Fouling in shellfish aquaculture

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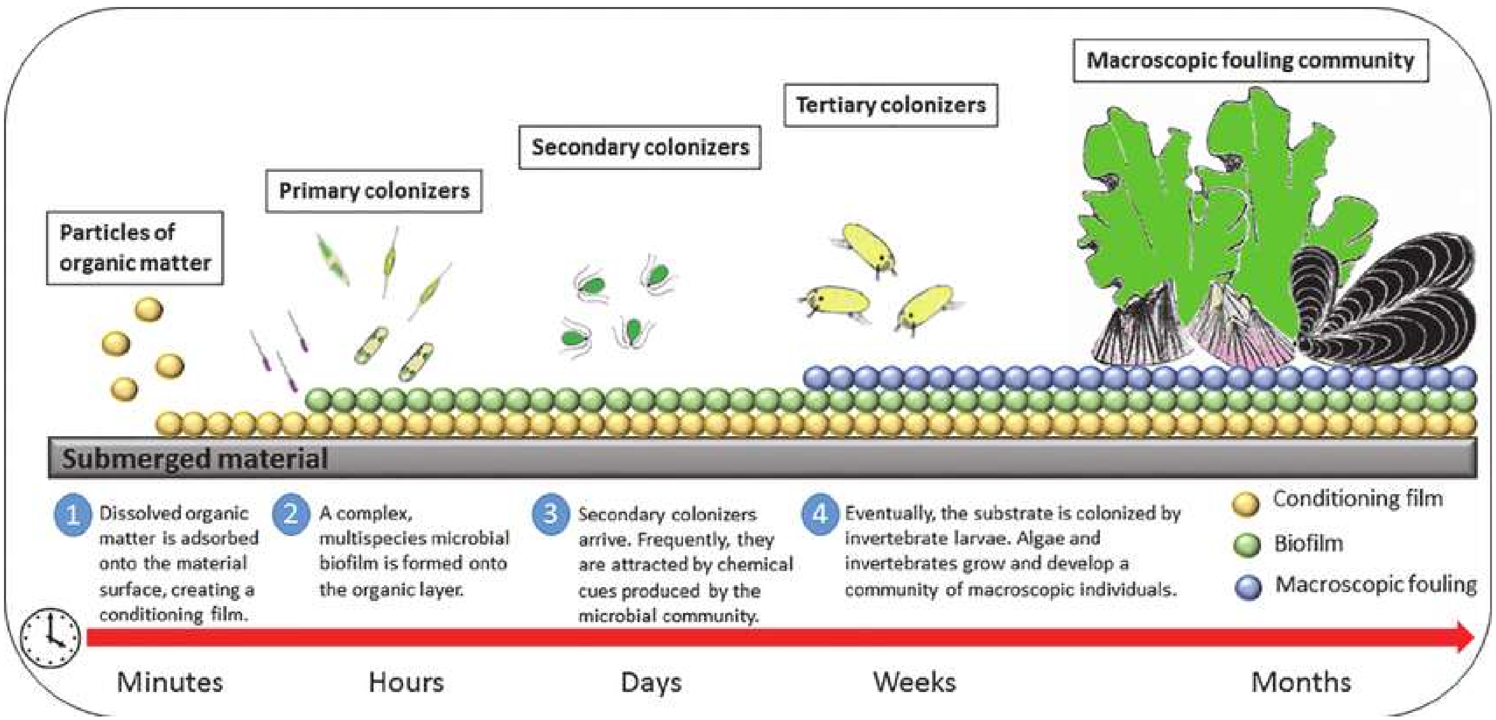
Fouling

- Shellfish aquaculture results in the placement of various structures in the water
  - The presence of such large and varied surfaces provides for a broad diversity of epibiotic organisms to settle and grow



Fouling

- Biofouling can have significant economic impact on farming operations
    - Conservative estimates of 5–10% of production costs attributed to biofouling
    - The direct costs of biofouling control
        - Salmon: US$ 0.03 to $ 0.12 per kg of salmon produced
        - Bay scallops: 30% of final market price
        - Oysters: 20% of final market price
        - US shellfish farms: 14.7% of total annual operating costs
    - The indirect effects of fouling on the production of cultured species remain largely unassessed (e.g. less food flux => slower growth)

The impacts of biofouling

- The effects of biofouling of shellfish and equipment fall into five major categories:

