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Biotech Promotion Policy and Technology Transfer Issues: Evidences from Aquaculture and Marine Biotechnology

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Abstract: The paper elaborates upon the judicious utilization of aquatic resources for bioprospecting of useful products and processes and development of novel technology packages for entrepreneurs and industry. Some of the leads of national institutes working in fisheries and marine sector on technology development, dissemination and extension through the Department of Biotechnology (DBT) support have been highlighted apart from technology packages and patent leads. The technology packages adopted by the end users are responsible for the flourishing economy of the sector. Various strategic approaches in technology generation, product development, commercialization, patents and novelty protection have also been suggested.

Keywords: Technology Transfer, Aquaculture, Marine Product and Process Development, Patents, Biotechnology Policy, India

Introduction

In the present scenario, when exponential advancements in biotechnology are taking place, a large consumption market has already been created in biotech products developed locally or made available through imports. These include primarily the products of old biotechnologies, although there is a shift of preference visible in the marketing of modern biotech products too, especially in biopharmaceuticals, agriculture, industrial products, environmental bioremediation processes and aquaculture and marine sector. The indigenous consumption of biotech products has increased the scope of trade as well as of new investments in most of the biotech sectors. However, the products required for human and animal healthcare have

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dominated the scene due to their wider applications. It is estimated that the total turn over of recombinant biotech products produced locally is about Rs. 600 million while for healthcare products the total consumption is in the range of Rs 2500 million.

There is ample potential in the country's aquatic resources both in freshwater and brackish water for augmenting fish and shrimp production using aquaculture, thereby increasing foreign exchange earnings through shrimp export and generating adequate employment opportunities besides increasing farmer's income. Ever increasing population, its food requirement, besides the problem of malnutrition have necessitated an optimal use of renewable resources in order to increase food production from them by adoption of new technology. Aquaculture and marine biotechnology is one such area in the fishery sector where food production has been increased from the aquatic resources, not fully utilized hitherto by adopting newer technology. The marine sector can contribute a large revenue through emphasis on research and development.

The Indian Government has promoted modern biotechnology in all areas of scientific endeavours. Starting from development of infrastructure, strengthening of extramural R&D research in Indian institutions and by generation of skilled manpower in biotechnology the state has helped to foster the development of biotechnology products and processes as well as to transfer the institutionally developed technologies and indigenous knowledge to industry. Since its inception the Department of Biotechnology (DBT) has played a very important role not only in the development and transfer of indigenous technologies to industry, but has also played a pivotal role in the promotion of biotechnology in the country, in the protection of Intellectual Property Rights and in ensuring the implementation of biosafety regulatory issues during the developmental process.

There is a slow but steady progress in the shifting of preference in the use of machinery for the development and production of biotech products. Among the developments in biotechnology in modern times, Genetically Modified Organisms (GMOs), involving microbes, plants and animals providing various molecules for use in pharmaceuticals, agriculture, food as well as the environmental bioremediation and management, are noteworthy. The successful commercialization of technologies is highly rewarding, as the innovative biotech products have immense potential to generate profits and returns on investments,

and thus impact the fortunes of companies in a very short span of the business period. The role of government agencies in promoting this emergent area is very important for the promulgation of various proactive policies, incentives and support to the biotech sector.

Promotion of Biotechnology through DBT

The growth of biotechnology in the country can be traced to the endeavour of the National Biotechnology Development Board in the Department of Science and Technology, Ministry of Science and Technology. It was not until late 1980s that the government's initiative in industrial policy change and the linked process of biotechnology development in the country gathered momentum with the establishment of an independent DBT by the Union Government. The main thrust of DBT has been to build competence in research institutions, provide industry-institution research collaborations to benefit society at large and stimulate international collaboration in socially relevant research in public-funded institutions. The initial emphasis in applications had been to promote traditional biotechnology. From 1987 onwards, certain specific areas have been taken up by the DBT for focussed development. These include the health care area, the development of immunodiagnostics, vaccines, recombinant DNA molecules, targeted drug delivery systems, microbial strain improvement and process optimization in antibiotics, and enzymes and bioactive molecules. In agriculture, apart from a focuss on crop plants, mass multiplication of elite planting materials by tissue culture techniques, development of hybrid high yielding seeds, region and crop-specific biofertilizers and biopesticides, and the development of transgenic disease-resistant and stress-tolerant plants were specifically taken up. In addition, in husbandry practices apart from perfection of embryo-transfer technology to develop high yielding milching animals like cattle and buffaloes, the major focus was on aquaculture and marine sciences and biotechnology. Development of recombinant organisms with high efficiencies of substrate conversion were emphasized under industrial biotechnology. Use of stress-tolerant microbial concentrates are being attempted for treating liquid effluents; concurrently planting of forest species of plants raised through plant-tissue culture are being attempted under environmental biotechnology.

