CAA whose standards govern the industry. These entities play a crucial role in ensuring compliance with environmental guidelines, setting the stage for sustainable practices, and overseeing the overall health of the sector. The private sector encompasses a diverse array of stakeholders, aquaculture businesses, and exporters. Exporters, acting as intermediaries between domestic producers and global markets, wield influence by adhering to international standards and advocating for sustainable practices to maintain the integrity and marketability of Indian shrimp. Individual farmers and hatchery owners form the backbone of shrimp cultivation. Feed producers hold significant sway in the industry, influencing sustainability through the formulation of feeds that reduce reliance on fishmeal and incorporate environmentally friendly ingredients free from Antibiotics.

The synergy and collaboration among these major stakeholders is essential for propelling Indian aquaculture shrimp towards a future characterized by sustainability, environmental stewardship, and global competitiveness.

### *3.1 Government Stakeholders*

Government entities play a pivotal role in shaping the trajectory of the Indian shrimp industry and influencing the adoption of sustainable practices. Regulatory bodies, such as the CAA, MPEDA & EIC, set the tone for industry standards, overseeing compliance with environmental regulations, and developing policies that impact shrimp farming. Collaboration between government agencies, research institutions, and industry stakeholders is essential to create a conducive regulatory environment that encourages sustainable practices and minimizes antimicrobial usage.

### *3.2 Private Sector and Exporters*

The private sector, comprising shrimp processors, aquaculture businesses, and exporters, holds substantial influence in shaping the industry landscape. Shrimp farmers and businesses are pivotal stakeholders in implementing sustainable practices and reducing antimicrobial usage. Exporters, connecting the Indian shrimp industry with global markets, have a vested interest in maintaining product quality and adhering to international standards. Their role in promoting and rewarding sustainable practices is crucial for the industry's long-term viability. Only a few exporters have fully integrated systems (having feed mills, hatcheries, and shrimp farms), while most of the processors focus on processing and distribution only. There are 647 sea food processing establishments in the country including 426 EU approved units[16]. *(source MPEDA website[16])*

### *3.3 Farmers and Hatchery Owners*

At the grassroots level, individual farmers and hatchery owners are key stakeholders whose daily practices directly impact the industry's sustainability. There are about 75,000 shrimp farmers, most of them small scale who produce about 90 per cent of the total farmed shrimp. Their adoption of best management practices, responsible antibiotic use, and adherence to environmental guidelines are pivotal. Education and support mechanisms for farmers can catalyze the transition towards more sustainable and environmentally friendly shrimp farming practices. Their adoption of best practices, responsible antibiotic use, and compliance with environmental guidelines are pivotal. Education and support mechanisms for these stakeholders are essential in driving the industry towards more sustainable and environmentally friendly practices. The farmers sell the shrimps to commission agents (intermediaries) who in turn supply the shrimp to processors. The hatcheries supply shrimp post larvae to farmers, there are around 500 hatcheries, predominantly located in Andhra Pradesh and Tamil Nadu.

### 3.*4 Aquaculture Feed Producers and Retailers*

The production and distribution of aquaculture feeds represent a critical link in the shrimp industry's supply chain. The total installed capacity of feed mills for shrimp feed production in India is about 1.6 million metric tons from 30 manufacturing plants[17]. (NACA 2017[17]). There are about two large feed manufacturers ( CP Group & Avanti feeds) which supply the majority of the Indian shrimp feed each having around five manufacturing units. Soybean meal is the major plant protein source used in shrimp feeds. Feed producers influence the industry by formulating sustainable feed options that minimize reliance on fishmeal and incorporate alternative ingredients. Collaboration with feed producers and retailers is essential to align business practices with environmental and social responsibility. Retailers, by promoting and selling responsibly sourced shrimp products, contribute to creating a domestic market demand for sustainably produced shrimp. Collaborative efforts with feed producers and retailers are instrumental in aligning business practices with environmental responsibility.

### *3.5 Consumers*

Consumers wield significant influence in steering the industry towards sustainability. The choices consumers make at the point of purchase can drive market demand for responsibly sourced shrimp. Increased awareness regarding the environmental and health implications of shrimp production practices can empower consumers to make informed decisions, thereby incentivizing the industry to prioritize sustainability. More than domestic consumers with respect to aqua cultured shrimp, it is the consumers in importing countries that drive production standards in the exporting countries, through demand for sustainable practices like organic produce and insistence on animal welfare norms. For example, eyestalk ablation is widely practiced in shrimp hatcheries, to encourage female shrimp broodstock to produce more eggs, but this raises serious welfare concerns especially in Western countries.

***Rise in domestic shrimp market: Seafood Companies try entry into Indian supermarkets amid global export challenges***

*The pandemic years have forced a change in trends and exporters are now also looking in the domestic seafood market, and try to gain a foothold focusing on high end Indian consumers through supermarket chains and online distribution networks.*

*India is a predominantly vegetarian country which gradually changed its outlook from the time of entry of broiler chicken industry in the late eighties. The availability of shrimps in India is rising with booming aquaculture activity pushing the production to over 9 lakh tonnes and making it a key commodity in the seafood exports worth $8 billion. Some seafood processors and exporters reckon that around 10 percent of the production can be sold in* *the domestic market as the export market is currently witnessing a decline in prices due to a glut and economic problems in US, and quality, and very recent freight issues to Europe.*



*The above example ITC MasterChef prawns which are slated to undergo about 200 quality checks including those for antimicrobials are widely available in Indian supermarket chains and through e-tailers like Amazon, Big Basket, and labelled to adhere to European and American quality standards and certified for good production practices. The increasing consumer preference for protein-rich seafood, the rising popularity of shrimp-based cuisines, and numerous advancements in aquaculture practices, are among the key factors driving the market growth.*