  (1) direct physical damage by invasive organisms that
  - bore into the shell (endoliths)
  - epibiotic calcareous organisms growing on the shell surface, affecting aesthetics

  (2) mechanical interference of shell function due to colonization of shells
  - particularly around the hinge and lip
  - affecting feeding ability and susceptibility to predators

  (3) biological competition for resources such as food and space
  - affecting growth and condition

  (4) environmental modification due to colonization of culture infrastructure
  - leading to reduced water flow, waste build-up, decreased oxygen levels and reduced food availability
  - in addition, biodeposition and the spread of non-indigenous organisms can have deleterious effects on surrounding natural ecosystems

  (5) increased weight from biofouling biomass on stock and equipment
  - e.g. panels, nets, ropes and floats
  - leading to greater production costs associated with extra maintenance requirements and loss of stock and equipment

Frequency of fouling control

- Highly site specific
  - Depends on how rapidly fouling organisms settle and grow on your site
- Need to monitor gear to ensure shellfish are getting enough water flow
  - Oxygen
  - Food (also competitors for food)
- There are other reasons to remove fouling organisms as well
  - Aesthetics/marketability

Common fouling organisms

- Macro-algae
  - Ulva
  - Enteromorpha
  - Codium
- Invertebrates
  - Solitary tunicates
  - Colonial tunicates
  - Hydroids
  - Tube worms
  - Boring sponge
  - Overset
    - Oysters
    - Barnacles
    - Mussels


Chlorophyta
Rhodophyta
Phaeophyta
Codium vermilara Stackhouse
Sphaerococcus coronopifolius Stackhouse
Cystoseira tamariscifolia (Hudson) Papenfuss
Codium adhaerens C. Agardh
Plocanium cartilagineum (Linnaeus) P. S. Dixon
Padina pavonica (Linnaeus) Thivy
Ulva lactuca Linnaeus
Osmundea pinnatifida (Hudson) Stackhouse
Sargassum vulgare C. Agardh

Algae

Sea lettuce (*Ulva* sp.)

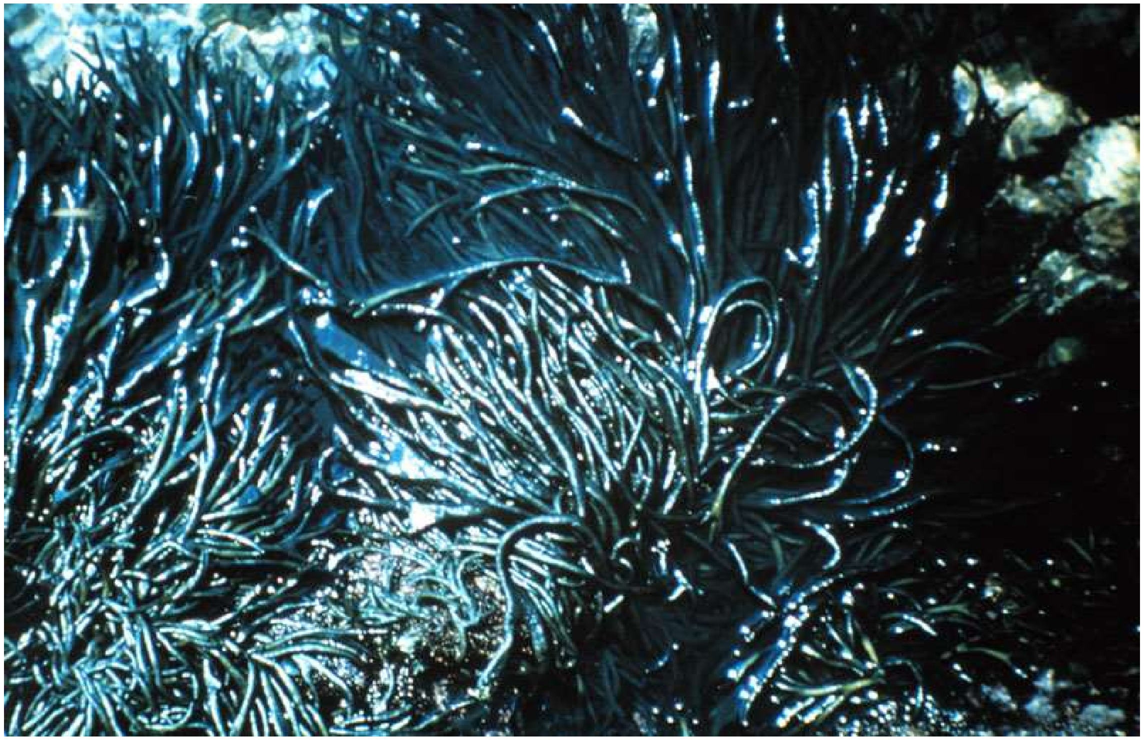
NATIVE

Algae

Hollow weeds (*Enteromorpha* sp.)

