

Review Article

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Review on Impact of Biofouling in Aquafarm Infrastructures

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ABSTRACT

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The biofouling issue is a tenacious issue throughout the history of aquaculture farming in the world, however it has elevated in priority as labour and electricity costs have arisen in recent years. Besides, fouling development is frequently fast on the grounds that the waters encompassing aquaculture activities are enhanced by natural and inorganic squanders (uneaten food, fecal and excretory material) created by high-density fish populations. The large surface area and structure of mesh material, especially multifilament mesh, is exceptionally appropriate for colonization and development of fouling. Biofouling of fish-cage netting is a critical operational issue to aquaculture. The occlusion of mesh and the subsequent limitation in water exchange adversely influences fish health by the reduction in dissolved oxygen (DO) and the accumulation of metabolic ammonia. Fouling is also reducing the cage floatation, cage deformation, increases structural fatigue, and may go about as a supply for pathogens. The effects of fouling differ significantly relying upon season and area, and are additionally impacted by cultivating techniques and practices. The impacts of these factors are reviewed and highlighted. Suggesting an effective biofouling control will help to develop non-toxic coating particularly suited for aquaculture applications in future.

Introduction

Any artificial or natural substance get in contact with water environment become colonised by marine organisms, a process which is called biofouling (Railkin, 2004). Within minutes of immersion, a surface becomes 'conditioned' through the adsorption of macromolecules such as proteins, present in the water. Bacteria colonise within hours as may unicellular algae, protozoa and fungi. These early colonisers form a biofilm, which is an assemblage of attached organisms that is often referred to as microfouling or slime

serve as a base for the growth of macrofouling, which consists of seaweed, and invertebrates such as barnacles, mussels, ascidians and hydroids.

Now a day, biofouling is a major biosecurity risk for the aquaculture industry, which includes direct impacts on cultures species (e.g. smothering, competition for space and food), deterioration of farm infrastructure (immersed structures such as cages, netting and pantoons) and effects on natural ecosystem functioning of adjacent areas.

The production infrastructure for the species in variably consists of a complex assortment of submerged components with aerators, pipes, cages, nets, floats and ropes. All of these structures serve as surfaces for biofouling. The presence of such varied surfaces provides for a broad diversity of epibiotic organisms to settle and grow. These marine algae and animals, are severely problematic to culture operations and can have significant economic impacts. Conservative estimates of around 5-10% is attributed to biofouling which directly affects the economic costs of control in aquaculture (Lane Willemsen, 2004). Globally, this equates to costs of US\$ 1.5 to 3 billion/yr. To minimize these impacts, the aquaculture industry uses technologies to manage and control fouling communities.

The composition of fouling communities and their effect in marine aquaculture is largely dictated by the properties of the fouling surface, and the protection and management of these surfaces is the key to biofouling control. Currently there is a substantial amount of information on the mechanisms of biofouling and an array of options are available that have shown promise in combating the problem for specific marine applications, eg ship and boat fouling prevention, electricity generator coolant water intake pipes, bivalve aquaculture structures in inshore waters, fish cage farms. Biofouling on marine pond farms has received little, if any, attention so that currently the primary means of dealing with fouling is manual cleaning. The approach taken to control biofouling is regular manual defouling as required and it is anticipated that a preventative approach would be more cost effective and reliable and provide significant farm management benefits. A broad range of antifouling options are now commercially available or being developed, including: - chemical, biological, electrical, ultrasound irradiation, surface

microtexture, novel materials approaches. The use of biocidal coatings with persistent or broadly toxic active ingredients, such as copper or organic toxins, may have govt. approval issues for the enclosed or semi-enclosed water bodies of marine pond farms and is not a preferred option for farmers. So prevention of biofouling using eco-friendly method is suggesting control options for aquafarm.

Impacts of biofouling in aquaculture structures

Biofouling is a significant issue for all forms of aquaculture operating in the marine and brackish water environment for aquaculture activities such as shellfish and finfish farming. The culture structures used for both and in the case of shellfish, the hard shell of the animals themselves, are severely impacted by biofouling and the industries need to employ a variety of approaches to control production limiting affects. A survey of shellfish culture operations in the USA put the cost of controlling biofouling at 14.7% of total operating costs (Adams, *et al.*, 2011). Manual cleaning of fish cages and shellfish structures continues to be the most common control measure (Adams, *et al.*, 2011). Biofouling is a specific problem in aquafarms mainly damaging the infrastructures and major key impacts are restricting the water exchange, increase disease risk and causes deformation of structures (Fitridge., *et al* 2012). Biofouling adds significant weight and drag to shell fish culture infrastructure, rapidly becoming a management issue.

