

# BIOTECHNOLOGY IN THE EXPLOITATION OF MARINE LIVING RESOURCES OF INDIA

A H PARULEKAR

National Institute of Oceanography, Dona Paula 403  
004, Goa, India.

*Abstract.* The age-old concept, that oceans generate inexhaustible living resources, warrants a fresh look towards the multiple use of self-generating marine resources for food, drugs, industrial raw materials, recreation and in the protection of environment. A plausible solution is the use of genetics, biochemistry and systems engineering under a broad gambit of biotechnology, for improving and increasing the yield from marine biota. Four distinct areas discernible for the possible use of biotechnology, namely seafarming; pharmaceuticals and bioproducts control of marine biofouling and containment of marine pollution, are reviewed. Advantages, constraints and scope of marine biotechnology, in the context of developing and underdeveloped countries are highlighted.

*Keywords.* Biotechnology marine living resources; seafarming; marine pharmaceuticals; biofouling.

## 1. Introduction

The concept of bioindustries in the exploitation and utilization of marine living resources is in vogue in India as elsewhere, for centuries together. The traditional practice, having the sole objective of food from the sea, involves wild hunting - capture fisheries - with primordial orientation to modern technological concepts. However, in the post-independence era, a moderate level of technological orientation and application in the field of location of fishable resources; propulsion of fishing crafts; performance oriented fishing gears and minimizing post-harvest losses, have been achieved.

Such technological inputs have resulted almost in a four-fold increase in the marine fish production of India. This singularly important result oriented process has rekindled the interest, and enhanced the aspirations of user community in coupling the technological advances with the traditional methods of capture fisheries.

Despite the so-called promises, the biotechnology has to offer in the exploitation and development of marine bioresources, the attention received and the progress, so far achieved in marine biotechnology are rather unmatching. However, the systems approach relevant to conversion of raw materials through biological transformations into useful products will prove to be the harbinger of vast opportunities, inherent with the marine biotechnology (Colewell 1984). The integration of genetics, molecular biology, biochemistry, engineering and material science would increase and diversify marine bioproduct industries; produce new marine based drugs and pharmaceuticals; protect ships and submerged structures from deterioration and clean-up the man-made marine pollution through appropriate biological control.

## 2. Scope and limitations of marine biotechnology

One of the most difficult tasks presently facing the scientists, is how to use the new tool of marine biotechnology, appropriately, for solving the problems related to marine bioindustries. A pitfall in the application of biotechnology, concept and technique, lies in the fact it that offers elegant and expensive solutions to trivial problems (Dibner 1986).

Inspite of limitations, the scope extends to the following four specific and important areas in which the

application of biotechnology promises to make a real difference:  
1. mariculture or seafarming 2. marine pharmaceuticals and biomedical  
3. control of marine biofouling and 4. containment of marine pollution.

The basic approach, for the useful application of technology in potential marine bioindustries, is the genetic engineering which is defined as the application of fundamental knowledge of the molecular basis of biological processes to practical industrial problems involving genetic transformation through cloning (Wilkins 1981). Gene manipulation creates new combination of heritable material by inserting nucleic acid molecules into virus, bacterial plasmids and other vector heritable material which it does not naturally possess but can be recreated through natural propagation. Thus, disease resistant, high yielding strains of economically important marine organisms are feasible by the insertion of new genes or the replacement of defective genes in cells of marine organisms.

### 3. Applications

#### 3.1. Mariculture or seafarming:

The largest industry at the moment having to do with the sea is the production of finfishes, shellfishes and macrophytes. Though mariculture has long been practised as an art, it is only in recent times, that sufficient biological and bioengineering knowledge and an understanding of the social and institutional influences for enabling to translate the art of mariculture by quantification, integration and generalisation into practical commercial technologies, has been envisaged (Ryther 1981).