*The domestic market for shrimp consumption in India currently stands at well under 50,000 MT per year depending on export surplus. However, there is substantial potential for growth in this market if supply side issues are addressed. Leveraging factors such as the burgeoning urban middle class, a sizeable population of young consumers, the ease of preparing shrimp dishes, and the perceived health benefits of seafood could lead to a substantial expansion of the domestic shrimp market in India. Addressing this critical issue by bolstering cold chain facilities would not only alleviate these logistical bottlenecks but also provide a significant boost to traders and farmers engaged in the shrimp business and serve as a catalyst for the growth of a vibrant domestic market.*

### *3.6 Major Importing Countries*

The global nature of the shrimp industry involves major importing countries that serve as both markets and influencers. These countries, often stringent in their import regulations, can shape industry practices by setting sustainability criteria for imported shrimp. Understanding and aligning with the expectations of major importing countries is critical for Indian shrimp exporters, influencing their practices to meet international standards and preferences. Regulators of importing countries like the US Food & Drug Administration (FDA) and EU Food & Veterinary Office (FVO), Japan Ministry of Health & UK Department for Environment, Food and Rural Affairs (DEFRA) all have played a role in control of antimicrobials in farmed shrimp.

The United States has strategic initiative aims to bolster the safety of shrimp entering the United States, particularly from exporting countries such as India, Ecuador, and Indonesia. The Regulatory Partnership aims to facilitate closer collaboration between the FDA and foreign counterparts, fostering the sharing of non-public information and the enforcement of stringent food safety practices across the entire supply chain including that for control of Antimicrobials. To ensure the efficacy of these arrangements, the FDA has instituted a thorough pre-signing assessment, rigorously evaluating the aquaculture food safety systems of partner countries. This includes a comprehensive examination of key elements and ongoing processes to ascertain the presence of preventive controls and competent oversight throughout the aquaculture shrimp supply chain. Through such collaborative efforts, the Regulatory Partnership Arrangements strive to address the challenges posed by antimicrobial use and enhance the overall safety of imported shrimp.

In conclusion, a multi-stakeholder approach involving collaboration and dialogue among government bodies, private sector actors, farmers, feed producers, retailers, consumers, and major importing countries is imperative for fostering sustainability and reducing antimicrobial usage in the Indian shrimp industry. Each stakeholder group plays a unique role, and collective efforts are essential to overcome challenges and chart a sustainable and prosperous future for the industry.

# 4. Characteristics of Aquaculture Production, Antimicrobial Usage and Sustainability

The history of shrimp farming diverges significantly from terrestrial animal husbandry. In terrestrial husbandry, the traditional cultivation of wild animals at low density in natural settings spanned thousands of years and held a deep connection with human civilization, then it rapidly progressed to the intensive culture of domesticated animals in controlled environments. In contrast, shrimp farming has a more recent origin, emerging in the last few decades. Despite shrimps boasting an ancestry of over 100 million years, the major impediment to their farming lay in the inadequate understanding of the life cycle of penaeid shrimp. This intricate cycle involves an oceanic reproductive phase, a complex series of larval stages, and an estuarine juvenile phase. The Penaeidea family bifurcates into two clades, with one clade displaying a distinct preference for deep waters. Notably, the Penaeidae clade, which favors shallow waters, encompasses all species farmed on an industrial scale. Among the species dominating global shrimp farming today are Penaeus vannamei and Penaeus monodon. These species thrive in shallow waters, enabling cost-effective cultivation in coastal aquaculture systems with relatively modest water volumes[18] *(Robalino J et al., 2016[18])*.

Unlike the millennia-old civilizational roots of terrestrial animal husbandry, shrimp farming's evolution is a testament to recent advancements in understanding and harnessing the unique life cycles and behaviors of these marine crustaceans.

Historically, farmers have predominantly relied on capturing wild shrimp to stock their ponds. Postlarvae or broodstock are harvested from the wild, with postlarvae directly introduced into ponds and broodstock spawned in captivity to produce postlarvae. However, this reliance on wild-caught shrimp poses a substantial risk to the industry. Wild shrimp may act as carriers of virulent pathogens, leading to the potential horizontal and vertical transmission of diseases within a shrimp culture facility or an entire shrimp farming region.

Epidemics triggered by viruses like the White Spot Syndrome Virus (WSSV) have resulted in significant economic losses in Asia and the Americas. These losses can be attributed, at least in part, to the utilization of infected, wild-caught shrimp[19] *(Lightner, 2003[19])*. To address these challenges, the shrimp farming industry needs to accelerate the adoption of genetic improvement strategies and move away from dependence on wild-caught shrimp, thus mitigating the risks associated with disease transmission and enhancing overall production efficiency.

Another notable drawback of cultivating wild-caught shrimp is the missed opportunity for farmers to capitalize on selective breeding and other genetic improvement strategies. In terrestrial animal husbandry, selective breeding has led to remarkable advancements in growth, feed conversion efficiency, disease resistance, and reproductive performance across successive generations. To illustrate, contemporary chickens grow twice as fast on half the amount of feed compared to their counterparts from 50 years ago, a transformation largely attributed to the selective breeding practices of poultry breeders[20] *(Boyle et al, 2001[20])*.

Despite the economic significance of farmed shrimp, the global shrimp farming industry has been slow in embracing genetic improvement strategies, a common practice in the more mature meat-producing industries such as poultry and swine. This reluctance has led to production inefficiencies and diminished profits for shrimp farmers. Despite the fact that many penaeid shrimp exhibit traits conducive to selective breeding—such as high fecundity, a relatively short generation time, and ease of captive reproduction—the shrimp farming sector has been slow to leverage these opportunities. This disparity underscores the need for the shrimp farming industry to embrace and integrate advanced genetic improvement strategies, aligning with the success witnessed in other, more mature segments of the meat-producing sector.