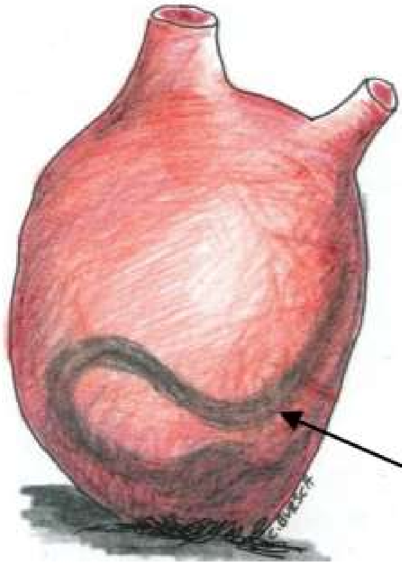
NATIVE

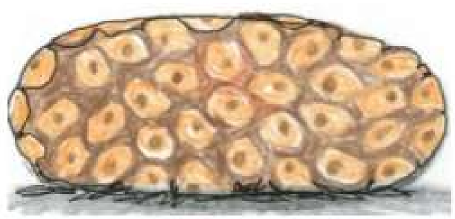
Algae
Dead man's fingers (*Codium tomentosoides*)



EXOTIC

Tunicata





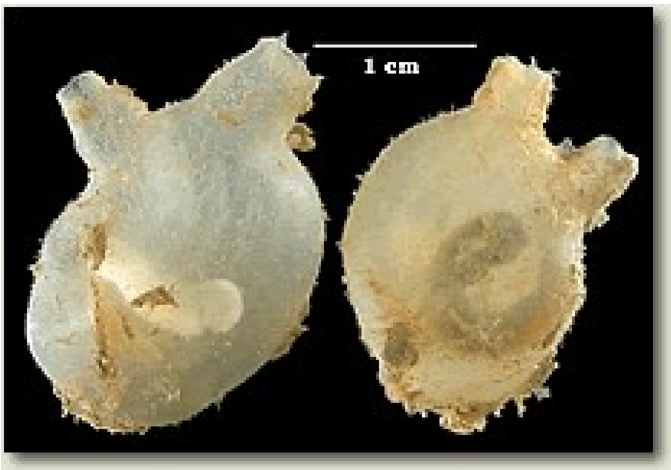
- Solitary or Colonial
- Firm or spongy
- Position of siphons lateral, terminal
- Tunic smooth, hairy or bumpy
- Presence of spicules (microscopic)
- Shape of gut

Solitary Tunicates
Styela clava
(Club Sea Squirt)

EXOTIC

Solitary Tunicates

Molgula manhattenensis (Sea Grape)



NATIVE

Molgula fouling an oyster cage

Solitary Tunicates

Ciona intestinalis (Vase Tunicate)