During the past decade the strategies have been reoriented to promote modern biotechnology in preference to traditional practice.

Through a multidisciplinary approach, the DBT has been instrumental in encouragement of biotech research by teaming up with various other scientific ministries, for example, Health and Family Welfare, Environment and Forests, Agriculture, Commerce and Industry, Small Scale Industries and Agro and Rural Industries, Department of Science and Technology, Department of Scientific and Industrial Research, Council of Scientific and Industrial Research, Indian Council of Medical Research, etc. This has helped in the promotion of biotechnology research and establishment of many foci in the country for research in modern biotechnology, medicine and biology apart from promotion of bioinformatics. In a network approach the DBT has been in close coordination with all the scientific agencies while 5,000 to 6,000 scientists interact with the Department every year in various capacities. Such a wide ranging interaction with scientists, technologists and engineers could promote biotechnology development in the country substantially. The DBT has consolidated a number of programmes in the last decade which include demonstration, popularization and extension activities and also the creation of awareness about biotechnology amongst the general public. Aquaculture and marine biotechnology and bioresources are important areas for demonstration and the training programme. The Department has also established international collaborations with a large number of countries for the indigenous promotion of biotechnology. The major emphasis has been on multi-centric multi-agency programmes.

Technology Development, Transfer and Commercialization

The DBT has a proactive interaction with institutes engaged in developing biotech products and processes and fills the market information and requirements gap by means of continuous interaction between scientists of the institutes and with industry for technology packaging, apart from reorienting such teams to work with the industry. The logistical support of the DBT has enabled many ill-equipped institutions to develop technologies which have been validated independently as per their claims. This has helped the academia and industry partnership in appreciation of each other's problems and a search for quicker solutions in the common goal of technology development, transfer and commercialization issues. Incentives have been provided to the ground workers and inventors engaged in the technology development by the sharing of the proceeds as well as

protection of their intellectual property. The product developmental work is being protected increasingly through the patent system while the awareness-building programme in the IPR issues by the DBT has started paying dividends. The industry had so far inadequate scientific capabilities to absorb and improve upon the technology it received which is now possible with the upgradation of their R&D facilities and infrastructure. The role of technology managers persently in catalyzing the development and transfer of technologies is now well appreciated both by the institutions as well as the industry with its proven usefulness to the society, which has gone a sea change.

Government Policies and Biotech Industry

The development of regionally-dispersed industries with manufacturing capabilities but without any perception of scope for their expansion and diversification adversely affected the industrial growth and lowered the production. This has also affected the foreign exchange reserves of the country. The central government, with the objective of developing a globally competitive industrial sector consequently took corrective measures by promulgating newer policies of planning, control of industrial capacities, regulation of locations of industrial units and approvals for foreign collaborations. Further, it adequately modified the previous developmental policies from July 1991 onwards. To attract foreign investors the Ministry of Industry further liberalized the licensing policy through the establishment of the Foreign Investment Promotion Board (FIPB) during 1997-98 and the Foreign Investment Implementation Authority (FIIA) in 1999 to facilitate the flow of foreign investment in the country. The biotech sector also got a boost with the liberalized policy and benefitted from an automatic registration process in industrial licensing. There is a 100 per cent rebate on R&D expenditure by a company and 125 per cent rebate on contract research through a public-funded R&D institution. These policies infused the corporate sector to set up their own R&D units to develop own technologies. Today, 100 per cent foreign equity investment is possible in all industrial sectors. In the pharmaceutical sector, 74 per cent foreign equity investment is automatic and over 74 per cent equity is also considered by the Union Government on a case-by-case basis to promote this sector. This has led to the establishment of technology parks in various sectors especially in knowledge-based industries such as drugs and pharmaceuticals, information technology including