Hudinaga (1942) in Japan was the first to systematically document and close the life cycle of marine shrimp. His pioneering work laid the foundation for what is now known as the global shrimp hatchery technology industry. The utilization of hatchery-produced seed was anticipated to enhance the reliability of shrimp farming, leading to the establishment of shrimp hatcheries in both the northern and southern hemispheres. Postlarvae were cultivated in land-based hatcheries using broodstock captured from the wild. These postlarvae were genetically wild animals, as their parentage originated from wild-caught broodstock sourced from the sea. Subsequent to this period, shrimp farming in each hemisphere predominantly employed native species. In the Western hemisphere, the focus was on the white shrimp, P. vannamei, while in Asia, shrimp farming revolved around the black tiger shrimp, P. monodon[21] *(GAA et al[21]).*

### *4.1 Development of Aquaculture Sector in India*

Shrimp aquaculture in India has a rich history marked by both successes and challenges, reflecting the potential and obstacles inherent in developing this industry. The sector experienced rapid growth in the 1990s, primarily driven by individual farmers. However, this expansion occurred in an environment characterized by a lack of robust regulatory guidance. During this period, the total area devoted to shrimp aquaculture witnessed a significant increase, yet more than 85 per cent of farms were relatively small, covering less than 2 hectares. On these smaller farms, the average shrimp production was approximately 0.73 tons per hectare, indicating lower yields compared to other shrimp-producing nations.

To enhance productivity, and in the absence of sufficient regulatory oversight, farmers imported seed stock and feed materials from countries like Taiwan and the Philippines, which claimed superior growth rates and productivity. The dominant species in cultivation during this phase was *Penaeus monodon*. However, in 1994, the industry faced a setback when a disease known as White Spot Syndrome Virus (WSSV) affected *Penaeus monodon*, leading to substantial losses and impacting various stakeholders and related industries across India.

Efforts to control the disease proved ineffective, prompting the recognition of the need for research and regulatory control as a significant national issue. Responding to negative assessments, as described earlier, in 1996, the Supreme Court of India imposed a ban on coastal aquaculture. Subsequently, an emergency session of the Indian Parliament enacted a bill to establish an Aquaculture Authority. Concurrently, due to continuous challenges, farmers began exploring alternative species for aquaculture.

In 2009, a pivotal shift occurred with the introduction of *P. vannamei* as a candidate species for aquaculture. By the end of 2017, the cultivated area had increased by 50 percent, and production had surged by almost 83 percent, propelling India to become the world's second highest shrimp producer. Despite these impressive statistics, concerns lingered about the extent of unregulated and/or unregistered farming practices. In response, the Coastal Aquaculture Authority Act was enacted in 2005 to regulate activities associated with aquaculture in coastal areas. Given the industry's expansive scope and potential for future growth, the imperative for ongoing regulation to safeguard and enhance shrimp aquaculture in India, as well as to maximize export potential, remains evident[22] *(Khedkar et al., 2020[22], "A Review on Shrimp Aquaculture in India: Historical Perspective")*.

### *4.2 Types of Shrimp Farm In India*

#### a. Traditional Farms

These include a variety of polyculture systems, usually with a large component of miscellaneous fish and a small component of shrimps. In these systems, ponds are filled with tidal water with no control over quality of stocking. Average production is comparatively very low and ranges from 200 to 500 kg per hectare per year (mixed species and sizes). In slightly improved traditional systems, the traditional ponds are stocked with wild shrimp seed (in particular from the tiger shrimp, *Penaeus monodon*), increasing overall yields and increasing the shrimp component.

#### b. Extensive Farms

Extensive systems apply monoculture and usually supply water through pumping from canals, creeks or the even the sea. Such farms are found in West Bengal state, Farmers use locally prepared feeds and, under good management, are able to harvest up to some 700 kg per hectare per crop. In modified extensive systems, ponds are prepared with tilling, liming and fertilization, which enables the application of higher stocking densities (up to 10 per square metre) and increases the potential yield to some 1 000 kg per hectare per crop.

#### c. Semi-Intensive systems

These are more recent pond systems, up to 1 hectare in size, with regular supply and drainage canals, controlled water exchange and higher stocking densities (in the order of 15 to 30 per square metre). The farms are usually located in estuarine areas and sometimes dilute estuarine water with fresh water to maintain optimum salinity. Pellet feeds are used, and application of drugs and chemicals (such as disinfectants, piscicides, fungicides and antibiotics) is common. Such farms are found in Andhra Pradesh state and average annual yields of semi-intensive farms in India are about 2 200 kg per hectare with an average of 2 crops a year.

#### d. Intensive systems

The ponds are 0.25 to 0.5 hectares in size with multiple aerators per pond and a central drainage system to remove accumulated sludge. Feeding with pelletized food takes place a number of times per day and the stocking density increases to 30 to 80 per square metre. Yields of over 8 000 kg per hectare are possible, but the actual average annual yield in India is about 4 500 kg per hectare. Although this system is very common in Thailand and Taiwan Province of China, it is frequently used in India.

Industrial aquaculture operations characterized by large ponds and “intensive” (e.g., chemical use, fertilizers, aeration devices) production have spread rapidly, greatly increasing the trade of farmed seafood, while also reducing costs. Intensive farms have largely replaced operations “extensive” systems.

### *4.3 Disease Challenges and Farming Systems Impacting Antimicrobial Usage*

Aquaculture shrimp farming has faced significant challenges marked by severe viral disease epidemics. One of the initial major outbreaks was the infectious hypodermal and hematopoietic necrosis virus (IHHNV), leading to the runt deformity syndrome in *P. vannamei*. The 1990s witnessed the emergence of several other formidable diseases. The yellow-head virus, affecting *P. monodon*, caused substantial mortality in Thailand and various Asian nations. Taura syndrome virus (TSV) surfaced in shrimp farms near Taura, Ecuador, in 1992, spreading across Latin America and Asia[23] *(Lightner, 1996[23])*. In 1992, China experienced the onset of white spot syndrome virus (WSSV), a devastating disease that later permeated through Asia and beyond via international trade in live shrimp. The early mortality syndrome

(EMS), initially identified in China in 2009, also known as acute hepatopancreatic necrosis disease, inflicted significant losses and spread globally. Additional diseases, including white feces disease (WFD) and a condition caused by protozoan gregarines and specific Vibrio species (referred to as *Enterocytozoon hepatopenaei*-EHP disease), have surfaced.