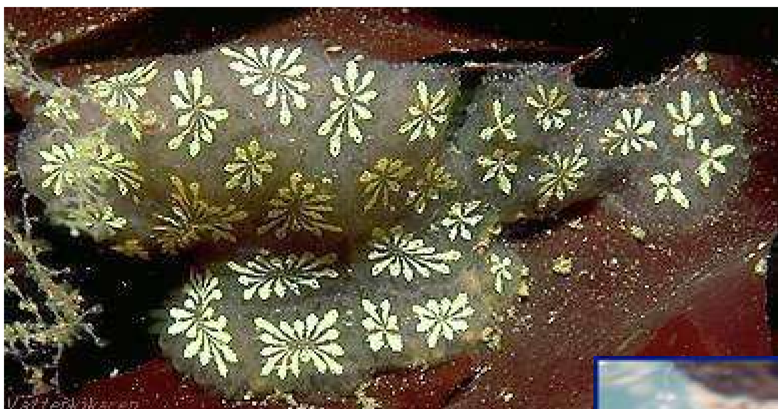
NATIVE

Ciona fouling an oyster cage

Colonial tunicates

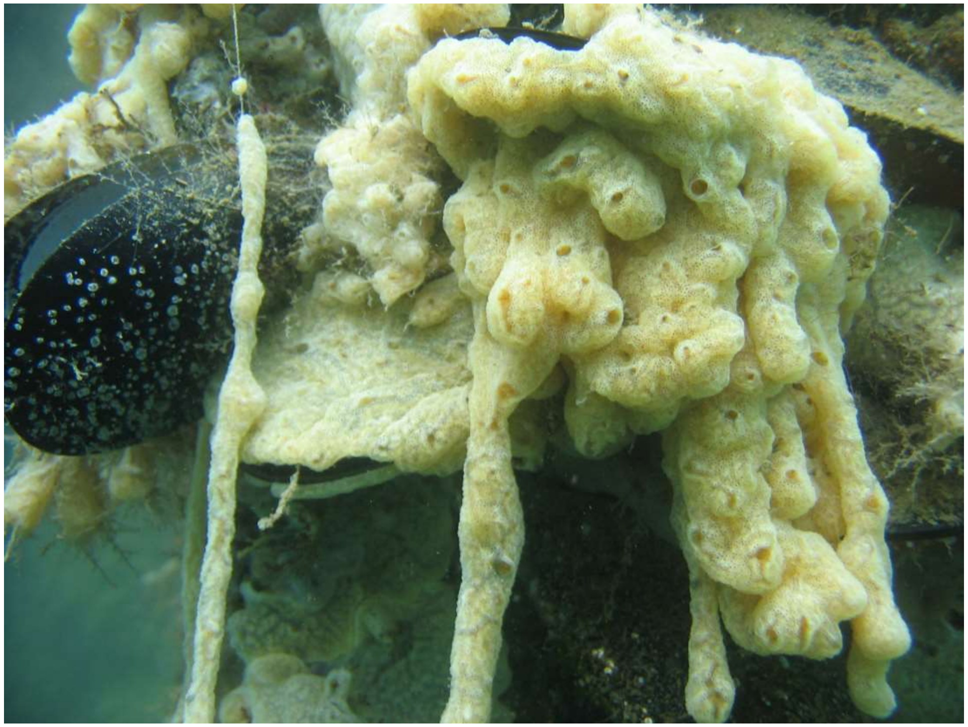
(Botryllus schlosseri & *Botrylloides violaceus*)

(Star Tunicate) (Orange-sheath Tunicate)



EXOTIC

Colonial tunicates
Didemnum sp.
(Pancake Batter Tunicate)



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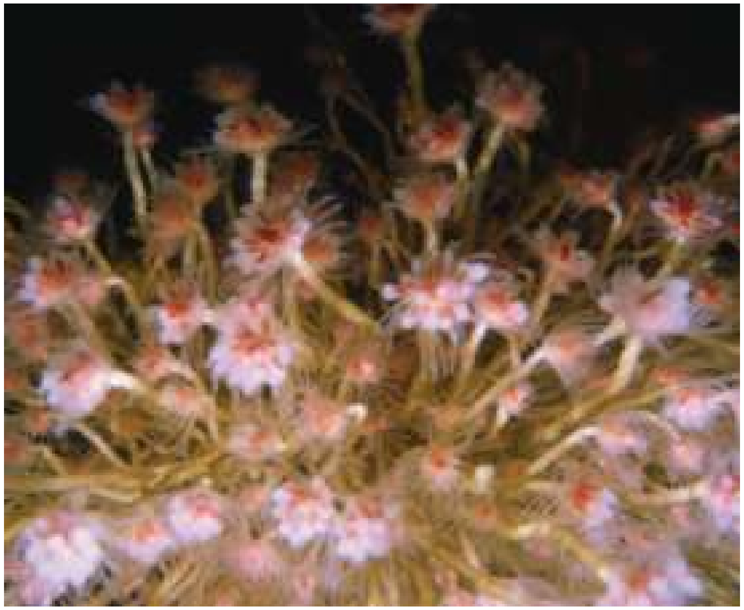
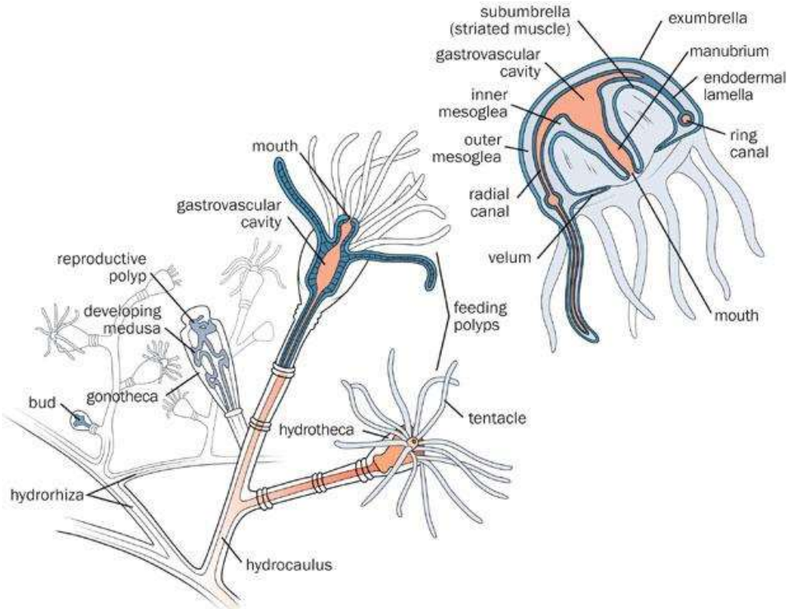
Hydroids