The slow pace of development of seafarming is largely due to the use of outmoded techniques, reducing the final yield (Qasim 1977). Traditional aquaculture by subsistence farming methods yields 200-500 Kg/hectare and such yields are considered normal (Parulekar and Dalal 1978). However, such production figures, while reflecting on the carrying capacity of the ecosystem, do not give any idea about the potentials. Like, most of the other bioindustries which require critical ecosystem management, the mariculture is extremely site specific and largely dependent upon specific characteristics of an ecosystem. Mariculture production systems require the integration of a large number of variables, some of which are uncontrollable but may be predictable. Though still not well understood, such variables deserve further elucidation in terms of systems engineering criteria (Ryther 1984).

In India, inland and coastal aquaculture productions have increased much more rapidly than the landings from the capture fisheries. This is despite a greater investment in capture fishery sector. By the year 2000 AD, India would be producing seven million tonnes per year through aquaculture (Dwivedi and Dunning 1983). Many marine organisms can now be grown successfully in captivity throughout their life cycle. Moreover, in the third world countries, especially within the tropics where labour is relatively cheap, marine pollution is comparatively less intense and virgin coastal lands are available with a long tradition of seafarming, the mariculture offers good prospects. These advantages outweigh the constraints of technical problems like lack of hatchery techniques and non-availability of high yield, disease resistant strains.

These constraints can eventually be circumvented by the application of genetic engineering. Dominant DNA techniques for the creation of new and improved strains of many if not all, existing and potential mariculture species. These advanced techniques would help to farm new varieties that grow faster and larger; contain more meat and less waste; grow within an expanded range of temperature and salinity; develop disease resistance; have characteristics amenable to mass cultivation and are more efficient in converting food to flesh (Wilkins 1981).

Advantages of marine organisms, as genetically suitable materials, for cloning, polyploidization, gynogenesis, monosex culture and self fertilization lie in the following facts:

- i. Genetic variability in marine invertebrates, like molluscs and crustaceans as also in cold blooded (poikilotherm) vertebrates, like finfishes is significantly higher than in warm blooded or homothermic vertebrates, like poultry and other livestock, which are commonly domesticated. The amount of variability available for genetic manipulation is greater in aquatic organisms than in their terrestrial counterpart.
- ii. Marine organisms, which are still unaltered by artificial selection, possess genetic material, in its pristine state of natural selection. This offers good scope for natural genotypes for appropriate hybridization.
- iii. Sex determination is more plastic in poikilothermic vertebrates and invertebrates of aquatic origin.

With sex reversal and proterandrous hermaphroditism as a characteristic feature of marine invertebrates, production of mono-sex stocks through hormonal control is easier. Also, self fertilization of hermaphrodites or of sex changed females with sperms stored from their male phase, enhances the production of fully inbred lines.

- iv. Fecundity in majority of marine organisms is far more greater than in terrestrial organisms. Thus, the production of a high fecundity strain, through cross breeding is greatly feasible.

Interspecific crosses in aquatic invertebrates and finfishes are often viable and mostly fertile.

With the recent advances in the development of technology of reproduction and rearing of a variety of marine organisms, it is reasonable to look into genetic techniques towards the further improvement of potentially cultivable species. Besides the traditional techniques of selective breeding, inbreeding and interstrain crossing, other procedures include polyploidization, gynogenesis, mono-sex culture and self fertilization (Newkirk 1980). Similarly, many of the seaweeds of commercial importance are characterized by complex alterations of haploid, sexual plants and diploid asexual sporophytic generations. The selective breeding of such variants and the resulting improved growth characteristics of the new high yielding strains of marine plants can immensely help in commercial production. Another approach is tissue culture of pure gametophytic clones (Jackson 1980).

Use of genetic engineering to the mass production of finfish, molluscs, crustaceans and seaweeds, in natural environments and hatchery systems, offer unmatched opportunities. Since, successful seafarming of many species of shellfishes and finfishes at the larval and intermediate stages can be manipulated and their genes cloned, the stage is set for the realization of the potential of genetic engineering for better yields in mariculture (Ryther 1981).