In India, the focus lies on two critical diseases, WSSV and EMS, as they emerged as major threats in the 1990s and 2010s, respectively. Despite disease-induced declines in shrimp production, such as the notable case of WSSV causing a significant drop in production in Ecuador from 130,000 t in 1998 to 45,000 t in 2001, the global shrimp production has steadily increased. The advent of specific pathogen-free (SPF) shrimp, enhanced broodstock lines, improved feeds, increased aeration use, and advancements in sanitary practices have contributed to this consistent growth[20] *(Boyde et al., 2021[20])*.

In India, EHP disease has become a major concern alongside WFS and WSSV. Many shrimp diseases, categorized as syndromes due to multiple etiologies and system impacts, manifest clinical signs such as growth retardation and increased size variability. In the case of EHP, growth retardation, soft shells, and chronic mortalities are typical symptoms. Antibiotics are often added to shrimp feed as a response to disease outbreaks, even when they may not be effective. Farmers resort to antibiotics, sometimes internationally prohibited, due to factors like a lack of technical knowledge, unawareness of residue implications, and insufficient financial incentives for adopting good farming practices.

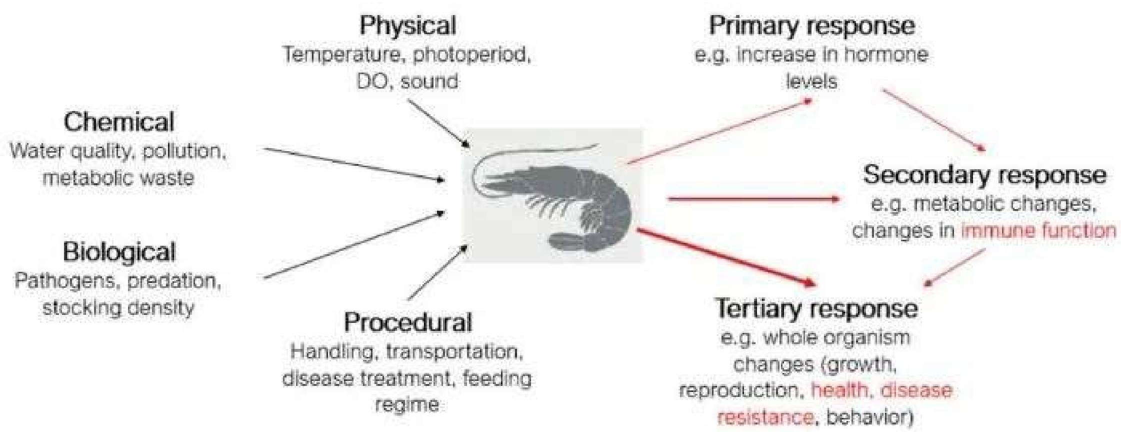



Figure 1: Types of stress experienced by shrimp during culture cycle and their various stress response. Source: dsm-firmenich

Shrimp diseases are largely treated by prevention, as treatment of disease post infection has largely proven ineffective. This prevention includes the introduction of specific pathogen-free (SPF) stocks, and a wide array of pond-level management approaches. Major shrimp diseases including WSSV and EMS cause rapid and severe mortality. In India there is no systemic disease surveillance in place for shrimp diseases, the laboratories in the private sector point to the incidence of EHP on the rise in the last three years while WSSV has been in retreat[22]. The best way to reduce the losses caused by diseases is to have good farm management and enhance shrimp immune system when a threat is perceived.

### *4.4 Environmental Impacts and Development of AMR*

The international trade and direct connection to aquatic environments in shrimp aquaculture present significant concerns regarding the development and dissemination of Antimicrobial Resistance (AMR). Predominantly situated in low- and middle-income countries, shrimp production lacks robust antibiotic regulations, creating an environment where human, animal, and environmental bacteria intermingle. In areas of shrimp cultivation, untreated waste often directly enters local water sources. There are no India specific comprehensive studies on the environmental dimensions of AMR, probably the global pattern remains relevant.

Crustacean farming, particularly shrimp, introduces unique risks due to their lack of an acquired immune system. This vulnerability increases the need for antimicrobial treatment, accounting for 87 per cent of global shrimp production in Asia[1]. (FAO 2022[1]). This region has also been identified as a global hotspot for AMR.

Mitigating these risks requires strategies promoting prudent antibiotic use and reducing the industry's contribution to the growing global AMR problem for long-term sustainability. The transmission of AMR genes through horizontal gene transfer (HGT) raises concerns about the rapid emergence of resistant pathogens globally. This process, occurring between unrelated bacterial species, facilitates the transfer of resistance genes from nonpathogenic environmental bacteria to animal or human pathogens, posing threats to health.

In 2012, the Thai shrimp industry faced a devastating blow when an unidentified disease wreaked havoc, subsequently spreading to other countries. Following extensive research, the causative agent was pinpointed as a strain of *Vibrio parahaemolyticus* carrying a plasmid housing genes encoding insect-related (Pir) toxins, specifically PirA and PirB. These toxins inflict severe damage to the hepatopancreas, leading to rapid mortality, particularly within the initial 30 days of cultivation. Originally dubbed “early mortality syndrome”, it is now accurately termed Acute Hepatopancreatic Necrosis Disease (AHPND).

Further investigations have revealed the horizontal transferability of these genes to other Vibrio species, including *V. campbelli* and *V. harveyi*. Vibrio, like many microorganisms, has the capability to form biofilms—a cooperative assembly of cells adhering to each other and often attaching to surfaces. Within shrimp ponds, abundant space and various substrates, such as pond liners, automatic feeders, aerators, and floating flora and fauna, provide ideal conditions for biofilm growth.