biotechnology. It is estimated that there are over 55 research and development laboratories in the public sector and that more than 20 are engaged in conducting research in the frontier areas of biotechnology in which the government has invested over Rs.10,000 million for creating R&D infrastructure and skilled manpower. The private sector that cannot invest large amounts to create their own sophisticated infrastructure to perfect their technologies can team up with the public labs for collaborative research. Thus the current liberalized policies have provided the necessary impetus to the entrepreneurs to set up substantial and competitive industrial units in the country with the necessary support from the union government. The government has increased greatly its proactive role for the industry in the matters of technology selection, technology evaluation, technology perfection and technology absorption by extending necessary clearances. These liberalized policies have made the market fairly competitive especially with the inflow of foreign direct investment. The indigenous research and development capabilities under the changed scenario have been improved to compete with the imported technologies.

Aquatic Resources: Stock and Utilization

In India, tanks and ponds occupy 2.85 million hectare of land, lakes and reservoirs occupy 2.05 million hectare of land, and there are 0.78 million hectare of derelict water bodies such as swamps, beels, ox-bow lakes, etc., 0.17 hectare km length of rivers and canals; and about 1.42 million hectare of brackish water land, lakes and estuaries. These resources have great potential. The estimated potential for fish production in the country, both marine and inland, is about 8.4 million tonnes comprising 3.9 million tonnes of marine and 4.5 million tonnes of inland fish production. Against this, the present fish production is about 6.18 million tonnes consisting of 3 million tonnes of inland and 3.18 million tonnes of marine. The annual production can increase if the available techniques are fully adopted and transfer of know-how and production of material inputs properly organized. In terms of cultivable species of fish/shellfish, the components are diverse to suit the varied ecological conditions of different water bodies as also to meet the regional preferences. With technologies available for breeding and culture of catfishes (*Clarias batrachus, Heteropneustes fossilis*) and murrels (*Channa* spp.) organized culture could be undertaken. Fish species like mahseer

(*Tor* spp.), hilsa (*Hilsa ilisa*), trout (*Salmo trutta*), *Ompok* spp., non-airbreathing catfishes like *Wallago attu*, *Mystus seenghala*, *Mystus aor* and *Pangasius pangasius* are being studied for incorporation into commercial culture practices. These rearing systems require various forms of intervention such as stocking, feeding, protection from predators, diseases, etc. and involve farm management. India has been paying greater attention to the aquatic resources by assigning importance to aquaculture during the last 2-3 decades. Aquaculture has acquired the status of one of the fastest growing sectors for increasing food production owing to the introduction of scientific fish/shrimp farming and artificial propagation for production and supply of quality seed. By virtue of this, India today occupies the second position, next only to China being the first in global aquaculture production, whereas in fish production it occupies the forth position. India earns over US$ 1.4 billion through its seafood export earning.

The Central Institute of Freshwater Aquaculture (CIFA) at Bhubaneswar, Orissa, the premier Institute for freshwater aquaculture under the Indian Council of Agricultural Research (ICAR) in the country, has over the years developed several technologies and packages of practices in different aspects of freshwater aquaculture relating to carps, catfishes, prawns and molluscs. With extension programmes and economic incentives during the last decade, fish culture that was once restricted to the Eastern states of West Bengal, Orissa and Assam, has become a major economic farming activity in states like Andhra Pradesh which has become an example for the rest of the country to emulate. With innovative practices like high stocking densities, water circulation and aeration, provision of feeds, etc. the production rates of 8-10 t ha yr have been achieved in the region as against the national average of 2 t ha yr. Thus, states like Andhra Pradesh, Punjab, Maharashtra, Haryana, Gujarat, etc. are taking up fish culture on a large scale, many with the objective of exporting the produce to fish-consuming states.

