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## A review on resilience of microbes in aquatic environment

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### Abstract

Microorganisms had a pivotal role in the aquatic environment by involving ecosystem productivity with relevant to the food chain from the primary producers to and flag end consumers to decompose the detritus. And also plays an important role concerning nutrient cycling, the nutrition of the cultured animals, oxygen production, digestion, water quality, disease control with the introduction of live useful microorganisms, and reduce the environmental impact of the effluent by natural mechanisms through Biofilters, Biofilms and Bioremediation process. The present review elevates the importance of microbes how they were champions in recycling, food web formation and how improves the healthy aquatic ecosystem.

**Keywords:** nutrient recycling, organic matter decomposition, primary production, para-probiotics, bioremediation

### 1. Introduction

Earth has been a bacterial world for at least the last 3.5 billion years. In the oceans of our young planet, bacteria were among the first forms of life to emerge. Long before plants or animals had evolved, bacterial colonies flourished and grew <sup>[1]</sup>.

And then, through two extraordinary events, bacteria changed the face of Earth. 2.4 billion years ago, one type of bacteria started to lease oxygen, creating the atmosphere as we know it <sup>[2]</sup>. And shortly after that – on planetary timescales at least – bacteria created the complex cells required for all plant and animal life to evolve. Bacteria built the world we live in today <sup>[3]</sup>.

#### 1.1. History of life on earth:

The origin of life is one of the great mysteries in the Universe. According to Geological or fossil record history of life on earth is described below:

Millions of years before present	Geological/fossil record (abstracted from Encyclopedia Britannica, 1986)
About 4,600	Planet earth formed
3,500 – 3,400	Microbial life present evidenced by stromatolites (sedimentary structures known to be formed by microbial communities) in some Western Australian deposits
2,800	Cyanobacteria were capable of oxygen-evolving photosynthesis (based on carbon dating of organic matter from this period). They would have been preceded by bacteria that perform anaerobic photosynthesis.
2,000 – 1,800	Oxygen begins to accumulate in the atmosphere
1,400	Microbial assemblages of relatively large unicells (25-200 micrometers) found in marine siltstones and shales, indicating the presence of eukaryotic (nucleate) organisms. These fossils have been interpreted as cysts of planktonic algae. (Eukaryotes are thought to have originated about 2,000 million years ago)
800 - 700	Rock deposits containing about 20 different taxa of eukaryotes, including probable protozoa and filamentous green algae
640	Oxygen reaches 3% of the present atmospheric level
650 - 570	The oldest fossils of multicellular animals, including primitive arthropods
570 onwards	The first evidence of plentiful living things in the rock record
400 onwards	Development of the land flora
100	Mammals, flowering plants, social insects appear

## 1.2. Types of Microbes

Microorganisms include members of the plant kingdom, protozoa, bacteria, and fungi. These organisms differ radically, and share only their small size; most are not visible without a microscope, though colonies of some can be seen with the naked eye.

Microorganisms affect animals, the environment, the food supply, and the healthcare industry of many. There are many different types of microbiology including environmental, veterinary, food, pharmaceutical and medical microbiology which is the most prominent.

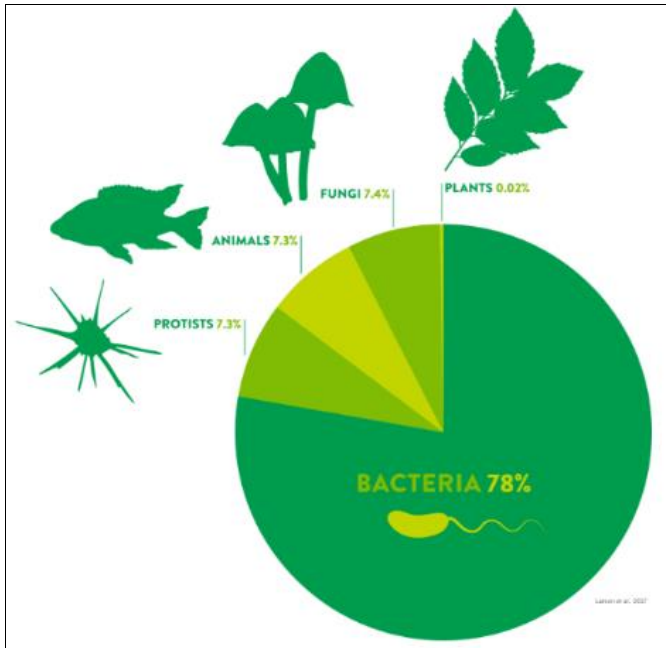


Fig 1: Microbial distribution

### 1.2.1. Harmful Microorganisms

Disease and decay are not inherent properties of organic objects, nor are they caused by physical damage, it is microorganisms that bring about these changes. We are surrounded by bacteria, viruses, and fungi (Fig. 1). Many cause diseases in cattle and crops and others are known for entering human bodies and causing various diseases. Like bacteria, Virus and Fungi