The initiation of biofilm formation occurs when a small group of bacterial cells communicates via quorum sensing, recruiting additional cells to establish an external matrix. Vibrio can then be shed from the biofilm, transforming into flagellated and highly virulent forms. This adaptive strategy affords Vibrio a significant advantage, as the biofilm serves as a protective barrier against antimicrobial products like disinfectants and antibiotics. Consequently, there is a notable risk of the emergence of AMR.

Despite the significant potential for AMR dissemination in shrimp farming environments, limited information is available on disease incidence, chemical usage, untreated waste release, and extensive human-water contact. But the fact remains that global reach of the shrimp industry amplifies the risk of AMR dissemination. The impact of resistant infections on shrimp health remains largely unknown, with some reported instances of mass shrimp larvae mortality linked to antimicrobial resistance. Standardized methods are crucial for comparability across studies, emphasizing the urgent need for a systematic surveillance mechanism in aquaculture, and India has started such a program, where data is continuously collected under the Indian Network for Fishery and Animals Antimicrobial Resistance (INFAAR), it remains unavailable to the public, limiting actionable insights.

Given the vulnerability of shrimp farms to flooding, the threat extends beyond economic consequences, serving as a rapid means of disseminating resistant bacteria and antibiotic residues over vast areas. Rising global temperatures may further exacerbate AMR concerns by favoring bacterial growth.

Co-selection with antimicrobials, including anti-fungicides, antiparasitic agents, and heavy metals, contributes to AMR emergence in shrimp farming. If these are present, selection for resistance genes can take place at lower antibiotic concentrations. Detectable levels of heavy metals in shrimp and pond water, such as lead, cadmium, chromium, copper, and zinc, through pond sanitizers pose additional challenges.

For comprehensive insights into the global effects of antimicrobials on aquatic environments, South Centre Research Paper 103, March 2020[23], titled "Antimicrobial Resistance: Examining the Environment as Part of the One Health Approach," provides extensive details.

# 5. MOVING TOWARDS SUSTAINABLE SYSTEMS

As mentioned in national AMR action plans, the principal means by which the risk of AMR dissemination in the shrimp aquaculture can be mitigated is through reducing infection and promoting the prudent use of antimicrobials. Some of the India specific interventions that can be attempted are grouped below

## *5.1 Regulate Antibiotic Sales and Usage*

For effective better control over the use of antimicrobial agents in aquaculture, national regulatory frameworks on the sales, use of antimicrobial agents are required. India like many other shrimp-producing countries do have regulations in place for the use of antibiotics in aquaculture, but there is a huge disconnect between regulation and enforcement. Ideally only veterinarians, or other licensed fish health professionals, should prescribe antimicrobials, and licensing would be enforced. This is not the case in India hence imports to the EU and US are regularly rejected due to the shrimp testing positive for prohibited antibiotic residues or residues above the maximum residue levels. This is especially true for Nitrofuran metabolite AOZ which alone accounts for more than 80 percent of all rejections from EU, Japan & US.

Similarly, there has been a growing concern within the EU over the level of antibiotic use in the Indian shrimp farming, and, accordingly, the rate of testing has been increased from 10 to 50 percent as mentioned previously. This is one of the probable reasons for reduced export of Indian shrimp into EU. However, although export restrictions undoubtedly help to reduce antibiotic usage, they only detect antibiotic usage immediately prior to harvesting, and do not apply to hatcheries and the major losses are borne by the exporters who cannot trace back the material to farms.

Despite significant progress in the development of AMR action plans, a significant barrier to reducing antibiotic usage in the India is the lack of resources to implement the regulations that are already in place. This calls for the need for smart regulations.

The term “smart regulation” was coined “to overcome the inefficiencies of traditional regulation on the one hand, and the pitfalls of deregulation on the other”. Accordingly, smart regulation describes a form of “regulatory pluralism” that embraces much more “flexible, imaginative and innovative forms of social control” than conventional regulation. The assessment stems from the fact that not only could smart regulation be effective in delivering policy objectives; it can also increase efficiency by doing so at least cost to the government, business and the community. Furthermore, it was developed as a useful way to approach regulating complex areas that involve multiple stakeholders with diverging interests.

Some existing regulatory arrangements and policy proposals for implementing NAPs on AMR do already advocate moving beyond a traditional regulatory approach by emphasizing the importance of multisectoral coordination and stakeholder engagement.

To these suggestions, smart regulation adds further useful elements, including a stronger emphasis on involving stakeholders in the design of regulatory standards (i.e., not just in the implementation of standards they have been unable to shape) across all relevant policy areas, the deployment of a broader range of regulatory tools and the goal of developing win-win regulatory options whenever possible. Smart regulation utilizes the existing institutional, legal and governance framework, including the traditional command-and-control approach, but also expands options for regulators. It could encourage behavior change, incentivize regulatory compliance and ensure the most efficient and effective application of the resources of different actors as well as greater acceptance and smoother implementation of regulatory instruments. As India has already an array of regulations in place for all stages of Aquaculture, the only hitch being the implementation due to large geographical spread of farms and thousands of small producers, use of technology enabled smart regulations can be a game changer vastly improving compliance in a sustainable way[24] *(Smart Regulations, BMJ)*

### *5.2 Improved Disease Detection and Control*

Accurate diagnosis of disease will drive selection of appropriate antimicrobials, and avoidance of classes critical for use in human health. This would prevent the use of antibiotics in case of viral infections. But many viral pathogens like WSSV infection have been shown to increase susceptibility to other bacterial pathogens. India has a large network of private PCR laboratories catering to WSSV detection, and this has considerably increased the detection and probably helped the country in sustained efforts in early diagnosis and prevention of this disease that had devastated the shrimp industry of Thailand and Vietnam. But with many new diseases emerging probably due to climate change and the remoteness of many farms, there can be further improvement in systems.