### 3.2 Marine pharmaceuticals and biomedical

There is a long tradition of using marine organisms, as a source of useful drugs and pharmaceuticals for alleviating the human maladies. Some of the best known examples are the following:

Liver Oil and Vitamin A & D	- Cod & Shark
Insulin	- Whale & Tuna fish
Antihelminthic	- Red alga, <u>Digenia</u>
<u>Agar agar and Alginic acid</u>	- Sea weeds

So far, it has been uneconomical to extract and purify a drug from a marine organism, which has to be collected from distant places, as majority of the marine biota display a most patchy distribution. Thus, only a few marine organisms are presently used as source of useful drugs (Ruigeri 1976).

In the recent past, attempts have been intensified to develop useful drugs, from marine organisms, like anticarcinogenic, antibiotic, hypotensive and hypertensive agents (Kaul 1979). Similarly, the marine toxins, possessing a specific functional group with strong physiological activity, have

the potentials to be used as a drug or pharmacological agent (Hashimoto 1979). Though harmful in their original and natural condition, the marine toxins can serve as a model for synthesis or improvement of other drugs.

Another type of marine bioactive substances are the industrial chemicals, in the form of sugars, enzymes and lipids. Some of such established and widely used compounds are: carageenan from red seaweed; agarose from seaweeds. spatone diterpenoid from tropical marine alga, okadaic acid from black sponge, paloclide from sponges and gorgonians, antitumour from sea hare and chitosan from the shells of marine crustaceans and molluscs.

Amongst the widely used industrial chemicals of marine origin, probably the chitosan, with present annual utilization of about 1,50,000 tons, is projected to have an annual demand of more than one billion tonnes in the next few years (Austin et al. 1981).

Some of the problems identified to be common to all drugs and pharmaceuticals of marine biotic origin are:

- i. Screening unfamiliar organisms is quite difficult.
- ii. Structures found in marine organisms have a tendency to be water soluble and non-volatile, to have high molecular weight, and hence, are rather difficult to handle.
- iii. Any antibacterial agent of marine origin may not be useful against mammalian pathogens.

The need at the moment is for strategies for collecting, culturing and screening of marine organisms from which



bioactive agents can be isolated and characterized. Most probably, the immediate success will occur in discoveries of novel antibacterials and antibiotics (Ruigeri 1976). Direct search for non-antibiotically active natural products in the marine environment, especially those described as unique to marine organisms, can open an entirely new source of industrial chemicals.

The use of biotechnology through genetic engineering can handle cloning and expressing the gene for a particular enzyme and/or hormone. Thus, a genetically engineered organism can be expected to express in terms of many enzymes which would be required to synthesize the desired bioactive compounds.

#### 4. Control of marine biofouling

Destruction and/or deterioration of marine structures, both mobile and stationary due to infestation by fouling and boring organisms, results in heavy financial losses to the tune of millions dollars per year in the world oceans as a whole. At present, the control of marine biofouling is attempted through chemical, electrochemical and mechanical treatments, with marginal to modest success but with serious side effects of environmental pollution.

An approach to regulate marine biofouling by biotechnological control through genetic mechanism, is being developed. The prevailing antifouling methods have to be evaluated with the intention to modify the same for their specific application. Since, the use of toxic chemicals in the prevention of biofouling may come under a total ban in the near future, the need to develop appropriate biological

control techniques for the eradication of marine biofouling, without causing the environmental perturbation is stressed. Perhaps with the direct viable techniques, the dynamics of colonization can further be elucidated and the goal of selective control of fouling, through biotechnological method be achieved (Colewell 1984).

#### 5. Containment of marine pollution

The marine environment has its own self cleansing and assimilative capacity, thus enabling to overcome the hazards posed by the entry of traditional pollutants, which are readily biodegradable (Goldberg 1981). However, the new generation chemical compounds - halogenated, synthetic organics, chlorinated products, dredged spoils, artificial radionuclides, trace elements and fossil fuel residues - cannot be degraded by marine organisms, which are devoid of specific enzymes. However, by using certain types of organisms - actinomycetes, fungi, phototrophic, oligotrophic and anaerobic bacteria - the containment of marine pollution can rationally be monitored.

It is possible to use microorganisms in pollution control through genetic manipulation (Kellogg et al. 1981) as described below:

- i. Amplification of enzyme concentration in an organism through selection of constitutive mutants and increase in the number of copies of genes for the enzyme or both.
- ii. Rearrangement of regulating mechanisms by specific genes in response to specific stimuli.