EXOTIC

Boring Sponge
Cliona

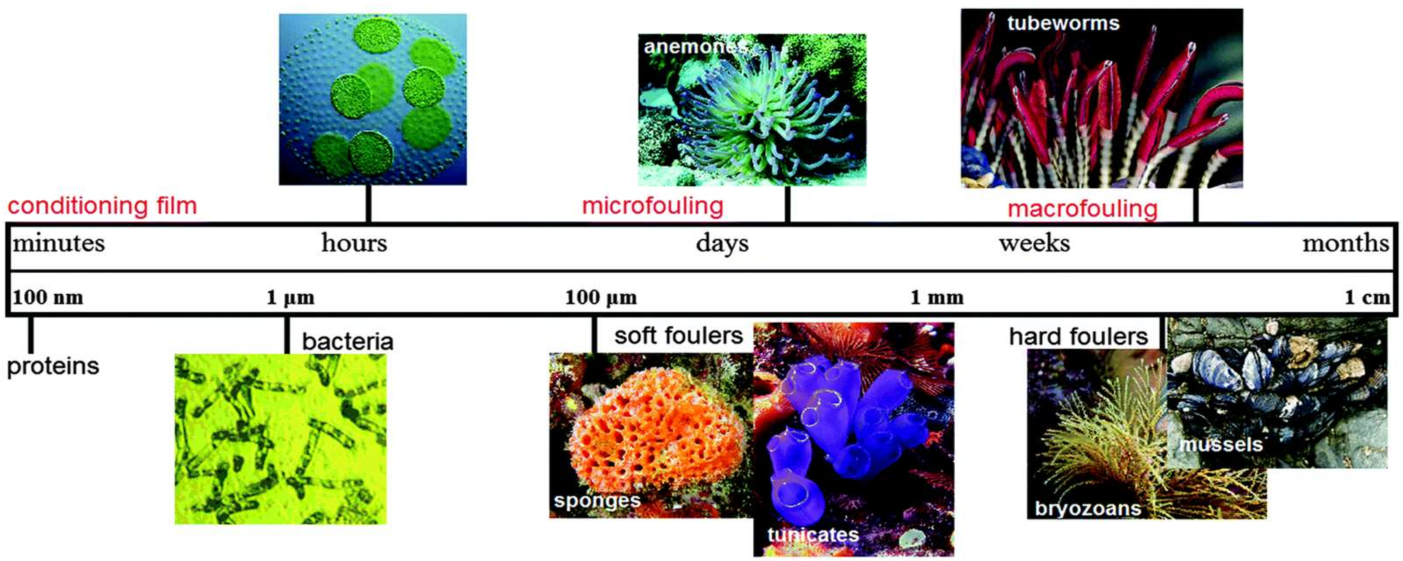
NATIVE

Over-set

NATIVE

Control of fouling

- Biofouling develops through a well-known ecological process
  - whereby macrofouling derived from the spores and propagules of algae, and the larvae of invertebrates, develops rapidly within days to weeks



- Various technologies and husbandry techniques to manage and control fouling communities