A notable feature of these laboratories are that in contrast to terrestrial animal husbandry where disease diagnostic services are provided by the government, most of the shrimp laboratories are run by private entities. In recognition of the importance of a comprehensive approach in dealing with endemic, emerging and exotic diseases/pathogens, India, has implemented a National Surveillance Programme for Aquatic Animal Diseases (NSPAAD). During the past years, the programme has facilitated the identification and characterization of as many as seven new diseases/pathogens though its implementation remains sketchy due to lack of institutional support.

Laboratory capacity and expertise is improving, however, through initiatives such as the UK Government-funded Fleming Fund[25], and technological advances such as the development of the portable MinION sequencer are increasing the accessibility of these applications to the shrimp industry. Further, newer pond-side PCR-based diagnostics, that are straightforward enough for farmers to use have recently been deployed to commercial farms in Thailand

### *5.3 Improved Hygiene and Farm Management*

Better management practices (BMPs) for shrimp farming are pivotal for achieving sustainable and responsible aquaculture. The Food and Agriculture Organization’s Code of Conduct for Responsible Fisheries[29] *(FAO, 1995[29])* forms the foundation for these practices, aiming to standardize management approaches. BMPs are adaptable to various shrimp production types, such as intensive and extensive methods, with a primary goal of minimizing disease risks and environmental degradation associated with each system.

Large vertically integrated companies possess the capacity to implement advanced biosecurity systems, effectively limiting disease spread within and between ponds. However, this control might be counterbalanced by higher stocking densities and perceived risks, leading to increased disease susceptibility and greater reliance on antimicrobials. Sustainability hinges on the adoption of BMPs, encompassing legal compliance, social responsibility, and sound practices from pond preparation to postharvest management.

The Marine Products Export Development Authority (MPEDA)[28] recommends specific BMPs for Indian farmers to enhance shrimp farming practices.

Pond Preparation Practices:

a. Increase Water Holding Capacity: This reduces disease risks and minimizes reliance on excessive water exchange. Maintaining a minimum water depth of 1.2 meters is crucial.
b. Complete Pond Draining: Eliminates disease-carrying organisms from previous crops, ensuring a fresh start. Wet preparation methods can be an alternative.
c. Organic Waste Removal: Eliminate organic matter from pond bottoms to prevent the release of toxic gases that can harm shrimp.
d. Dry and Plough the Pond Bottom: Sun drying kills harmful organisms, oxidizes organic matter, and reduces sludge. Ploughing enhances these effects and helps control gastropods.
e. Fertilization and Liming: Improve mineral content, especially in ponds with low soil fertility or those in use for extended periods.

By adhering to these BMPs, farmers can achieve better production, higher productivity, and improved returns, while fulfilling environmental and social responsibilities. However, challenges persist for subsistence farmers in India, who may find it harder to implement control measures. These farmers, often engaged in polyculture, may resort to antimicrobial use even at slight suspicions of infections, highlighting the need for targeted support, awareness, and resources to facilitate sustainable practices.

### *5.4 Better Regulation of Feed and Probiotic Manufacture and Sales*

Oral antimicrobial treatment is often administered to shrimp through medicated feed or by adding the antimicrobial to normal farm feed. Antimicrobial use for growth promotion was banned by the European Union in 2006 and heavily regulated in the United States in 2017. As many antimicrobials used in Shrimp farming are easily available directly to farmers without valid prescriptions, antimicrobials often find their way to healthy animals as a result of group medication. Group medication of antimicrobials should be administered only when microbial infections result in serious mass mortality or morbidity with strict compliance to withdrawal periods so as to prevent accumulation of drug residues. There is still some lacuna in feed safety in India as it is not considered a priority item in contrast to food safety. The CAA should ensure that all inputs are tested and certified.

### *5.5 Better Farmer Awareness and Engagement*

India offers a range of courses on aquaculture management for farmers to attend, ranging from governmental and non-governmental organization workshops, to other farmer awareness programs though State Fishery Departments and National Centre for Sustainable Aquaculture (NaCSA)

The National Centre for Sustainable Aquaculture (NaCSA) was established by MPEDA in 2007 as an outreach organization for uplifting the livelihood of small-scale shrimp farmers. More than 90 percent of Indian shrimp farmers belong to small-scale or marginal category with operational holdings of less than two hectare per individual. Till recent years, each farmer's production system was independent and unsynchronized with that of neighboring farmers. They mostly adopted traditional methods for operating their farms and did not have access to technological innovations and scientific applications. NaCSA started grouping these farmers into societies and educated them on better management practices (BMP) for safe and sustainable shrimp farming. NaCSA also trained these farmer societies to follow cluster approach in shrimp farming. However, surveys conducted on farmers' knowledge of antibiotic use have suggested that they have a limited understanding about the purpose of antibiotics

Aqua farmers sometimes use various antibiotics indiscriminately to prevent losses due to diseases. Such extensive use of medicines and antibiotics often leaves residues, affecting the health of consumers as well as the marine habitat. Sustainable aquaculture depends on environment-friendly treatment strategies for fish diseases. There is a need to set up systems for capacity and awareness building among aqua farmers and to ensure easy access to soil and water testing and extension services in order to guide them with proper diagnosis and action. Limited access to extension services and absence of disease surveillance mechanisms make shrimp aquaculture vulnerable and force farmers to undertake distress harvesting. This reduces the duration of production cycles, makes the production process intensive and puts stress on available natural resources. A strong disease surveillance system that monitors the incidence of diseases along with extension services that can provide inputs on quality of soil, water, etc., is required for ensuring sustainable production[30].

