EFFECTS OF BIOFOULING ON SHELLFISH AQUACULTURE

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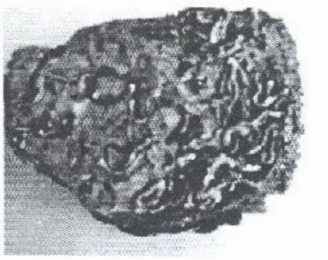
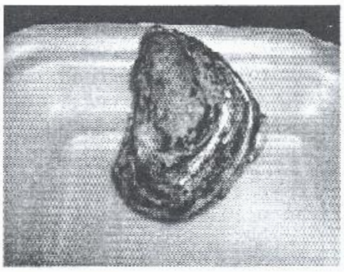
ABSTRACT
The culture of oysters, clams, scallops, and other molluscs is collectively one of the fastest growing sectors of the aquaculture industry. An inherent issue with shellfish culture methods, particularly for off-bottom culture (i.e. floating trays, racks, long lines, strings, rafts), is biofouling. This can occur directly, by biofouling of the animals themselves, or indirectly, by fouling of cages, nets, filters, and other equipment. Problematic biofouling species have been identified and segmented into six groups: algae, barnacles, mussels, tubeworms, ascidians and hydroids. Controlling and mitigating biofouling can result in significant costs for commercial shellfish culture operations.

Key words: epibiosis, filter feeding, competition for food, aquatic invaders, marketability.

INTRODUCTION
Biofouling or biological fouling is the accumulation of fouling organisms on suitable substrates submerged under water. Such accumulation is referred to as epibiosis when the host surface is another organism. According to some estimates, over 1700 species comprising over 4000 organisms are responsible for biofouling (RTBOT, 2012). Biofouling organisms can be broadly divided into two based either on their sizes or their chemistry and biology composition. In terms of size, biofouling is divided into microfouling- biofilm formation and bacterial adhesion, and macrofouling- attachment of larger organisms. While in terms of composition, biofouling is divided into hard or calcareous types (e.g. barnacles, encrusting bryozoans, molluscs, polychaetes, zebra mussels), and soft or non-calcareous types (e.g. seaweed, hydroids, algae, biofilm/slime). Commensal or parasitic association of epibionts with their host constitutes biofouling, which may contribute to significant losses to the fishery industry (Quinn *et al.*, 2009). This can occur directly, by biofouling of the animals themselves (Rodriguez & Ibarra-Obando, 2008), or indirectly, by fouling of cages, nets, filters, and other equipment (Braithwaite & McEvoy, 2005).Shellfish are a very popular and nutritious food source worldwide and their consumption has risen dramatically. The culture of oysters, clams, scallops, and other molluscs is collectively one of the fastest growing sectors of the aquaculture industry (Charles *et al.*, 2011). An inherent issue with shellfish culture methods, particularly for off-bottom culture (i.e. floating trays, racks, long lines, strings, rafts) is biofouling, Fig. 1. Biofouling of cage netting and a subsequent decrease in water flow and food availability is a major obstacle for growers of filter feeding shellfish (Katherine *et al.*, 2002).



Fouled oyster shell



Foul-freed oyster shell

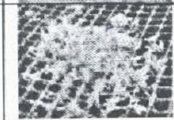
Fig.1. Mangrove oyster, *Crassostrea gasar*

Shellfish and biofouling organisms
Problematic biofouling species have been identified and segmented into six groups: algae, barnacles, mussels, tubeworms, ascidians and hydroids, Table 1. Oysters and ascidians are filter-feeding organisms and exploit a common resource because of overlap in the size of particles they filter from the water column, especially when in dense infestations (Aguirre-Munoz *et al.*, 2001). In oyster culture, intensive competition for living space and food develops among oysters and fouling organisms (Arakawa, 1990). Fouler smothers mussels and oysters, preventing them from opening their shells to filter food; making starved and weakened shellfish easy targets for predators. Clubbed tunicates (*Styela clava*) interfere with the settlement of oyster and mussel larvae and compete for space and food with young oysters and mussels (Charles *et al.*, 2011). It is assumed that fouling organisms reduce scallop growth by competing for food and space or by reducing water flow through nets, and hence the supply of food and oxygen and removal of waste products (Lu & Blake, 1997).

Biofouling and aquaculture
Biofouling of commercial bivalve species has deleterious impacts on product growth, marketability, and profitability (Braithwaite & McEnvoy, 2005). Any fouling cover that develops on the shells of oysters is logistically problematic for oyster farmers because each oyster has to be manually cleaned, representing a large labor cost (Aguirre-Munoz *et al.*, 2001); also the organisms can cause shell deformities that decrease the

marketability of the product (Taylor *et al.,* 1997). A case study is found in a survey of existing commercial culture operations conducted among growers in seven U.S. regions (Charles *et al.*, 2011), where the survey solicited information on business descriptors, perception of biofouling as a problematic issue, and costs associated with control. Respondents indicated that efforts to control biofouling accounted for an average of 14.7% of total annual operating costs. Over 40% of respondents indicated that biofouling affected the marketability of their product. Survey findings suggested that the total costs associated with biofouling control by shellfish growers in the regions studied exceed $21 million.