The Effect of Biofouling in aeration devices rises the cost of production through electricity consumption, increased maintenance cost and labour cost. It has been estimated that the current drawn by paddle wheels can be up to 50% greater when heavily fouled. One farm estimated that on average across the farm

power consumption was increased by 20% and 50% extra maintenance and repair cost due to fouling. Aerator surfaces that are typically subject to fouling are generally stainless steel and plastic. By far the greatest wetted surface area of paddlewheels and other aerators are plastics, particularly high density polyethylene (HDPE) which is used to construct the floats and the motor cover. HDPE has some inherent fouling control properties as a result of its surface characteristics but this does not prevent colonization. Even under ideal conditions HDPE can only restrict the adhesive strength of foulants such as barnacles, tubeworms and algae. Biofouling reduce the efficiency of oxygen transfer in aquafarms (Mann, 2011). In the aquafarms, it is found that the fouling on cage netting greatly reduce the efficiency (Willemsen, 2003). The costs associated with biofouling can be very significant (Beaz *et al.*, 2005). The replacement of nets is expensive, annual costs to replace nets and reapply antifouling for a medium-sized UK salmon farm is estimated to be ±€ 120.000. Biofouling growth on fish cages and infrastructure has three main negative effects:

Restriction of water exchange due to the growth of fouling organisms causing net occlusion. When fish are held in high density in net pens, this leads to poor water quality as flushing is reduced. Lowered dissolved oxygen levels result and the removal of excess feed and waste is inhibited;

Disease risk due to fouling communities acting as reservoirs for pathogenic microorganisms harboured by macro- or microbial fouling species on cage netting, or lowered dissolved oxygen levels from poor water exchange increasing the stress levels of fish, lowering immunity and increasing vulnerability to disease.

Cage deformation and structural fatigue due to the extra weight imposed by fouling. The

maintenance and loss of equipment directly contributes to production costs for the industry.

Cleaning oyster cultures is estimated to be 20% of the market value and biofouling can reduce growth rates by over 40%. The estimated cost of fouling on cultured mussels in Scotland is ± 450-750.000 Euro per year for farmers, and the problem is worsening (Campbell and Kelly, 2002).

Control of biofouling in aquaculture

Unlike other industries where biofouling is a problem, such as shipping, few studies have examined the impact and sought cost-effective solutions for the aquaculture industry. The most common methods to control the problem are mechanical cleaning or using antifouling coatings.

Mechanical cleaning, involving brushing, scraping or cleaning using water jets, is labour intensive and tedious (Hodson *et al.*, 1997). Air/sun drying when nets or oysters are hoisted out of the water and desiccation or heat kills but does not remove fouling. Cleaning of shellfish can be combined with immersing the biofouled shellfish in either hot or fresh-water, chlorine, salt solution or lime (Arakawa, 1980). The stress of the immersion medium kills the fouling.

Applying a biocidal coating on the surface is still widely used in aquaculture. Net coatings are usually low-tech versions of coatings for vessels. Small amounts of the active substance are released to deter or kill the fouling. The lifetime of such coatings, mostly based on copper oxide (Cu₂O), is limited to one season, while the costs for treating nets are high.

Antifoulants are known sources of pollution from aquaculture and are responsible for elevated levels of copper close to fish-farms.

In addition to Cu₂O, organic biocides with improved environmental profiles (e.g. biodegradable) are available (Costello *et al.*, 2001), but these are generally not targeted at the aquaculture industry. Fouling prevention strategies for culture equipment such as ropes, floats, panels, nets and trays have traditionally used heavy metals including copper, nickel and tin. Unlike tributyltin and nickel, copper based coatings remain in use despite their negative impacts on developing vertebrates and invertebrates (Oliva *et al.*, 2007), and their ability to concentrate in shellfish tissues (Chang sheng *et al.*, 1990). Environmental problems associated with commonly used biocides have led to increasingly restrictive legislation and the banning of some compounds for use on vessels and in aquaculture, most notably TBT (IMO, 2002) and in some member states copper, Irgarol and Diuron.