Aquaculture and Fish Breeding Technologies

While the technologies of induced carp breeding and composite carp culture gave a fillip to the freshwater aquaculture industry in the country during the sixties and the seventies, several new components are being added in recent years, with the aim of optimizing the productivity levels. The practice of fish culture is also being employed for treating wastewaters and agro-based industrial effluents like distillery wastes.

This adds a new dimension to the practice of aquaculture that is eco-restoring, environment-compatible and economical. Being basically a carp country, both the indigenous and exotic carps, viz., catla, rohu, mrigal, silver carp, grass carp and common carp account for a bulk of the production. Several other candidate species include *Labeo calbasu, Labeo fimbriatus, Labeo gonius, Labeo bata, Puntius pulchellus, Puntius kolus, Puntius sarana, Cirrhinus cirrhosa* and even minor carps that fetch a high price in the markets.

Different carp culture systems that have been standardized with minimum achievable production rates are composite carp culture (4-6 t/ha/yr), sewage-fed fish culture (3-5 t/ha/yr), weed-based polyculture (3-5 t/ha/yr), biogas slurry-fed fish culture (3-5 t/ha/yr), integrated fish farming with poultry, pigs, ducks, horticulture, etc. (3-5 t/ha/yr), intensive pond culture with feeding and aeration (10-15 t/ha/yr), pen culture (4 t/ha/yr), cage culture (10-15 kg/m^2/yr), and running-water fish culture (20-25 kg/m^2/yr). Intensification of culture systems is being standardized in pond culture, cage culture, pen culture and running-water fish culture/flow-through systems. A significant achievement in this direction has been the production of 15 tonnes ha yr in carp culture with high stocking densities, biofertilization, supplementary feeding, aeration and water replenishment.

The techniques of breeding and seed rearing in cases of catfish species, viz. Magur, *Clarias batrachus*; Singhi, *Heteropneustes fossilis,* having been standardized, their culture is increasingly being adopted. With standardized breeding and hatchery management practices in cases of freshwater prawns, *Macrobrachium rosenbergii* and *M. malcolmsonii,* high density nursery rearing and semi-intensive culture with a targetted production of 5 t ha yr with the giant freshwater prawn are envisaged. Prawn seed production in synthetic seawater and salt solution and seed production throughout the year under controlled conditions have been achieved in case of the riverine prawn.

Efforts in recent years have been directed towards increasing productivity from the existing systems as well as countering the problems emerging with the intensification of aquaculture practices. Advancement of carp maturity to the month of March over the prevailing period of June-July and breeding of the same individual four times a year with gaps of 45 days between two successive breedings have made it possible to provide fish seed almost throughout the year. Successes achieved in cryopreservation of

spermatozoa have eliminated the need for maintenance of male broodstock and attempts at cryopreserving the ova and the embryos are presently underway. With alternatives to crude pituitary gland extract available for induced breeding, sequencing and synthesis of GnRH are being carried out in order to evolve an indigenous replacement for the imported products. Having produced integeneric hybrids of carps as also gynogens and androgens, the application aspect pertains to the sterile triploid grass carp that could be stocked in irrigation canals for control of aquatic vegetation. Genetic assessment of riverine stocks of rohu for selection is an ambitious programme that would provide superior stocks with sustained vigour and an improved rohu is about to be released.

Production of cultured freshwater pearls has been a major achievement in recent years and is a step towards diversification of commercial aquaculture. With different stages of collection and conditioning of freshwater mussel, *Lamellidens* spp., preparation of mantle tissue, surgical implantation of graft and appropriate nuclei in the internal organs of the recipient mussels, post-operative care and culture before harvesting of pearls having been standardized, different kinds of pearls like regular, irregular, half-round pearls and pearl images have been produced.

The investigations of nutritional requirements of fish/shellfish species take into consideration the specific requirements of amino acids, vitamins and minerals for formulations of balanced diets, while commercial diets like the one for carp feed, CIFACA have been released. Apart from investigations on the microbial pathogens and parasites, chemical formulations like CIFAX have been prepared for treatment of epizootic ulcerative syndrome in fishes. Aquaculture biotechnology comprising aspects of genetic improvement of fish/shellfish, synthesis and use of hormones, biofertilization, bioprocessing or organic matter, serodiagnostics and immunoprophylaxis, etc. is expected to play a major role in improving the aquaculture productivity in the years to come.