### *5.6 Certification to Best Practices*

Aquaculture certification and labelling programs have become the primary tool to address sustainability issues in farmed seafood, which includes promoting prudent antimicrobial usage especially in Ecuador. There are various certification programs that have been introduced by international private schemes, such as Global Aquaculture Alliance's Best Aquaculture Practices (GAA-BAP), Aquaculture Stewardship Council (ASC) Asian Seafood Improvement Collaborative (ASIC), and Monterey Bay Aquarium's Seafood Watch (MBASW). One of these aquaculture sustainability certification schemes is the "best aquaculture practices" (BAP) certification of the Global Aquaculture Alliance (GAA). These certification standards cover seafood processing plants, farms, hatcheries and feed mills. The standards contain requirements for food safety, environmental management, animal welfare, and labor and social aspects. Indian firms that have Four-star BAP status denotes that the processing plants, farms, hatcheries and feed mills from which a group sources are BAP-certified. It's the highest such achievement in the BAP program. The Aquaculture Stewardship Council has also granted its certification to an Andhra Pradesh-based group that operates hatcheries and shrimp farms with ponds, as well as a shrimp processing facility. The government certification schemes to best aquaculture practices using FAO tools may also be a game changer to small and marginal Indian farmers due to affordability constraints, but wider adaptation is wanting.

### *5.7 Adoption of Less Water-Intensive Techniques*

The aquaculture production process uses fresh water, thus putting stress on water resources in the habitat. Newer land-based intensive aquaculture systems, such as recirculating aquaculture systems (RAS), solar recirculating aquaculture systems, raceway aquaculture systems, and biofloc-based aquaculture systems are now being tried out. To reduce usage of water, new age technologies like RAS may be adopted, especially in places where access to water is limited. The super-intensive system for white shrimp, *P. vannamei*, is one that uses lined ponds, raceways, or tanks for stocking densities of over 150 shrimp per m2 during growth and applies a significant level of technology including RAS. Biofloc is now the most commonly used technology for intensive shrimp culture. It relies on effective beneficial microbe manipulation to minimize the need for water exchange and propitiate in-pond nutrient reuse that contributes to reduce waste and the need for supplemental protein requirements. Proficient microbial manipulation is needed to form aggregates that are key to successful system operation, which requires appropriate engineering, supplies, and management. The biofloc occupies significant space in the water column and colonizes the shrimp gut, thus limiting potential vacant niches for pathogen development and providing a more varied nutrient base, improving digestibility, nutrient availability, and overall reduction in Antimicrobials.

### *5.8 Better Traceability of Aquaculture Shrimp*

Traceability, the ability to track a product to its source throughout the supply chain, holds paramount importance in ensuring food safety, fostering sustainable production and consumption, and preventing misappropriation at any stage. Escalating consumer concerns about food safety, processing, distribution, and sustainability underscore the global priority of traceability in the food supply chain.

Aquaculture products undergo eight crucial phases: source identification, hatchery operations, nursery operations, growing techniques, harvesting, processing, market distribution, and consumption. The intricate nature of this process introduces opportunities for fraudulent activities and misappropriation within the aqua supply chain, making effective management and traceability challenging.

Recognizing the immense potential of this sector, it becomes imperative to regulate the environmental footprint of aquaculture activities. The adoption of traceability emerges as a pivotal solution, ensuring the sustainability, transparency, and integrity of the entire sector through reliable product information. A product marked by social responsibility not only translates into higher profit margins but also enhances customer loyalty and improves brand reputation.

Traceability systems, grounded in cutting-edge technologies such as blockchain, Internet of Things (IoT), Wireless Sensor Networks (WSN), and Radio-Frequency Identification (RFID), offer reliability from production to consumption. Blockchain, in particular, proves instrumental in addressing traceability challenges by integrating fish farmers, fishers, and all stakeholders. It facilitates the collection of specific data on environmental impact, feed, growth, and fish health — critical factors for sustainable production. The application of blockchain in supply chain management effectively ensures traceability from the upstream, crucial for combating disease outbreaks and curbing the use of prohibited chemicals. Successful large-scale implementations, such as the IBM Food Trust in countries like Norway and Ecuador, highlight the potential of digital technologies in enhancing traceability. Each shrimp has an identifier, which is applied through blockchain. Anyone can follow the full journey of the life of the shrimp through the supply chain. However, challenges persist, especially at the small-scale farmers' level in Asia, where the dispersion of hatcheries, farms, and processors complicates full traceability implementation. Further efforts are needed to develop this sector sustainably, considering the diverse and widespread aquaculture landscape across India.

### *5.9 Protecting Coastal Ecosystems*

Between the years 2000 and 2020, the primary direct drivers of global mangrove loss were aquaculture development (27 percent) and natural retraction (26 percent), with additional contributions from conversion to oil palm (8 percent), rice cultivation (8 percent), and other forms of agriculture (12 percent)[26]. In the crucial region of Southeast Asia, home to the world's largest expanse of mangroves, it is imperative to persist in addressing the land-use drivers of mangrove loss. To preserve the remaining mangrove forests, agricultural development should be strategically directed[26].

Environmental challenges associated with shrimp aquaculture encompass mangrove and wetland loss due to pond conversion, the gathering of wild post-larvae and broodstock, the utilization of fishmeal in shrimp diets, the spread of shrimp diseases, impacts on water quality and salinization, and the application of chemical substances, including antimicrobials. Recognizing the unsuitability of mangroves for semi-intensive and intensive shrimp farms, recent trends in India have seen shrimp pond expansion on higher land away from mangrove areas. Traditionally, only extensive shrimp farms were situated in low-lying coastal wetlands, but the preference has shifted to supra-tidal land (above the maximum tide level). This shift is attributed to cost-effectiveness in pond construction, improved drainage, and soils more conducive to intensive culture.

Mangrove areas are deemed unsuitable for shrimp culture due to the alkaline water conditions required for optimal shrimp growth, coupled with the inherently acidic nature of soils in mangrove areas. The strict environmental laws protecting wetlands in India further complicate aquaculture activities in such regions. Consequently, the contribution of aquaculture to mangrove areas is minimal compared to the burgeoning activities of the growing urban coastal population and related anthropogenic factors in India.