When fish net cages impregnated with toxic coatings do become fouled they need to be removed and cleaned. This costly process causes stress to the fish resulting in mortality (estimated at 2%). Net washing plants have problems dealing with the copper containing waste and sludge. The waste must be specially disposed of and such safeguards evidently increase costs. Some other antifouling methods certainly exist, examples of which are biological control using grazers (Hidu *et al.*, 1981; Lodeiros and Garcia, 2004); avoidance when cultures are removed or repositioned during periods of heavy fouling settlement (Rikard *et al.*, 1996); new materials (coatings) such as silicone based fouling-release coatings (Baum *et al.*, 2002), generally in combination with mechanical cleaning (Hodson *et al.*, 2000) or coatings for netting (McCloy and De Nys, 2000; De Nys *et al.*, 2004); new cage designs to limit fouling on shellfish or fish net cages (Menton and Allen, 1991); and spraying with an antifouling solution such as acetic acid

(Carver *et al.*, 2003). These methods are only being used locally or are under development. Biofouling persists as a significant practical and economic barrier to the development of competitive aquaculture and there is a need for cost effective, sustainable solutions to the fouling problem. The antifouling sector, mainly fulfilling the needs of the shipping industry, has for decades undertaken a great deal of research into developing toxic and non-toxic antifouling strategies. Virtually none of this work has considered the specific needs and issues related to aquaculture. It will prove fruitful to utilize this knowledge base to develop sustainable and environmental benign approaches to reducing the biofouling problem within aquaculture.

Natural antifouling methods

The negative and significant impacts that biofouling has on viability and profitability of aquaculture has necessitated a long and persistent effort in biofouling control. Historically, the aquaculture industry has borrowed antifouling (AF) technologies from other marine industries which focus on chemical AF technologies. AF paints to control biofouling are commonly used on surfaces in marine transport, oil and gas industries (Yebra *et al.*, 2004; de Nys and Guenther 2009; Durr and Watson 2010). These paints leach biocidal compounds such as heavy metals and organic biocides onto the surface, producing a thin, toxic layer which prevents the onset of biofouling. However, many of the chemicals and heavy metals involved are recognized as dangerous in the environment, with detrimental effects on the survival and growth of shellfish (Paul and Davies 1986; reviewed by Fent 2006) and fish (Lee *et al.*, 1985; Short and Thrower 1986; Bruno and Ellis 1988) and this has prompted an effort to prevent or mitigate biofouling in aquaculture through alternative methods.

Natural product antifoulants (NPAs) are globally accepted and one of the most promising environmentally benign option to control marine biofouling. After the ban of TBT based antifouling paints and environmental concerns associated with other toxic biocides, there is a growing need for the effective eco-friendly antifoulants for marine applications (Yanget *et al.*, 2007; Bao *et al.*, 2013). Research interest on natural product antifoulants has been increased in the recent years that were evident from the growing number publications (Bao *et al.*, 2013; Keifer, PA and KL. Renillafoulins Rinehart, 1986). In nature, many marine sessile organisms are keeping their surfaces free from fouling organisms (Renillafoulins Rinehart, 1986; Yang *et al.*, 2006) mainly through the production of secondary metabolites (Hentschel *et al.*, 2001, Pawlik *et al.*, 2012). The secondary metabolites produced by many marine organisms that showed inhibitory activities against the biofouling organisms would be the ideal lead molecules for the development of natural product antifoulants that can be incorporated into paints (Clare, 1996, Feng *et al.*, 2009).

The compounds belonging to terpenoids, steroids, carotenoids, phenolics, furanones, alkaloids, peptides and lactones extracted from the marine organisms showed antifouling activities (Feng *et al.*, 2009). Among the marine organisms, antifouling activities were largely reported from sponges and corals (Hellio *et al.*, 2005; Limna mol *et al.*, 2010; Dobrestov *et al.*, 2015; Taylor *et al.*, 2007). Sponges especially attracted the attention of the researchers due to their close relationship with wide variety of microbes and presence of large number of biologically active secondary metabolites (Taylor *et al.*, 2007). Another important group attracted the attention of investigators is the ascidians from

which good number of antifouling molecules were reported in the literature (Mayzel *et al.*, 2014; Trepos *et al.*, 2014). Antifouling activities were also reported from seaweeds, seagrasses, (De nys *et al.*, 1995; Helio *et al.*, 2002), bryozoans (Walls *et al.*, 1993; Kon-yaet *et al.*, 1994), mangroves and microorganisms (Burgess *et al.*, 1999; Kennedy *et al.*, 2009; Satheesh *et al.*, 2012; Viju *et al.*, 2014).