Control of biofouling

- Methods to avoid, mitigate or prevent the effects of biofouling in shellfish culture fall into five broad categories:

  (1) **avoidance** of natural recruitment to prevent settlement and growth of biofouling

  (2) **physical removal** ranging from scrubbing and brushing to chemical dips and sprays

  (3) **biocontrol** using natural species

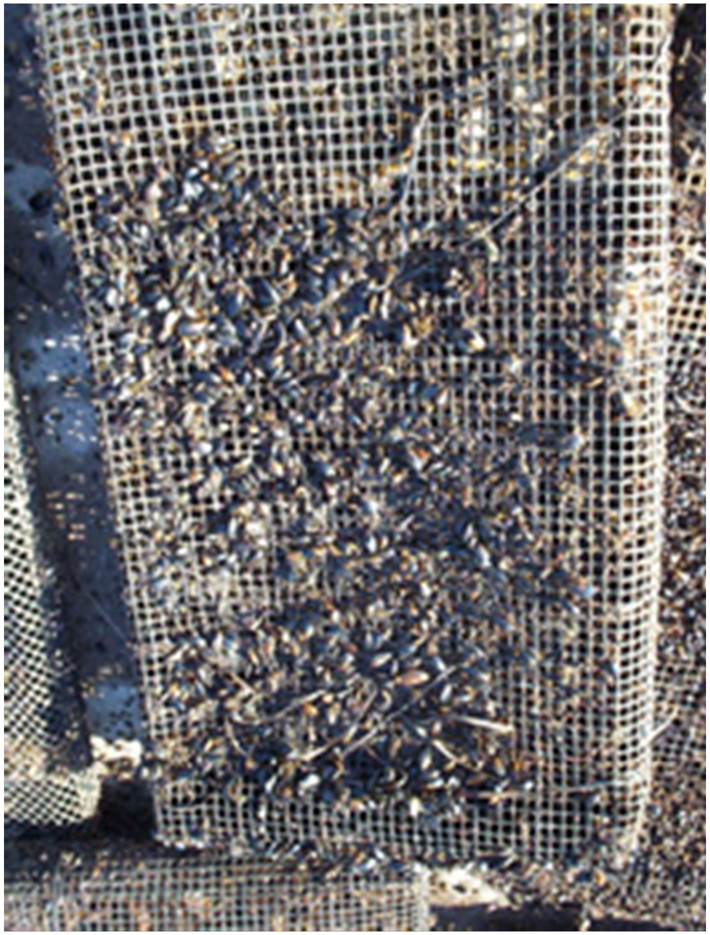
  (4) **antifouling** coatings and organic biocides

Avoiding natural fouling recruitment

- Understanding the larval and settlement biology of biofouling organisms offers the opportunity to manage an annual strategy to minimize colonization by fouling species
  - e.g. barnacle set generally happens in late winter and very early spring (February/March)
  - they set in shallow areas on hard substrate
  - Can you overwinter your oyster gear into areas that deters barnacles setting (e.g. deeper water)?
- Not always easy due to unpredictability of natural cycles

Physical Removal

- This will make up the bulk of your workday
  - However, we won't spend a lot of time on this because your options are fairly straight forward!
- Find some way to remove the fouling materials!



Fouling control

- Physical removal
  - Brushing
  - Power washing

Fouling control

- Air drying
  - 24 to 48 hours

- Intertidal
  - Air dry with every tidal cycle for 2 hours

Fouling control

- Gear rotation
  - NRCS EQIP program
    - 25% redundancy in gear
    - Remove and replace
    - Clean fouled gear shoreside

Fouling control – Chemical dips

- ONLY use these techniques on shellfish species that can completely close their valves (i.e. oysters and some clams)
- **Freshwater dip**
  - May require exposure times of minutes to days
- **Brine dip** (oysters over 5 mm)
  - Saturated brine solution (~25 lbs salt in 10 gals seawater)
  - Leave oysters out for 30-60 minutes to ensure closed
  - Dip for 5 to 15 minutes
  - Air dry for 2-4 hours
- **Acetic acid**
  - 5% acetic acid (vinegar strength)
  - Spray with garden sprayer
- **Hydrated lime** (used for starfish – probably will work for tunicates)
  - aka "Slaked lime" = Calcium hydroxide
  - 40 g/L in a tank
  - Dip for 20-30 seconds
- Some growers have combined hydrated lime with brine for a "double dip"