- iii. Introduction of new enzymatic functions into organisms not possessing them.
- iv. Alterations of the characteristics of specific enzyme, such as, substrate specificity; kinetic constants or factors of pH optima.

Such modifications can be achieved through

- i. In vitro recombinant DNA manipulation.
- ii. In vitro modification via transposon mutagenesis or transposon mediated gene manipulation.
- iii. Genetic exchange via. transduction transformation or conjugation protoplast fusion and specific site mutagenesis.

The plausible and moderately successful approach to genetic engineering in the control of environmental pollution is through plasmid assisted molecular breeding (PMAB). By using continuous cultures of strains containing several molecular breeding plasmids, not only degradative enzymes but also a mechanism to deal with the original toxicity, can be envisaged.

## 6. Future research

The future lines of research in this field of bio-technology include:

- i. Plasmid assisted molecular breeding.
- ii. Metabolic pathway analysis, especially in relation to degradative pathways, and
- iii. Plasmid ecology - stability, mobility, gene exchange and recombination.

New trends in the biological treatment of industrial waste water, involve studies on the basic biology of the anaerobic digestion processes which promise more efficient systems.

Considering the advancement made in the use of genetic engineering and recombinant DNA techniques in the field of marine biology and biological oceanography, it can optimistically be envisaged that the marine biotechnology may significantly contribute to the production of food, drugs and conservation of self generating living resources in the marine environment.

#### Acknowledgements

I sincerely thank my students and colleagues, Shri.Z.A. Ansari and Dr.S.G.Prabhu Matondkar, for their simulating discussions and comments.

#### References

- Austin P R, Brine J R, Castle and Zikakis J P 1981 Chitin: new facets of research; Science 212 749-753
- Colewell R R 1984 Biotechnology in the marine sciences. In: Biotechnology in the Marine Sciences. (Eds.) R R Colewell E R Parisher & Sinskey A J, John Wiley & Sons, New York. pp 3-36
- Dibener M D 1986 Biotechnology in Europe; Science 232 1367-1372.

- Dwivedi S N and Dunning N P 1983 Progress and potential of aquaculture: A note on development in India; In: Living Resources: The University of Chicago Press, Chicago, USA. pp 60-74
- Goldberg E D 1981 The Crystal Mountain Report: an approach to defining ocean assimilative capacity; In: Use of the oceans for man's wastes Symp. Proc. National Academy Press, Washington D.C pp 1-10
- Hashimoto Y 1979 Marine toxins and other bioactive marine metabolites Japan Scientific Press, Tokyo
- Jackson G 1980 Marine biomass production through seaweed aquaculture; In: Biochemical and photosynthetic aspects of energy production (Eds.) A S Pietro, Academic Press, New York, pp 31-58
- Kaul P N 1979 The sea's biomedical potential; Impact of Science on Society 29 123-124
- Kellogg S T, Chatterjee D K and Chakravarty A M 1981 Plasmid assisted molecular breeding: new techniques for enhanced biodegradation of persistent toxic chemicals; Science 214 1133-1135
- Newkirk G F 1980 Review of the genetics and potential for selective breeding of commercially important species; Aquaculture 19 209-228
- Parulekar A H and Dalal S G 1978 Prospects for aquaculture in India; Research Industry 9 1-6

- Qasim S Z 1977 Role of aquaculture in rural development; Invention Intelligence 12 107-111
- Ruigeri G D 1976 Drugs from the sea; Science 194 491-497
- Ryther J H 1981 Mariculture Ocean ranching and other culture based fisheries; Bioscience 31 223-230
- Ryther J H 1984 Biotechnology: A potential U.S. contribution to mariculture; In: Biotechnology in the marine sciences (Eds.) R R Colewell Pariser E R and A J Sinskey John Wiley and Sons, New York, pp 123-132
- Wilkins N P 1981 The rationale and relevance of genetics in aquaculture: An Overview; Aquaculture 22 209-228