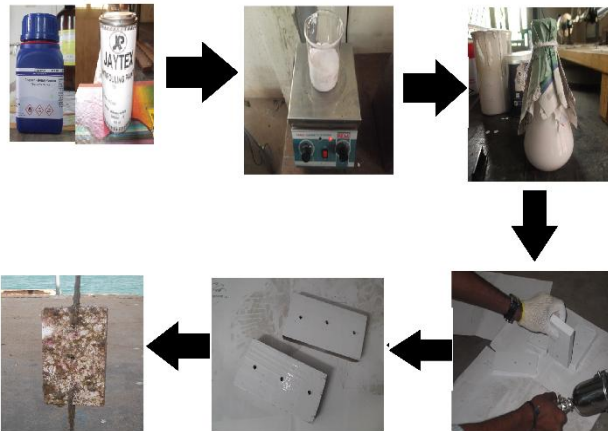
Few antifouling coatings based on natural products from the marine organisms such as Sea Nine- 211, Netsafe and Pearlsafe have already been commercialized (Jacobson and Willingham, 2000; De Nys *et al.*, 2004). During the past five decades' bioactive metabolites from the marine environment attracted the attention of researchers all over the world for the discovery of lead compounds in medicine and industry (Jones *et al.*, 2007; Dunlap *et al.*, 2007; Devi *et al.*, 2010; Mayer *et al.*, 2011; Felczy kowska *et al.*, 2012; Cong *et al.*, 2014; Cortes *et al.*, 2014). Due to the concern on exploitation of large amount of marine organisms for natural products discovery, marine microbes are considered as the viable source for searching bioactive molecules. Many novel bioactive metabolites with antifouling activities were reported from marine microbes in the literature (Egan *et al.*, 2002; Bhattarai *et al.*, 2007; Bowman, 2007; Ortega-Morales *et al.*, 2008; Soliey *et al.*, 2011). Sessile soft-bodied marine organisms are having inherent antifouling property, i.e. they produce secondary metabolites as a chemical means of warfare, protection from predation, competition for space, prevention of over growth/ biofouling, combat poisoning and fight infections. Thus there is an intense research activity to seek novel, environmentally benign methods of fouling control.