Fouling control - hot water dip

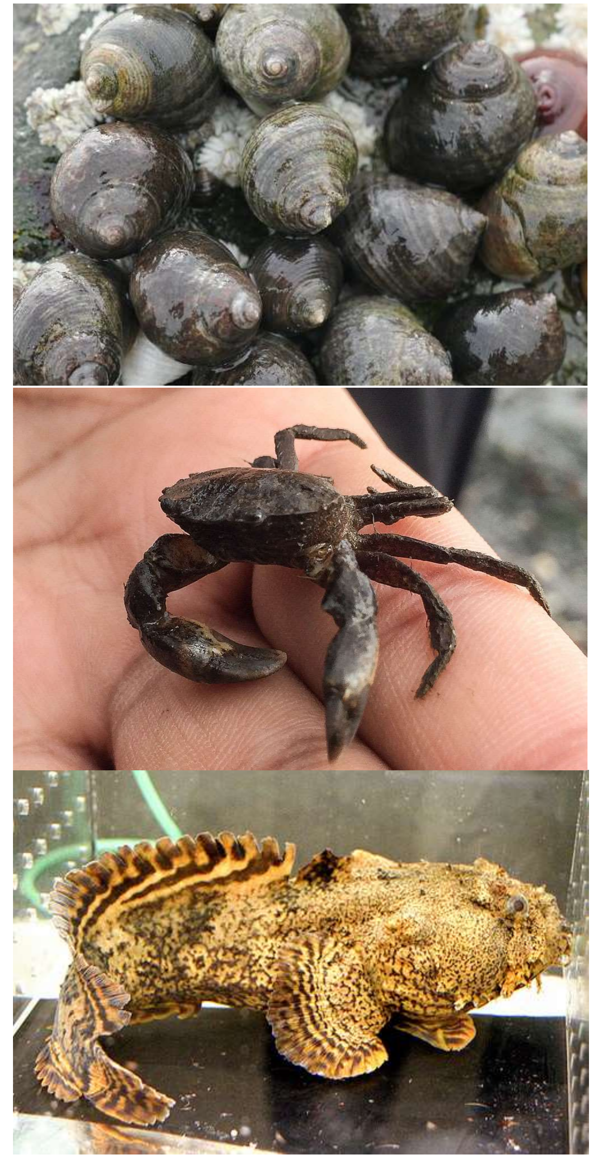
- **Hot water dip**
  - 82^{o}C (182^{o}F) dip for 3 seconds immediately followed with a cool water dip
- **Korean: Hot water treatment**
  - Heat up seawater to 55-60^{o}C (130-140^{o}F)
  - Soak oyster in the heated sea water for 10 to 15 seconds.
  - This method is effective in eradicating *Mytilus* spp., *Balanus* spp., and Ascidians
- **Alaskan**
  - Do not hot dip seed!
  - Oysters between 1.5–2.0” – 130^{o}F for 30 seconds
  - Oysters greater than 2.0” – 130^{o}F for 45 seconds

Caveats for using chemical dips

- Do not subject small seed to dips
- Do not plan dipping during the most stressful times of the year
  - Winter/Spring (when water temp. is the coldest)
  - Heat of Summer (when water temp. is the hottest)
- ALWAYS pre-test your dipping protocol on a small number of individuals first
  - Monitor their survival for a week or two after treatment

Biocontrol

- Predation of pest species by other marine organisms
  - Periwinkles or sea urchins placed in oyster bags may cut back of algal fouling
  - Crabs will consume many small soft-bodied fouling organisms
    - But need to make sure of size differential between crab and shellfish
  - Fish can consume crabs and other consumers entering the cage/bag system
    - Oyster toadfish (*Opsanus tao*)



Antifouling Coatings & Biocides

- Traditionally used antifouling paints containing toxic levels of tin, nickel or copper
  - Copper-based paints commonly available now (TOXIC)
- Other strategies for antifouling coatings
  - Ablative coatings – slough off from surface
  - Non-toxic antifouling coatings

NETMINDER
AQUACULTURE COATINGS

GRAS

Biofouling In Summary

- Significant management issue
  - increased operational expenses
  - deleterious impacts on bivalves
- Understand the fouling communities on your farm
  - mitigate with timing of placing out gear
  - time of year to treat crop
- Mechanical removal of biofouling remains dominant in shellfish culture
- Future developments need to advance the development of non-toxic, low surface energy coatings