# Anti-fouling Paints and Boat Bottom Maintenance

## 1.3 Understanding the Structure and Stages of a Fouling Community

A biofilm of bacteria and microscopic algae pave the way for attachment of:

- barnacles
- bivalves
- sponges
- polychaetes
- sea anemones
- seaweeds
- bryozoans
- sea squirts
- worms

Drag: is friction that happens as a vessel moves through the water.

- slows sailboats
- causes power boats to use more fuel
- reduces maneuverability
- increases hull deterioration

Microfouling: refers to biofilm formation and bacterial adhesion.

Macrofouling: refers to attachment of larger organisms.

Hard fouling: Calcareous organisms including:

- barnacles
- mollusks
- polychaetes and other tube worms
- bryozoans
- zebra mussels

Soft fouling: Non-calcareous organisms

- seaweed
- hydroids
- algae
- biofilm slime

NOTE: Most larger fouling organisms require a biofilm to attach.

There are four stages of the ecosystem of the marine fouling community.

Within the first minute that an unprotected surface is submerged there are chemical Van Der Waals interactions so the unprotected surface will become covered with a conditioning film of organic polymers.

Within 24 hours there will be bacterial adhesion and then diatom adhesion.

A biofilm will be in place by the end of the first week, with secondary colonization to which macrofouling organisms will attach such as:

- tunicates
- sessile cnidarians like anemones
- mollusks

### Biofouling as a Process

Steps in the Development of a Biofilm Over One Week:

- Transport of organic molecules and bacteria towards a submerged surface
- Absorption of organic molecules, resulting in a "conditioned" surface which is more favorable for attachment of bacteria
- Attachment of bacteria to the conditioned surface
- Metabolism of attached microorganisms resulting in faster adherence to the surface
- Growth of bacteria
  (NOTE: Detachment of part of the bacterial film can be caused by over development of biofilm and loss of mechanical strength due to action of the current)
- Diatom settlement
  (When settling of diatoms occurs, biological factors begin to outweigh the physical factors for attachment of fouling organisms.)

Larvae and spores of other fouls come along in a month to a year.

In summary: bacteria → then autotrophs like algae that make their own food → followed by heterotrophs that need external sources of food

- same process for salt water and fresh water
- same for different kinds of substrates and different surface properties
- Succession of fouling organisms is determined by biological interactions rather than seasons, etc.
- success depends on biological feedback from fouling organisms to one another

Microfouling: bacteria and diatoms are dominant, also have unicellular fungi, other algae, and protists

Macrofouling: spores of macroalgae, larvae of invertebrates, lower chordates like ascidians

Five Stages of Fouling:

- Transport
- Attachment
- Growth
- Settlement
- Development

NOTE: Biofilms induce and stimulate macrofouling

### All About Macrofouling

Initial macrofouling organisms are fast growing, colonial organisms which establish within 2-3 weeks to two years, and include:

- sea anemones
- hydroids
- ascidians (tunicates, sea squirts)
- polychaetes
- serpulids
- bryozoans

Secondary macrofouling organisms are slow growing organisms which establish within several years and may be more dependent on seasonality. They Include:
- sponges
- other ascidians
- mussels and other mollusks

NOTE: Barnacles are less dependent on biofilms

NOTE: Hydroids prepare microenvironments for bryozoans to colonize the substrate

NOTE: In Delaware, mussels settled better on substrates occupied by ascidians and hydroids

NOTE: Red algae (some) may inhibit the settlement and growth of other species

Course of development and aborted succession may be affected by:
- conditions under which biofouling takes place
- geographical region
- location of water area
- degree of physical stability of the environment
- set of species in adjacent communities
- season in which substrate was submerged
- duration of substrate submersion in water
- distance from bottom

Under unstable conditions for fouling, succession can be inhibited many times:
- may even get bare patches
- or may get a more complicated course of succession

NOTE: "Underwater mechanical cleaning of a vessel hull for macrofouls is not always effective and may result in even faster fouling: Why? Because antifouling paint is removed by the cleaning!"
- Removal of tenacious fouls like barnacles often takes a chunk of antifouling paint leaving a spot that is totally unprotected and quickly fouled again
- The process of recovery of mechanically disturbed fouling communities was experimentally shown to occur in 3-9 days in fresh water.
- Recovered communities may have even more species than initial undisturbed communities because of bare patches that have recolonized.

Soft Versus Hard Fouling

Recruitment is the first step to establishing and maintaining a population of fouling organisms. Fouling occurs very rapidly on newly immersed, unprotected surfaces. Heterogeneous mixes of organic material create a conditioning film which subsequently influences settling of microbes. Bacteria and diatoms settle within HOURS and form a microfilm layer. After this, macrofouling develops within DAYS.

Soft Fouling:

Macroalgae Soft Fouls:
- Enteromorpha
- Ulva
- Ulothrix
- Ceramium
- Ectocapus
- Cladophora
- Polysiphonia

Invertebrate Soft Fouls:
- Soft corals
- Anemones
- Hydroids
- Sponges
- Tunicates

Hard Fouling:

Invertebrate Hard Fouls:
- Barnacles
- Mussels
- Tubeworms

Level of Fouling Pressure Depends On:
- Location and time of year
- Tropics are worse:
- Warmer water
  - Uninterrupted breeding season

Results of Fouling on Vessel Hull:
- Decreases speed
- Increases the consumption of fuel and therefore the cost
- Loss of time, money
- Increases cleaning, maintenance, and repair
- Increases in heavy metal pollution from antifouling paints and practices
- Unacceptable heavy metal concentrations shown in mussels is a strong indicator of marine pollution
  - Heavy metals that accumulate in micro and macro algae have long term impacts on food chains in coastal communities

The most common macroalgae fouling is caused by:
- Green algae: Enteromorpha and Ulva
- Brown algae: Ectocapus

Chemotaxis: may be a stimulant for settling of fouling algae.

Phototaxis: light may play an important part in motile algae cell site selection as well as dispersal, recruitment, and attachment.
- Macroalgae recruitment may be influenced by positive or negative phototaxis
- Negative phototaxis is a useful adaptation to increase the likelihood of finding a suitable substrate on which a motile cell can attach, especially in shallow coastal areas

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