Table 1. Some representatives of the types of fouling organisms (CRAB, 2012)

Species	Descriptive notes	Picture
Alaria esculenta (Dabberlocks) Algae/Chromophycota	Brown algae, claw shaped holdfast, short cylindrical stipe, wavy membranous lamina ca. 70mm in length, supple and flexible to texture, max. Length 2m, permanently attached, solitary, found in high density, yellow to olive green, low intertidal to subtidal to 8m depth, found on very exposed shores at depth of up to 35m.	
Ulva intestinalis (Gut weed) Algae/Chlorophycota	Green algae, inflated, irregularly constricted, tubular, generally unbranched fronds 100-300mm in length, common epiphyte on shells and other algae, occur on all level of the shore.	
Jania rubens (Red algae) Rhodophycota	Red algae, calcareous jointed fronds, form thick tufts, usually attached to other algae, epiphyte, and upper sublittoral to a depth of 8m.	
Balanus crenatus (Acorn barnacle) Barnacle/Crustacea	Barnacle, shell comprised of six shell plates cover, shell plates are white smooth and slightly toothed or ridged in large individuals, calcareous base with average basal diameter 25mm, epifaunal, sublittoral, can be found in the lower shore, solitary, permanently attached.	
Balanus improvisus (Acorn barnacle) Barnacle/Crustacea	Barnacle, white or grey conical smooth wall shell, shell opening diamond-shaped and toothed, base up to 15mm diameter, base is calcareous, flat, thin and permeated by pores, height less than base diameter, mid-shore to sublittoral, brackish water and estuarine.	
Mytilus edulis (Common blue mussel) Bivalve/Mollusca	Bivalve, roughly triangular shaped shell, shell is smooth with a sculpturing of concentric lines, purple or blue but brown have been observed, average length range 50-100mm, attaches with hair-like byssus threads, high intertidal to subtidal, from open coast rocky shores to rocks and piers in estuaries and sheltered harbours, solitary and gregarious, found in dense masses of up to 5 layers, commonly fouled with barnacles and seaweed.	
Pomatoceros triqueter (Keel worm) Tubeworm/Polychaete/ Annelida	Polychaete, white smooth irregular and curved calcareous tube, a distinct ridge on the tube tapers at tail end, tube 3.5mm wide and 25mm length, bright white to cream, epibenthic, sublittoral down to 70m depth, encrust rocks, stones and shellfish, solitary, permanently attached.	
Botrylloides leachi (Colonial sea squirt) Ascidian/Sea squirt/Chordata	Ascidian, sessile, filter feeding, subtidal, colonial or unitary, average length 1.5-3mm, plain orange, pink or bright yellow, gregarious, non-migratory.	
Tubularia indivisa (Tall tubularia) Hydroid/Cnidaria	Hydroid, large100-150mm height, stem holding a solitary conical flask shaped polyp brightly coloured with shades of pink and red, erect fused stem with dense tuft at base, central cluster of 40 oral tentacles surrounded by 20-30 larger tentacles, intertidal to shallow shore, found on lower shore rock pools to 280m depth.	

SOURCE: CRAB, 2012

Solutions to try to reduce the amount of fouling in bivalve aquaculture systems have been tested, although, eradication is unlikely populations could be reduced so that deleterious impacts are undetectable (Cigarria *et al.*, 1998). In some systems manual cleaning during grow out has been found to be effective if it can be performed on a monthly basis (Enright, 1993). A number of physical (e.g. heat, exposure to sun, boiling, and concentrated brine bath) and chemical (e.g. insecticides, herbicides) techniques have been developed to limit biofouling in oyster culture (Arakawa, 1980,1990). Although these methods are effective, they increase labor costs during grow out (Cigarria *et al.,* 1998). Spraying chemicals to control fouling and predation is not an option for shellfish growers (BCSGA, 2002).Compared with chemical methods of eradicating fouling (e.g., DDT, chlorides), biological control is less likely to produce side effects such as pollution and it holds promise for the future of the fisheries industry (Arakawa, 1990). To deal with these problems, growers use a combination of avoidance, prevention and pro-active methods. Currently, no cost effective solution exists despite the testing of many prospective control techniques (Patrick *et al.*, 2012).