## 6. Conclusion

Antimicrobial Resistance (AMR) in aquaculture, particularly in the context of Indian shrimp farming, emerges as a critical and complex challenge with profound implications for public health, environmental sustainability, and the economic viability of the shrimp industry. This study, titled "AMR in Aquaculture: Enhancing Indian Shrimp Exports through Sustainable Practices and Reduced Antimicrobial Usage," has delved into multifaceted dimensions of this issue, aiming to not only uncover the underlying causes and manifestations but also to propose actionable strategies for mitigating AMR risks.

### *The Global Scenario of AMR in Aquaculture*

As we conclude this study, it is imperative to recognize the global significance of AMR in the aquaculture sector. With the exponential growth of aquaculture to meet the escalating demand for seafood, the use of antimicrobials has become pervasive due the increase in disease burden, leading to the emergence of resistant strains of bacteria. The interconnectedness of aquaculture systems, environmental factors, and the health of aquatic organisms highlights the urgency of addressing AMR on a global scale.

### *Indian Shrimp Industry Dynamics*

Zooming into the Indian shrimp industry, the study has illuminated the intricate dynamics that contribute to AMR. From the historical context of disease outbreaks to the current practices of antimicrobial usage, the sector faces a delicate balance between meeting production demands and ensuring the long-term health of shrimp populations. The sheer economic significance of shrimp exports from India underscores the need for sustainable practices that safeguard both environmental and human health.

On the supply side, diseases continue to be the primary challenge to the productivity and profitability of shrimp farming in India. On the demand side, marketplace diversification especially retaining the lost EU market is high on the list of requirements as more than half of India’s shrimp goes to the United States and about one-quarter to China. To reduce the overdependence on these two markets, India needs to increase its market share in other markets, particularly the European Union and Japan, each of which accounted for nearly one-third of India’s exports until 2012-13, which was lost majorly due to presence of banned antimicrobials. This even becomes more significant as economic recession in US can hugely impact global shrimp prices as consumers tend to avoid buying of costly protein, especially shrimps.

### *The Role of Sustainable Practices*

A central theme that resonates throughout this study is the pivotal role of sustainable practices in mitigating AMR risks. Sustainable aquaculture does not only involve responsible use of antimicrobials but extends to habitat preservation, water quality management, and ethical considerations in the industry. It is encouraging to note that the Indian shrimp industry, despite historical challenges, is gradually shifting towards sustainable practices nudged on by government policies. The adoption of best management practices (BMPs), improved disease detection, and a focus on hygiene and farm management all contribute to creating a more resilient and responsible industry.

### *Challenges and Opportunities in Sustainable Aquaculture*

However, the journey towards sustainable aquaculture is not without its challenges. The expansion of shrimp ponds, often at the cost of coastal ecosystems, exemplifies the delicate balance between economic interests and environmental conservation. Addressing this challenge requires a comprehensive approach, involving regulatory frameworks, community awareness, and a shift in industry practices. The study emphasizes that coastal ecosystems and mangroves, once considered incompatible with shrimp farms, must be preserved as vital ecosystems that contribute to biodiversity, storm protection, and water purification.

### *The Importance of Traceability and Certification*

One of the key recommendations emerging from the study is the significance of traceability and certification in promoting responsible aquaculture. The ability to trace the origin of shrimp products throughout the supply chain ensures transparency and accountability. Certification programs, such as the Global Aquaculture Alliance Best Aquaculture Practice (GAA-BAP), play a crucial role in incentivizing and recognizing sustainable practices. Embracing these programs through government and industry support, not only elevates the industry's image but also assures consumers of the ethical and ecological integrity of the shrimp they purchase.

### *Innovations and Technological Solutions*

The conclusion of this study acknowledges the role of technological innovations in addressing AMR in aquaculture. The integration of blockchain, the Internet of Things (IoT), and Radio-Frequency Identification (RFID) technologies can enhance traceability, data collection, and overall efficiency in the shrimp supply chain. As the industry moves towards a more digitalized future, these innovations become instrumental in achieving sustainable and responsible aquaculture practices.

### *The Call for Collaborative Action*

It is evident that tackling AMR in Indian shrimp aquaculture requires a collaborative effort from multiple stakeholders. Government bodies, regulatory agencies, industry players, researchers, and consumers all play crucial roles in the journey towards sustainability. The study emphasizes the need for continued research, adaptive management strategies, and the establishment of clear regulatory frameworks that align economic interests with environmental and public health priorities. The blue economy, where shrimp aquaculture is a major contributor, can help India achieve national goals for socioeconomic growth.

### *Looking Ahead*

In conclusion, the study envisions a future for the Indian shrimp industry where sustainable practices are not merely a choice but a necessity. The industry needs to look to enhance the domestic market presence. A future where the economic success of shrimp exports goes hand in hand with environmental stewardship and societal wellbeing. The challenges presented by AMR in aquaculture are formidable, but the opportunities for positive change are equally vast. The transition to sustainable practices is not only an investment in the longevity of the industry but a commitment to preserving the delicate balance of our aquatic ecosystems and safeguarding the health of global consumers.

As the Indian shrimp industry charts its course forward, guided by the principles of sustainability and reduced antimicrobial usage, it is poised to become a global exemplar in responsible aquaculture. Through continued collaboration, innovation, and a shared commitment to best practices, shrimp aquaculture can overcome the challenges of AMR and pave the way for a more resilient, ethical, and prosperous future.

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## FIGURES

**Chapter 1:**
Figure 1: The State of World Fisheries and Aquaculture 2022 (2022). Towards Blue Transformation. Rome, FAO. In FAO eBooks. https://doi.org/10.4060/cc0461en

Figure 2, 3 & 4: The Marine Products Export Development Authority, Ministry of Commerce and Industry, Government of India, Annual Report 2021-22. Downloaded from https://mpeda.gov.in/ on 22.10.23

**Chapter 4:**
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