### 1.2.2. Useful-Microorganisms

Decomposers Bacteria and most Fungi are saprotrophic and have an important role in an ecosystem as decomposers, they break down dead or waste organic matter and release inorganic molecules Green plants take these nutrients which are in turn consumed by animals, and the products of these plants and animals are again broken down by decomposers. Yeast is a single-celled fungus that lives naturally on the surface of the fruit. It is economically important in bread-making and brewing beer and also in the making of yogurt. Most microorganisms are unicellular; if they are multicellular, they lack highly differentiated tissues (Fig. 2).

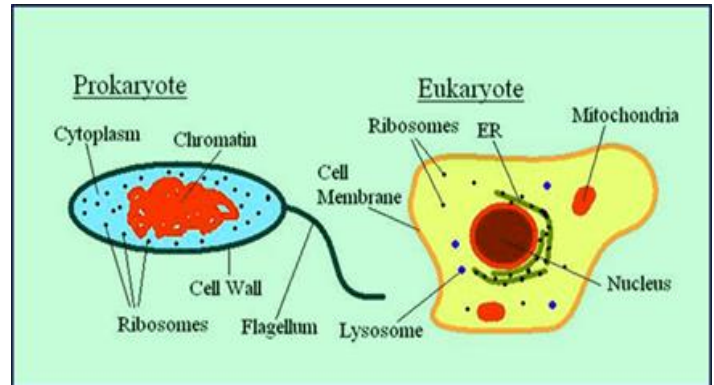


Fig 2: Unique characteristic of Animal cell

## 2. Beneficial bacteria play a may act in function and activities like

- Oxygen producers
- Decomposers
- Bioremediation
- Production of food: *Lactobacillus*, *Lactococcus*
- Pest control: *Bacillus thuringiensis*
- Digestion
- Study of biology
- Production of medicines
- Nitrogen-fixing bacteria
- Flashing fish
- Symbiosis with fungus

### 2.1. Bacteria feeds the world:

Bacteria are agents of change. If food is fermenting, bacteria are often at work. If a crop is growing, bacteria have helped supply nitrogen to make it happen. And if waste is decaying, once again, bacteria are busy [4].

Bacteria are champions of recycling, driving the circulation of carbon, nitrogen, sulphur, and phosphorus around the planet. Bacteria turn these elements into substances plants and animals can use in life – and then after death, bacteria break them down again. All life needs nitrogen to grow, but neither plants nor animals can access it without assistance from bacteria. Nitrogen-fixing bacteria convert nitrogen gas from the air into ammonia, in the soil, in water, and nodules on the roots of bean and pea plants [5].

Nitrifying bacteria then turn the ammonia into nitrates which the plants can use to make proteins. These enable the plants to grow larger, with more roots and leaves, and to produce more abundant crops which animals and people eat. Bacteria act as decomposers, breaking down dead organisms and sending nitrogen back into the soil as ammonia. They also release nitrogen back into the atmosphere through the de-nitrification process [6].

The mechanism used by bacteria and fungi to improve soil organic matter, nutrient availability and aggregation:





more inefficient and so animals intercepting organic matter before it is completely oxidized by the terminal bacteria, e.g. sulfate-reducing bacteria, will have access to digestible organic matter. Where there are large quantities of detritus in the pond, it would be a major food source [8].

### 3. Other application of microbes in aquatic systems

#### 3.1. Biofilters:

A biofilter is a bed of media on which microorganisms attach and grow to form a biological layer called biofilm. Biofiltration is thus usually referred to as a fixed-film process. Generally, the biofilm is formed by a community of different microorganisms (bacteria, fungi, yeast, etc.), macro-organisms (protozoa, worms, insect's larvae, etc.), and extracellular polymeric substances (EPS) [9]. The aspect of the biofilm is usually slimy and muddy (Fig. 5).