Effects and impacts of biofouling according to CRAB, 2012

Problematic for stock species as can compete for space and resources. Obstruct opening of bivalve shells. Reduce the value of shellfish.Increases the weight of equipment particularly lines making them so heavy that mussels can slip off before they can be harvested. Increases labour and production costs as a result of cleaning and removal of biofouling.Cause damage to infrastructure through burrowing. Negative effect on infrastructure and equipment by obstructing the flow of water through net reducing clearance rates, levels of dissolved oxygen and overall fish welfare.

Principles of management

Combat settlement; by avoidance method. One suggested solution is to monitor fouling communities, and when the population of a fouling species is observed, to immediately target that population (i.e. racks) for maintenance and cleaning to try to remove the biomass of that species before it becomes sexually mature (Aguirre-Munoz et al., 2001). Protect equipment and stock; by prevention method. Onshore net washing, air drying nets and trays, biological control (Sea urchins and periwinkles), lowering lines below photic zone during major spatfalls, coatings (use of copper sulphate and silicon), (CRAB, 2012).Removing biofouling; by control method. Manual or mechanical cleaning, dipping (freshwater or chemical solution), (CRAB, 2012).

CONCLUSION

Biofouling can severely increase the weight of cages, reduce its buoyancy, cause physical damage to the nets, retard the exchange between the water within and outside of the cages, compete with the cultivated species for food and substrate resources, and can even affect the stock growth directly. Controlling and mitigating biofouling can result in significant costs for commercial shellfish culture operations (Charles *et al.*, 2011). Feasible and realistic fouling control solutions will only be successful when they are developed with local farming practices and constraints in mind.Because more labor is hard to afford and time is always limiting, a successful management solution to control fouling communities would be one that is low cost, low time investment, and ideally can be easily incorporated into other maintenance or routines already in place (Cigarria *et al.*, 1998). However, shellfish aquaculture can be exciting and profitable for the person willing to work hard and deal with the challenges and risks.

REFERENCES

Aguirre-Munoz, A., R. W. Buddemeier, V. Camacho-Ibar, J. D. Carriquiry, S. E. Ibarra-Obando, B. W. Massey, S. V. Smith & F. Wulff. (2001). Sustainability of coastal resource use in San Quintin, Mexico. Ambio 30:142–149.

Arakawa, K. Y. (1980). Prevention and removal of fouling on cultured oysters. A handbook for growers, Maine Sea Grant Technical Report No 56. 38pp.

Arakawa, K. Y.(1990). Competitors and fouling organisms in the hanging culture of the Pacific oyster, *Crassostrea gigas* (Thunberg), Mar. Behav. Phys. 17: 67-94.

BCSGA (2002). Fouling and Predation. BC Shellfish Growers Association. Unit F-2002 Comox Ave.., Comox, BC V9M £m6 250.890.7561.

Braithwaite, R. A. & L. A. McEnvoy (2005). Marine biofouling on fish farms and its remediation. Adv. Mar. Biol. 47:215–252.

Charles M. Adams, Sandra E. Shumway, Robert B. Whitiatch, Tessa Getchis (2011). Biofouling in Marine Molluscan Shellfish Aquaculture: A Survey Assessing the Business and Economic Implications of Mitigation. Journal of the World Aquaculture Society Vol. 42 issue 2, pages 242-252.

Cigarria, J., J. Fernandez and L. P. Magadan (1998). Feasibility of biological control of algal fouling in intertidal oyster culture using periwinkles. Journal of Shellfish Research, Vol. 17 No. 4, 1167-1169.

CRAB (2012). Organisms fact sheet. Types of fouling organisms. Collective Research on Aquaculture Biofouling. www.crabproject.com

Enright, C. (1993). Control of fouling in bivalve aquaculture. World Aquacult. 24:44–46.

Katherine A. Ross, John P. Thorpe, Trevor A. Norton, and Andrew R. Brand* (2002). Fouling in scallop cultivation: Help or Hindrance? Journal of Shellfish Research Vol. 21 No. 2, 539-547.

Lu. Y. T. & N. J. Blake (1997). The culture of the southern bay scallop in Tampa Bay, an urban Florida estuary. Aquae. Int. 5:439—450.

Patrick Cahill, Kevin Heasman, Andrew Jeffs, Jeannie Kuhajek & Douglas Mountfort (2012). Preventing ascidians fouling in aquaculture: screening selected allelochemicals for anti- metamorphic properties in ascidians larvae. Biofouling: The Journal of Bioadhesion and Biofilm Research Volume 28, Issue 1, pages 39-49.

RTBOT.net. (2012) Biofouling information, videos, News and Images about biofouling..

Taylor, J. J., P. C. Southgate & R. A. Rose (1997). Fouling animals and their effects on the growth of silver-lip pearl oysters, *Pinctada maxima* (Jameson) in suspended culture. Aquaculture 153:31–40.