Biofouling in Paddlewheel aerator

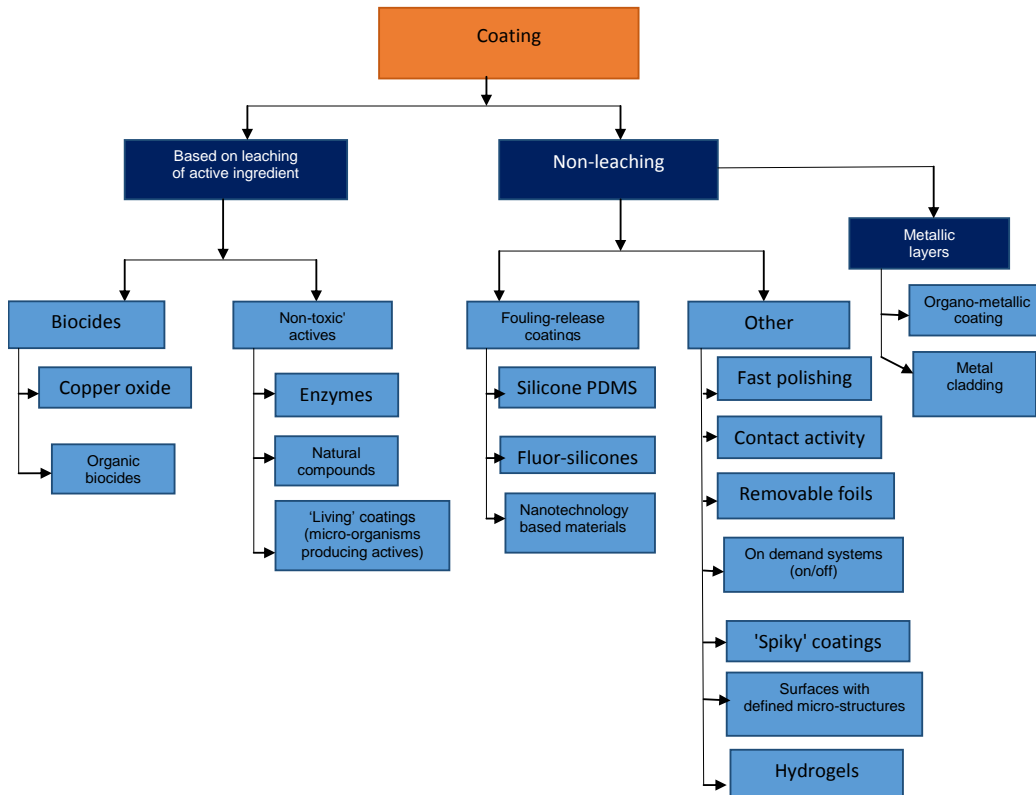
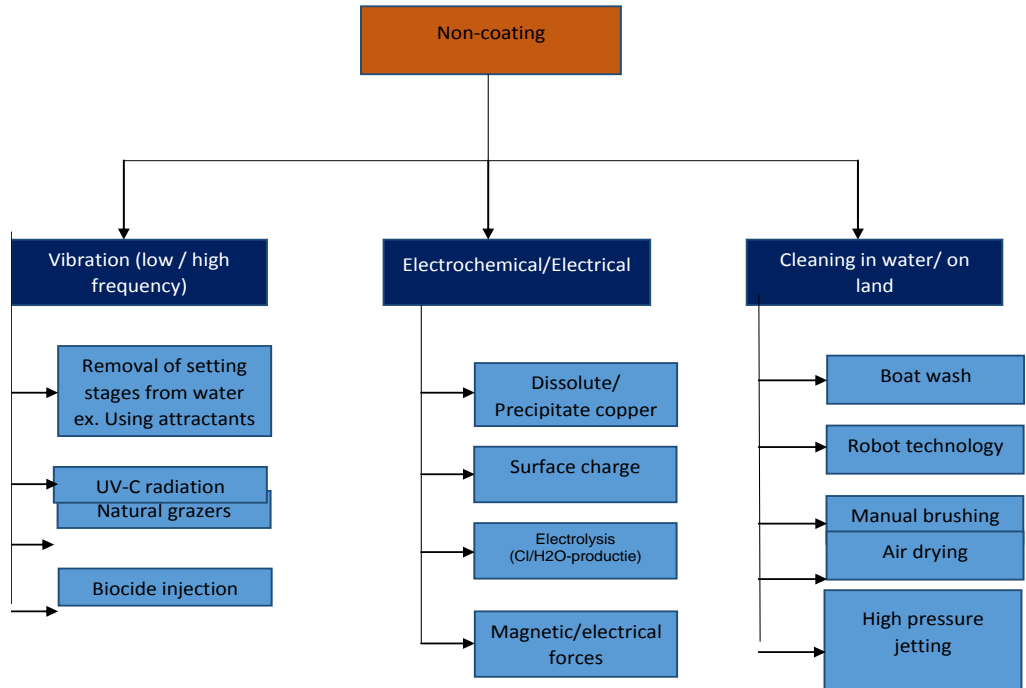


Biofouling in floating cage



One of the antifouling technique (spray coating using copper)

Antifouling strategy/technology



In conclusion the occurrence of biofouling in aquaculture is an important management issue resulting in increased operational expenses and detrimental impacts on the species being cultured. Surprisingly, for an issue with such high impact in a growing global industry, scanty information exists on its effects and costs. The expansion of tropical aquaculture and the trend towards greater use of offshore sites both present new challenges in understanding the impacts of fouling and implementing successful control measures. Given the limited choice of products currently available, quantitative studies on the spatial and temporal variation of fouling species, and farm management on fouling development, are essential to assist the industry to choose the most cost effective and practical methods for fouling control, both now and into the future. In terms of control, the mechanical removal of biofouling remains dominant in shellfish and fish culture, and copper coatings on fish nets are the only consistently effective form of biofouling prevention at an industrial scale. Further developments need to rely of incremental improvements in these technologies by effective environmentally benign method of control biofouling in aquaculture. Using of biocides as an antifouling is making organisms to suffer in many ways instead of that environmentally benign antifouling method is more valuable for aquaculture farm industries. Therefore, while the aquaculture industry remains a step behind other maritime industries in control methods it can also benefit from the broader research effort across maritime industries to solve a cosmopolitan, persistent and complex problem, biofouling.

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