Organic matter and other water components diffuse into the biofilm where the treatment occurs, mostly by biodegradation. Biofiltration processes are usually aerobic, which means that microorganisms require oxygen for their metabolism. Oxygen can be supplied to the biofilm, either concurrently or counter currently with water flow. Aeration occurs passively by the natural flow of air through the process (three-phase biofilter)

or by forced air supplied by blowers.

Microorganisms' activity is a key factor in process performance. The main influencing factors are the water composition, the biofilter hydraulic loading, the type of media, the feeding strategy (percolation or submerged media), the age of the biofilm, temperature, aeration, etc.

#### 3.2. Biofilms

- Biofilms are a layer of organic matter which help to attach microbes on rock, pipes, shells, plants etc.,
- Beneficial (wastewater treatment) and can be harmful (pipeline corrosion, medical implants).
- Microbes growing in a biofilm are more resistant to antibiotics, predation, desiccation, changes in environmental factors (pH, temperature).

Suggested processes and organisms to incorporate in the design of a synthetic biofilm community in a biological aerated filter (BAF) for use in microbial reconditioning of rearing water. Denitrification is carried out in the anoxic, bottom layer by heterotrophs or autotrophs, whereas nitrification takes place in the upper oxic part of the biofilm.

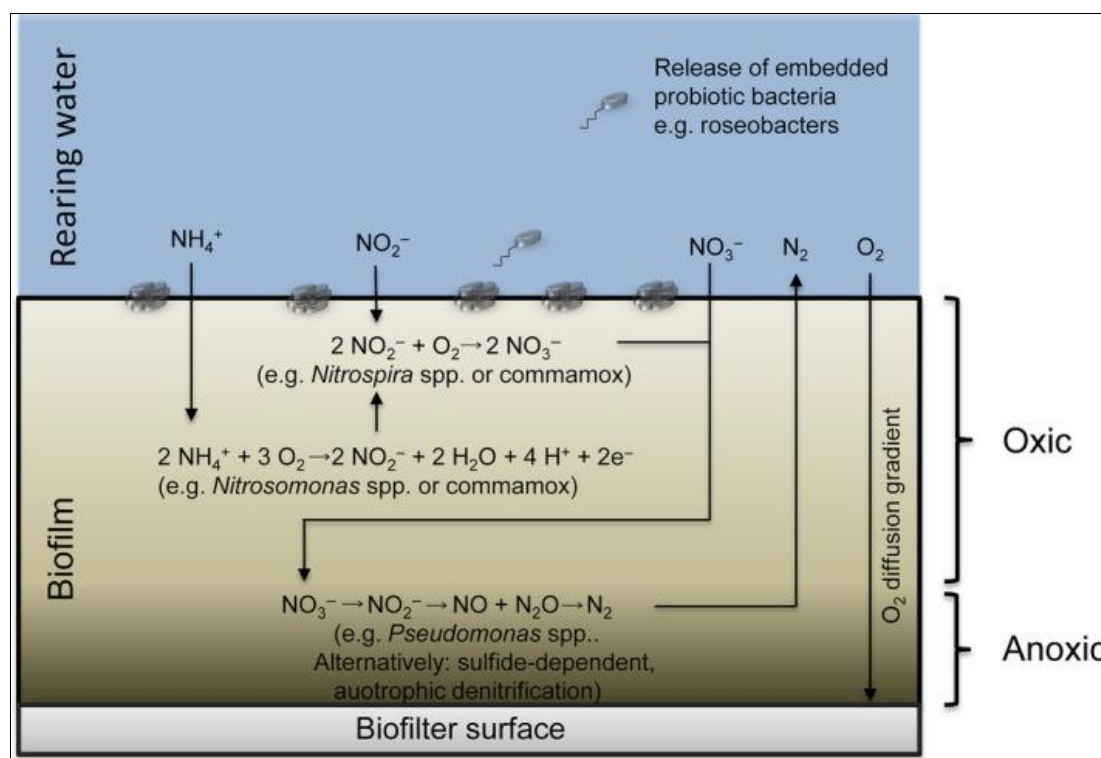


Fig 5: Dynamics of Biofilters

#### 3.3. Biofloc

It is an innovative and cost-effective technology in which toxic materials to fish and shellfish such as Nitrate, Nitrite, Ammonia can be converted to useful products, i.e., proteinaceous feed. It is the technology used in aquaculture systems with limited or zero water exchange under high stocking density, strong aeration and biota formed by biofloc. The culture of biofloc will be productive in the case of culture tanks exposed to sun.