With concerns regarding pollution control and environmental management, it is necessary that farming practices incorporate these aspects in management. It may be mentioned that freshwater aquaculture is not only highly compatible with any of the farming systems, crop-based or livestock-based, but also that these systems could receive, process and treat a number of organic wastes, mainly domestic

sewage. This aspect needs to be exploited to a greater extent to develop resource recovery-based waste treatment measures through aquaculture. In Indian freshwater aquaculture, sustainability of the production system is of a high order. Being organic-based it has to be the watchword in the planning of development programmes.

Linkage Development and Technology Transfer

Strong linkages between research organizations and development agencies are highly essential not only to transfer the technologies from the laboratory to the field, but also to obtain a feedback on the prevalent problems and technology adoption levels. Weak extension machinery has often been identified as the case for low production levels (see Table 1). With the country having varied agro-climatic zones, it is necessary that the technologies are subjected to multilocational testing and suitable modifications are incorporated in the packages of practices in different regions. It is relevant to mention here that the CIFA, Bhubaneshwar is presently developing a national freshwater aquaculture development plan for the country on a district basis, to serve as a blue print for enhancing aquaculture productivity from the present national mean level of 2 t/ha/yr to 3-5 t/ha/yr. Annex 1 provides a detailed list of such initiatives.

Through the Mission Mode programme implemented in coastal and inland states, infrastructure in terms of prawn complex comprising hatchery, feed mill and farming system was set up for freshwater prawn, *Macrobrachium rosenbergii* and brackish water species. This is being used for regular seed production. A multi-species prawn hatchery was established, both for penaeid and non-penaeid species and different grades of feed were produced to stock the ponds and reservoirs and supply to the end users. A freshwater prawn production of 1.5 to 2.0t/ha was achieved from the grow-out culture operation. Farmers and the entrepreneurs adopted this technology.

Protocol for Technology Transfer and IPR Issues

The Ministry of Science & Technology, Department of Biotechnology, Government of India has brought out guidelines explaining the detailed protocol on technology transfer and IPR-related issues for the benefit of R&D institutes, scientists and project investigators (PIs). This is to enable such pioneers to file patent application for their invention and to motivate transfer of the technology for commercialization. The benefits of this

Table 1: Technologies Developed under Aquaculture and Marine Biotechnology Programme

S.No.	Technology	Institute Developed	Industry Procured
1.	A heat-killed whole cell vibrio vaccine	College of Fisheries, Mangalore	Mangalore Biotech Laboratory, Mangalore
2.	To overcome the problem of viral diseases in shrimp aquaculture and for simultaneous detection of WSSV and MBV, development of highly sensitive method. "Combi kit - WSSV, MBV" a test kit, for specific detection of pathogens	Department of Microbiology, UAS, College of Fisheries, Mangalore	Mangalore Biotech Laboratory, Mangalore
3.	Polyclonal antibody based immunodiagnostic kits for detection of different bacterial pathogens in finfish and shellfish	Central Institute of Fisheries Education	GlaxoSmithKline Pharmaceuticals, Mumbai
4.	Polyclonal antibody-based immunodiagnostic Assay for the detection of white spot syndrome virus	Anna University, Chennai and CAH Abdul Hakeem College, Malvishram	Posiden Biotech, Chennai
5.	Bioreactors for prawn hatchery	Cochin University of Science and Technology	M/s Oriental Consultants, Coimbatore
6.	Monoclonal Antibody-based Diagnostics – RapidDot kit	College of Fisheries, Mangalore	Under Commercialization

Source: Compiled by the Author.

process learning is the access to rewards through royalties for the inventions made in various sectors of biotechnology including aquaculture and marine biotechnology. There are several patents filed in this area (see Annex 2).

