

BIOFOULING IN EUROPEAN AQUACULTURE: IS THERE AN EASY SOLUTION?

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Introduction

Surfaces immersed in the marine 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. Finally a layer of macrofouling colonises the surface, consisting of larger algae such as brown and green seaweed, and invertebrates such as barnacles, mussels, ascidians and hydroids.

Biofouling is a complex and recurring problem in all sectors of the European aquaculture industry. Given the low cost margins, current priorities of the industry and operating environments it is vital that low cost, practical and easily applicable methods are found and introduced to control biofouling. This paper reviews the problems associated with biofouling in aquaculture and solutions to reduce the effects of fouling. The EC funded research project *Collective Research on Aquaculture Biofouling* (CRAB) is targeting the main biofouling issues.

The biofouling problem in aquaculture

The diversity and intensity of biofouling in aquaculture is site specific, depending on season, geographic location and local environmental conditions. There are many problems associated with fouling in aquaculture (Lane and Willemsen, 2004). Problem areas include fouling on **infrastructure** (immersed structures such as cages, netting and pontoons) and **stock species** (farmed species, particularly shellfish such as mussels, scallops and oysters). Examples are shown in Figure 1. Biofouling greatly reduces the efficiency of materials and equipment: it physically damages equipment (abrasion/brittleness/increased load) and flow can be significantly reduced directly reducing foods supply. Biofouling communities can directly compete for resources with cultured organisms and can include predators and harbour diseases. The selling of biofouled produce (shellfish) is affected on aesthetic grounds or because the fouling is not compatible with product processing or packaging methods. In addition biofouling can have direct toxic affects: a number of benthic marine organisms within biofouling communities produce secondary metabolites that act as antipredation strategies or natural antifoulants. These chemicals can be toxic to other marine organisms, including cultured organisms. Significant losses of cultures are also attributable to deoxygenation and

degradation products when biofouling communities die or simply swamp the cultures/cages preventing oxygen and waster product exchange.

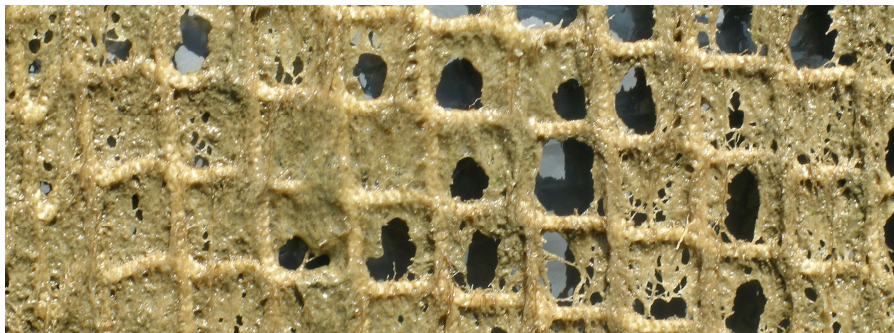


Fig. 1. Biofouling in aquaculture (pictures by the author). Top: Oyster with barnacle fouling. Bottom: Hydroid fouling on nylon netting.

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 are estimated to be \pm €120.000. 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 \pm 450-750.000 Euro per year for farmers, and the problem is worsening (Campbell and Kelly, 2002). For many small (often family-run) businesses this can be the difference between profit and loss in a sector under extreme economic pressure. What strategies are available for farmers to reduce the effects of biofouling? Let us first assess common approaches in aquaculture before considering other applications such as shipping for alternative solutions.

Current antifouling strategies 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 (Figure

2) 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.



Fig. 2. Manual cleaning of oysters (picture by the author).

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 (Cu_2O), 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 Cu_2O , 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. 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. In the next years the choice and availability of biocides for use as antifoulants will become much more restrictive within Europe with the application of Biocides Directive EC 98/8/EC (European Commission, 1998). 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 & 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 and shellfish based on natural antifoulants (McCloy and De Nys, 2000; De Nys *et al.*, 2004); **new cage designs** to limit fouling on shellfish (Gillmor, 1978) 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.

Other potential strategies: what can we learn from other applications?

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. The wide diversity of potentially available antifouling solutions is summarised in Figure 3. Virtually none of this work has considered the specific needs and issues related to aquaculture. It will prove fruitful to utilise this knowledge base to develop sustainable approaches to reducing the biofouling problem within aquaculture.