The principle of this technique is the generation of nitrogen cycle by maintaining a higher C: N ratio through stimulating heterotrophic microbial growth, which assimilates the nitrogenous waste that can be exploited by the cultured species

as a feed. The biofloc technology is not only effective in treating the waste but also grants nutrition to the aquatic animal. The higher C: N is maintained through the addition of carbohydrate source (molasses) and the water quality is improved through the production of high-quality single-cell microbial protein. In such conditions, dense microorganisms develop and function both as bioreactors controlling water quality and protein food source (Fig. 6). Immobilization of toxic nitrogen species occurs more rapidly in bio floc because the growth rate and microbial production per unit substrate of heterotrophs are ten-times greater than that of the autotrophic nitrifying bacteria. This technology is based on the principle of flocculation within the system [10].

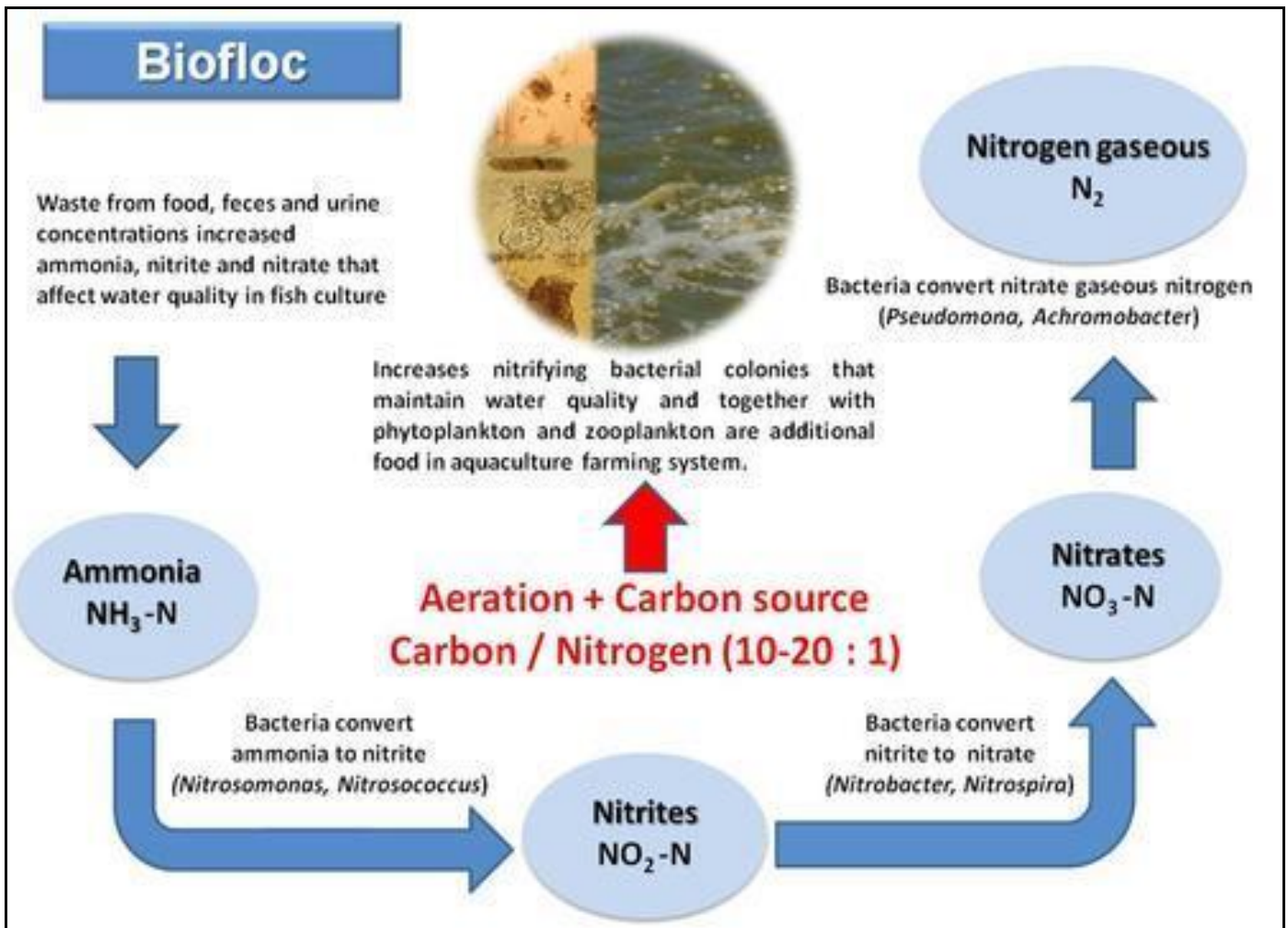


Fig 6: Nutrient cycle in Biofloc aggregates

### 3.4. Bioremediation:

Bioremediation is defined as the process whereby organic wastes are biologically degraded under controlled conditions to an innocuous state or levels below concentration limits established by regulatory authorities.

By definition, bioremediation is the use of living organisms, primarily microorganisms, to degrade the environmental contaminants into less toxic forms. It uses naturally occurring bacteria and fungi or plants to degrade or detoxify substances hazardous to human health and/or the environment. The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated site. Contaminant compounds are transformed by living organisms through reactions that take place as a part of their metabolic processes [11].