(i) Benefits to Implementing Agencies

With the protocol to be followed, the funding agencies are encouraging the institutes to protect their inventions on the IPR generated through R&D efforts. It must be ensured that the patent is assigned in the name(s) of the inventor(s) and that this is entered in the register of patents as the proprietor of the patent. Necessary steps are to taken for commercial exploitation of the patent on an exclusive/non-exclusive basis and to permit the investor(s) to retain the benefits and earnings out of IPR and also to determine the share of the inventor(s) and the other person(s) from the actual earnings, which shall be limited to one third of the actual earning.

(ii) Benefits to Institutions and Industrial Concerns

IPR may be generated through joint research by institute(s) and industrial concern(s) through joint research owned by them, as mutually agreed by all the parties through a written agreement. The institute and industrial concern may transfer the technology to the third party for commercialization on an exclusive/non-exclusive basis and the third party can get the product, exclusively licensed to market and be manufactured in India. Joint owners are allowed to share the benefits and earnings arising out of commercial exploitation of IPR. The institute determines the share of the inventor(s) and other person(s) from such actual earnings, which should not exceed one third of the actual earnings. The institute shall create a patent facilitating fund, in which not less than 25 per cent of the earnings through technology transfer/ IPR and the same can be utilized by the institution for innovation and the filing of new patent applications, protecting their rights against infringements for creating awareness and building competence on IPR and related issues.

(iii) Benefits to the Funding Agencies

Institution(s)/agencies, where the funding is being provided, are required to provide details of the patent obtained, benefits and earnings out of the IPR and the turn-over of the product periodically to the funding ministry/department. The funding agency can also be kept

informed of the market potential of the product and its sustainability in the longer run. The receiving agencies shall keep the funding agencies informed of the utility of the funds provided, the viability and the outcome. The institute shall acknowledge the DBT for the patent obtained/technology transferred. The government shall have a right to a royalty free license for the use of the Indian patent for the purposes of the government of India. The guidelines are being reviewed and revised form time to time.

(iv) Patent Facilitation Cell

A single window awareness-cum-facilitation mechanism is also functioning in the Department of Biotechnology. This creates awareness and understanding on IPRs for the benefits of scientists and researchers. It also organizes workshops, seminars, conferences, etc. at all levels and for introducing patent information as a vital input in the process of formulation of R&D programme in biotechnology and provides patenting facilities to biologists and biotechnologist in the country for filing Indian/foreign patents. The nodal agency also keeps a watch on developments taking place in the area of IPR and addresses various important policy issues for scientists and the biotech industry. The patent facilitation cell also encourages the PIs to submit applications in proforma for examining their inventions and other IPR-related issues. National agencies like the National Research Development Corporation (NRDC) and Bioconsortium India Limited (BCIL) or any other attorney of the approved DBT panel are being appointed on a felt need basis for assessment and advocacy of the patents for filing, both nationally and internationally. The DBT committee/attorney, after assessment, recommends the patent for filing/granting in India, in Asian countries, and globally. The fee/ consultancy of the application/attorney is met by DBT. The DBT has filed so far more than 100 Indian/international patent applications, out of which a dozen patents have been granted.

Technology Transfer Options Under Joint Collaborative/ Bilateral Projects

The time has come to strengthen R&D in aquaculture and marine biotechnology through judicious efforts and joint collaborative R&D projects. The projects could include the following: breeding and seed production programme in non-conventional species, namely, groupers, seabass, mullet, marine ornamental fishes, penaeid and non-penaeid

prawns, crabs, lobsters and mollusks, etc.; culture of live-feed organisms including Artemia cultivation; programme on selective breeding and development of disease-resistant brood stock; diagnostics and vaccines; marine genomics and transgenics; and cage culture technology in marine species (feed formulations and disease management). The establishment of well organized R&D facilities along with provision for transfer of technology and extension system for the above is the need of the hour. Prior to technology transfer, its consistency, economic viability, social acceptance and environment consciousness have to be critically reviewed. It is difficult to identify and eliminate the evils of aquaculture without setting up standards of transfer of proven technology. A new institute in ICAR or the government sector can be formed to carry out R&D connected with seawater-based aquafarming, employing skilled technical manpower with sound financial support for effective technology transfer, technology development, joint IPR and commercialization. Exchange of knowledge through joint workshop and training of scientists

It expected that in future many technologies will be developed in the Indian R&D institutions and that these would be transferred to the industry with their absorption and commercialization. Success in the commercialization of such technologies may be strengthened by learning from our failures and by taking corrective steps in all sectors of technology development, its transfer and deployment through commercialization. The Department has been playing a responsible proactive role for the promotion of biotechnology in the country since its inception and would continue its efforts. DBT has also set a good standard in venturing the aquaculture technologies for commercialization through R&D investments.