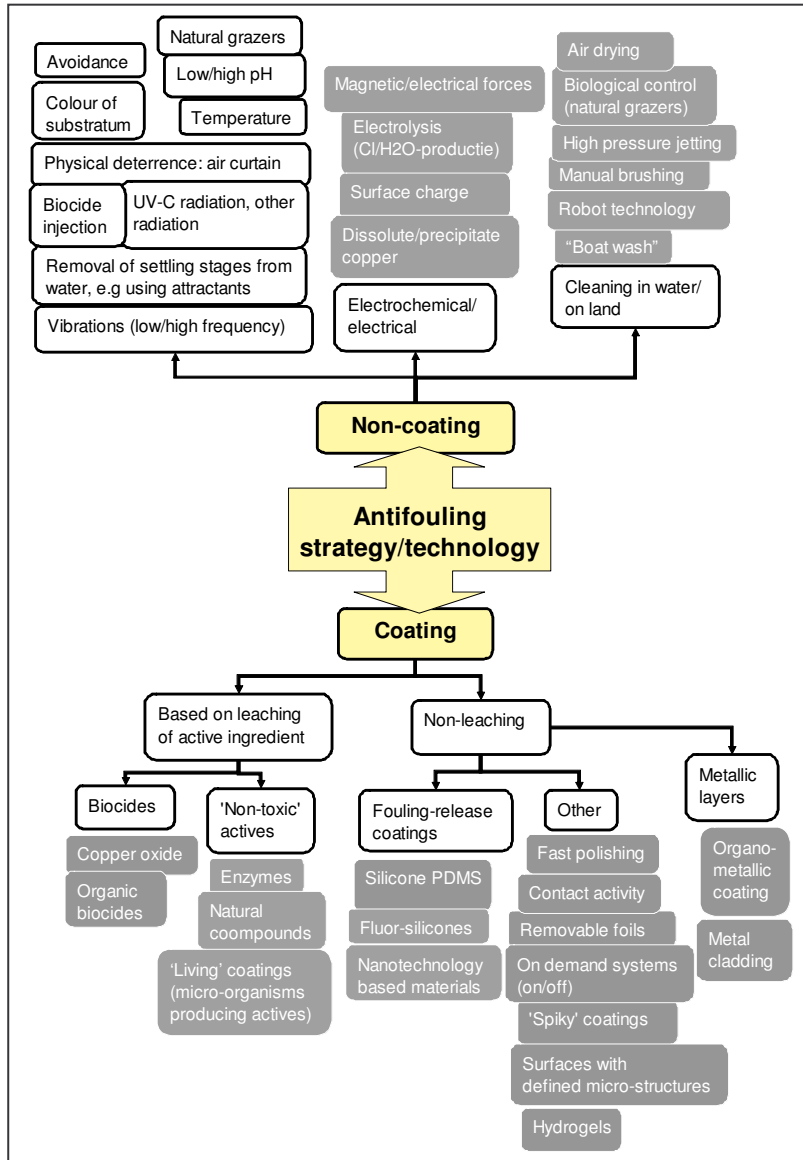


Fig. 3. Technologies and strategies to combat biofouling on submersed surfaces.

CRAB: a collective approach to reduce the impact of biofouling for the aquaculture industry

What is required in Europe is an evaluation of the biofouling problems at a local and regional level and a concerted action to solve the problem in a practical and cost effective way. The aim of the pan-European project CRAB (Collective Research on Aquaculture Biofouling, www.crabproject.com) (Lane and Willemsen, 2004) is therefore to develop and implement effective biofouling management strategies for the aquaculture industry. The CRAB consortium is composed of 4 RTD organisations, 4 industry associations and 15 small-medium enterprises, including 6 shellfish farms and 5 finfish farms. Key deliverables are best practice guidelines, training courses and materials for industry workers on biofouling and suitable control techniques, sustainable antifouling strategy management and decision support tools. A key ambition is to increase the knowledge base of the European aquaculture community. Informing farmers about the importance and extent of biofouling at a local and regional level, combined with effective training in management tools, will give farmers the skills and know-how to make appropriate choices for their farming situation.

The following strategies are covered in CRAB: biological control, new materials (coatings), husbandry practices, cleaning practices and electrochemical antifouling methods. Modifying and field-testing those strategies will determine which ones can find their application within the European aquaculture industry.