Biodegradation of a compound is often a result of the actions of multiple organisms. When microorganisms are imported to a contaminated site to enhance degradation, we have a process known as bioaugmentation. For bioremediation to be effective, microorganisms must enzymatically attack the pollutants and convert them into harmless products.

As bioremediation can be effective only where environmental conditions permit microbial growth and activity, its application often involves the manipulation of environmental parameters to allow microbial growth and degradation to proceed at a faster rate.

### 4. Role of microorganisms in aquatic animal health:

Microorganisms are of great importance to aquaculture where they occur naturally and can be added artificially, fulfilling different roles. They recycle nutrients, degrade organic matter and, occasionally, they infect and kill the fish, their larvae or the live feed. Also, some microorganisms may protect fish and larvae against disease (Fig. 6). Hence, monitoring and manipulating the microbial communities in aquaculture environments hold great potential; both in terms of assessing and improving water quality, but also in terms of controlling the development of microbial infections. Such as

#### 4.1. Probiotics

Live microorganisms that, when administered in adequate amounts, confer a health benefit on the host.

#### Significance of Probiotics in Aquaculture

Probiotics use in aquaculture show a great impact on aquatic organisms. Probiotics decrease accumulation of organic load and efficiently maintain water quality. A modern probiotic organism can easily fulfill the desires of sustainable aquaculture development because it can heighten two major key factors of growth performance and disease resistance [12]. Lactic Acid Bacteria, a popular probiotic strain, can be applied to control bacterial pathogens. Besides, another well-known probiotic organism, *Bacillus* sp. is used to diminish

metabolic waste in aquatic system. Many strains of *Aeromonas* sp., *Pseudomonas* sp., *Vibrio* sp. act against

infectious hematopoietic necrosis virus to show antiviral activity.