Conclusion

India has a long coastline (8129 km) including shelf area and huge marine and brackish water resources. Natural product development for marine resources are very promising, especially for drugs and pharmaceuticals, novel enzymes and chemicals, bio-molecules, biomaterials, products of food and industry applications, bioremediation and probiotics, etc. As the presently available drugs are reported to be ineffective due to development of multi-drug resistance, research may think of a new source, which is marine-based and could be a potent and viable option. By adopting the modern technologies

for fisheries, production will be increased manifold. This will also ensure improvement in the socio-economic conditions of the targeted beneficiaries and also help them to generate additional income for their livelihood. Realization of the potentials of the freshwater aquaculture sector would greatly add to the nutrition, employment and economy. The sector requires further support in terms of extension for technology transfer and financing of core activities.

Aquaculture and marine biotechnology is a major area for promotion, as it has a large scope for product and process development. Numerous projects are being funded by an independent Task Force set up by the DBT. The development of culture technology in new aquaculture species and the factoring in of techno-economic viability consideration also forms part of the programme. This is relevant for its direct application to society through technology development, dissemination and adoption for the benefit of coastal and inland people. Various natural product development projects are being supported through funding mechanisms after rigorous review and monitoring.

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Annex 1: Technologies Developed

- Culture technologies for tiger shrimp, freshwater prawn and carp polyculture for higher production.
- Freshwater pearl production.
- Hatchery technology for clam, mussel and freshwater prawn seed.
- GnRH analogues as fish spawning agents.
- Process for EPA/DHA production using marine fish tissue and oils.
- Process for production of *Tachypleus amoebocyte lysate* (TAL).
- Bio-conversion feed for aquaculture.
- Process know-how for fermented fish viscera and poultry intestine silage.
- Feed technology for semi-intensive/intensive prawn aquaculture
- *Eucheuma* seaweed cultivation.
- A scale-up process for production of bacteriological grade agar.
- Immunostimulants for shrimp.
- Diagnostic kit for white spot shrimp virus.
- Monoclonal antibody-based diagnostic kit for white spot shrimp virus.
- Diagnostics for detection of fish pathogens for *Aeromonas*, *Pseudomonas*, *Vibrio* and *Edwardisiella* spp.
- Bioreactors for penaeid and non-penaeid shrimp hatcheries.
- A chemical mixture for EUS treatment in fish.

Annex 2: Patents Developed and Filed

- Process for synthesis and formulation of GnRH - a technology for fish spawning agents.
- Production of PUFA enriched artemia diet for shrimps.
- Novel process for the extraction of antifouling compounds from the horseshoe crab.
- Bioreactor for nitrifying water in prawn hatcheries.
- Development of oligonucleotide primers for detection of White Spot Shrimp Virus (WSSV).
- Sequences of a portion of the genome of whitespot syndrome virus of shrimp.
- Method for production of carrageenan and liquid fertilizer from fresh seaweeds.
- Improved process for producing enriched EPA concentrates.
- Process for preparation of fermented silkworm pupae silage useful as an ingredient in animal feeds.
- New and improved process of preparation of *Tachypleus Amoebocyte Lysate* from Indian Horseshoe crab, *T. gigas*.
- Designing and fabrication of an indigenous fermentor for nitrifying water in prawn hatcheries.
- Transformation of the solution phase heme-Histidine rich protein based antimalarial drug discovery method to the solid phase.
- A new molecule for cardiac development promoting activity.
- Cardiac development promoting activity of perivitelline fluid of embryos of Indian Horseshoe crab, Tachypleus gigas (Müller).
- Development of aqueous extracts having anti-WSSV property from mangrove plants endemic to Indian coastal zones and their administration as prophylactics to protect shrimps from the virus.