Knowledge based management tools will be developed, combining understanding of fouling processes, the best available antifouling practices and cost/benefit analyses. The outcomes of CRAB will be disseminated to the general European aquaculture industry through scientific and general publications, organising workshops, and producing biofouling management tools and guidelines.

Concluding remarks

Biofouling is a costly problem for finfish and shellfish farmers, the extent of which varies at the local and regional scale, and depending upon the farming practices employed. Uncontrolled biofouling on aquaculture infrastructure and stock leads to increased maintenance costs and production losses (low growth/poorer quality). Currently there are no sustainable and cost-effective solutions to the biofouling problem in aquaculture. More effective control and management of the biofouling problem is expected to reduce production costs and secure the quality of product. Potential cost savings are estimated to be 5-10% of the market value, €130-260 million.

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References

- Arakawa K. 1980. Prevention and removal of fouling on cultured oysters: a handbook for growers. Maine Sea Grant Technical Report No. 56.
- Baum C., W. Meyer, L.G. Fleischer and D. Siebers. 2002. Biozidfreie Anti-fouling Beschichtung, EU Patent EP1249476A2.
- Beaz D., V. Beaz, S. Dürr, J. Icely, A. Lane, J. Thomason, D. Watson and P.R. Willemsen. Sustainable Solutions for Mariculture Biofouling in Europe. ASLO Meeting, Santiago da Compostela, Spain, 19th June 2005.
- Campbell D.A. and M.S. Kelly. 2002. Settlement of *Pomatoceros triqueter* (L.) in two Scottish lochs, and factors determining its abundance on mussels grown in suspended culture. *J. Shellfish Res.* 21:519-527.
- Carver C.E., A. Chisholm and A.L. Mallet. 2003 Strategies to mitigate the impact of *Ciona intestinalis* (L.) biofouling on shellfish production. *J Shellf Res* 22:621-631.
- Costello M.J., A. Grant, I.M. Davies, S. Cecchini, S. Papoutsoglou, D. Quigley and M. Saroglia. 2001. The control of chemicals used in aquaculture in Europe. *J Appl Ichthyol* 17:173-180.
- De Nys R.C., P. Steinberg, T.S. Charlton and V. Christov. 2004 Antifouling of shellfish and aquaculture apparatus. Unisearch Limited, US, p 32.
- European Commission. 1998. Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market. Official J. of the EC, L 123/1. <<http://europa.eu.int/comm/environment/biocides>>
- Hidu H., C. Conary and S.R. Chapman. 1981. Suspended culture of oysters: biological fouling control. *Aquaculture* 22:189-192.
- Hodson S.L., T.E. Lewis and C.M. Burke. 1997. Biofouling of fish-cage netting: Efficacy and problems of in situ cleaning. *Aquaculture* 152:77-90.
- Hodson SL, C.M. Burke and A.P. Bissett. 2000. Biofouling of fish-cage netting: the efficacy of a silicone coating and the effect of netting colour. *Aquaculture* 184:277-290.
- IMO. 2002. International Maritime Organization, Antifouling Systems, <http://www.imo.org>.
- Lane A. and P.R. Willemsen. 2004. Collaborative effort looks into biofouling. *Fish Farming International* September 2004: 34-35.
- Lodeiros C and Garcia N (2004) The use of sea urchins to control fouling during suspended culture of bivalves. *Aquaculture* 231:293-298
- McCloy S and R. De Nys. 2000. Novel Technologies for the reduction of biofouling in shellfish aquaculture. In: Fisheries N (ed) Flat Oyster Workshop, Sydney, p 19-23.
- Menton DJ and J.H. Allen. 1991. Spherical (Kiel) and square steel cages: First year of comparative evaluations at St. Andrews, NB. *Bull Aquacult Assoc Canada* 91:111-113.
- Railkin A.I. 2004. Marine biofouling: colonization process and defenses. ISBN 0-8493-1419-4. CRC Press.
- Rikard F.S., R.K. Wallace and C.L. Nelson. 1996. Management strategies for fouling control in Alabama oyster culture. *J Shellf Res* 15:529
- Suquet M., B. Petton, Y. Normant, A. Dosdat and J.L. Gaignon. 1996. First rearing attempts of pollack, *Pollachius pollachius*. *Aquatic Living Resources* 9: 103-106.