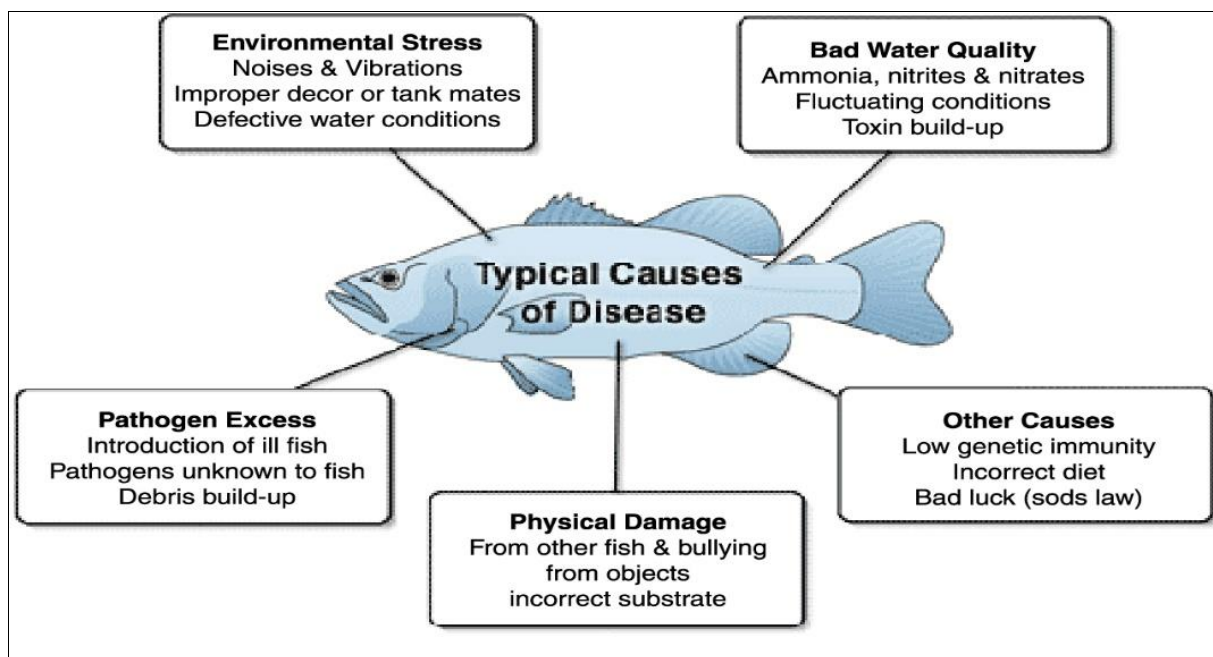


Fig 6: Schematic view of Disease occurrence

Table 1: Uses of Probiotic in aquaculture system [13]

Uses of Probiotic	Probiotic Species	Gram Positive/negative Bacteria	Target aquatic species
Water quality	<i>Bacillus</i> sp.	+ve	<i>Penaeus monodon</i>
	<i>Vibrio</i> sp. NE 17	-ve	<i>Macrobrachium rosenbergii</i>
	<i>Lactobacillus acidophilus</i>	+ve	<i>Clarias gariepinus</i>
Control of diseases	<i>Enterococcus faecium</i> SF 68	+ve	<i>Anguilla Anguilla</i>
	<i>Pseudomonas fluorescens</i>	-ve	<i>Oncorhynchus mykiss</i>
	<i>Lactococcus lactis</i>	+ve	<i>Epinephelus coioides</i>
	<i>Pseudomonas</i> sp.	-ve	<i>Oncorhynchus mykiss</i>
	<i>Bacillus</i> sp.	+ve	Penaeids
	<i>Vibrio alginolyticus</i>	-ve	Salmonids
Growth promoter	<i>Lactobacillus lactis</i> AR21	+ve	<i>Brachionus plicatilis</i>
	<i>Bacillus</i> sp.	+ve	Catfish
	<i>Streptococcus thermophiles</i>	+ve	<i>Scophthalmus maximus</i>
	<i>Bacillus coagulans</i>	+ve	<i>Cyprinus carpio koi</i>
	<i>Bacillus</i> NL 110	+ve	<i>M. rosenbergii</i>
Digestion	<i>Lactobacillus acidophilus</i>	+ve	<i>Clarias gariepinus</i>
	<i>Vibrio</i> NE 17	+ve	<i>M. rosenbergii</i>
	<i>Lactobacillus helveticus</i>	+ve	<i>Scophthalmus maximus</i>
Improvement of immune response	<i>Clostridium butyricum</i>	+ve	Rainbow trout
	<i>L. casei</i>	+ve	<i>Poecilopsis gracilis</i>
	<i>L. acidophilus</i>	+ve	<i>Paralichthys olivaceus</i>

**4.2. Prebiotics**

Prebiotics are non-digestible food ingredients that stimulate the growth or activity of beneficial gut commensal bacteria in host thus improves host health. Live microorganisms as a Food ingredient acts as prebiotic must possess the following criteria such as showing resistance to gastric acidity, hydrolysis by digestive enzyme, fermentation by gastrointestinal microflora and increase the abundance of intestinal bacteria related to health [14].

**Prebiotic Organisms**

Nowadays, carbohydrates use as the most efficient prebiotics which can be classified based on molecular size or step of

polymerization. Various food substances such as non-digestible carbohydrates, some proteins and peptides, certain lipids act as prebiotic ingredients. Prebiotic compounds like fructooligosaccharides, mannanoligosaccharides, inulin or B-glucanare considered as the most effective prebiotics in aquaculture. Prebiotics are mainly fermented by Bifidobacteria, Lactobacillus, and Bacteroides.

**Significance of Prebiotics in Aquaculture**

Prebiotics are an essential dietary supplement that enhances growth performance as well as microbial activities of digestive tract, also booststhe immune system, and improves stress resistance.



**Table 2:** Different Prebiotic substances in aquaculture [15]

Prebiotic substances	Subtype	Aquatic Organisms
Oligosaccharide	Fructooligosaccharides (FOS) Mannanooligosaccharide (MOS) Galactooligosaccharide (GOS) Arabinoxylan-oligosaccharide	<i>Salmo salar L.</i> <i>Megalobrama terminalis</i> <i>Paralichthys olivaceus</i> <i>Acipenser stellatus</i> <i>Oreochromis niloticus</i> <i>Dicentrarchus labrax</i> <i>Panulirus ornatus</i> <i>Sciaenops ocellatus</i> Atlantic Salmon Siberian sturgeon
Polyoligosaccharide	Inulin	Nile tilapia <i>Huso huso</i> <i>Pseudoplatystoma sp.</i>

#### 4.3. Synbiotics

Synbiotic defines as nutritional supplements combining probiotics and prebiotics in the form of synergism therefore improving the beneficial effects of individual probiotics. Synbiotics were stated to ‘characterize some colonic foods with interesting nutritional properties that make these compounds candidates for classification as health-enhancing functional ingredients. Synbiotic positively affects the host by improving the survival and inserting of live microbial dietary supplements in the digestive tract by selectively stimulating the growth and/or by triggering the metabolism of one or a limited number of health-promoting bacteria, hence promoting the host “welfare”[16].

**Table 3:** Application of synbiotic on different aquatic organisms [17]

Synbiotic (Probiotic/Prebiotic)	Aquatic Organisms
<i>Enterococcus faecalis</i> / MOS, PHB	<i>Oncorhynchus mykiss</i>
<i>Bacillus clausii</i> / MOS, FOS	<i>Paralichthys olivaceus</i>
<i>Bacillus subtilis</i> / Chitosan	<i>Rachycentron canadum</i>
<i>Bacillus subtilis</i> / FOS	<i>Larimichthys crocea</i>

(MOS-Manna oligosaccharide, PHB- Plyhydroxybutyrate acid, FOS-Fructooligosaccharide)

#### Significance of Synbiotics in Aquaculture

Synbiotics can be applied through supplementation or external bathing to develop growth performance, proper feed utilization, disease resistance, digestibility, and stimulation of the immune system of aquatic organisms.

#### 4.4. Paraprobiotics

The non-viable counterparts of the probiotic organisms, also known as paraprobiotic, can be used to harness similar beneficial effects. Considering the limitations of probiotic application, paraprobiotics constitute a potential alternative strategy for improving the health and wellness of fish and shellfish in aquaculture. Eventhough the concept of paraprobiotic is relatively established in higher vertebrate models and related food production sectors, its application in aquaculture is still in its early stage [18]. In light of this, the present review delineates the concept of paraprobiotic, inactivation methods used for its preparation, the role of paraprobiotic in modifying biological responses as well as their potential application in aquaculture.

#### 5. Conclusion

##### 5.1. Microbes

The health of aquatic animals depends upon both micro eubiosis in the intestine of cultured animals and microbial ecological equilibrium. The production of various primary producers depends largely on the availability of different nutrients. The dynamics of the availability of most of these nutrients is determined by the prevailing microbial activity of the bottom soil.

##### 5.2. Probiotics

It is essential to understand the mechanisms of action to define selection criteria for potential probiotics. More information on the host/ microbe interactions *in vivo*, and development of monitoring tools (e.g. molecular biology) are still needed for better understanding of the composition and functions of the indigenous microbiota, as well as of microbial cultures of “probiotics”[19]. The use of probiotics is an important management tool, but its efficiency depends on understanding the nature of competition between species or strains.

##### 5.3. World shaping bacteria

Today, bacteria shape our world in countless invisible ways. From species that rust iron and filter water, to those that live inside other creatures and influence both biology and behavior, bacteria are constantly at work. We rely on bacteria in innumerable ways. After a storm, the smell in the air comes from a chemical called geosmin that dead soil bacteria release. Humans can detect it at incredibly low concentrations, leading to the theory that in our past it helped us seek out sources of water. Our bodies contain as many bacteria as they do human cells. Among the species that live in us are those that help repair our skin, tune our immune system and control how our fat is stored. This kind of coexistence is called symbiosis – and bacteria have evolved an incredible range of intimate relationships with us and with other species in this way.

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