Internal Hull Biofouling: Effects of Surface Properties and Resuspension of NO-BOB Sediments

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Questions

- Relationship of ballast water biofilms to transport of nonindigenous, exotic species to new ports?
- Comparative aboard-ship biofilm growth/sampling methods?
- Influences of ports (water quality), materials (surface energy), and ballast exchange on biofilm characteristics?

Prior Work

- PBU (Portable Biofouling Unit)
  - Flow cells
  - Surface Energy

- Benchmark Organisms
  - Immunofluorescence Staining
  - 5 species, all Gram negative rods, comprise max. 39% of biofilm species

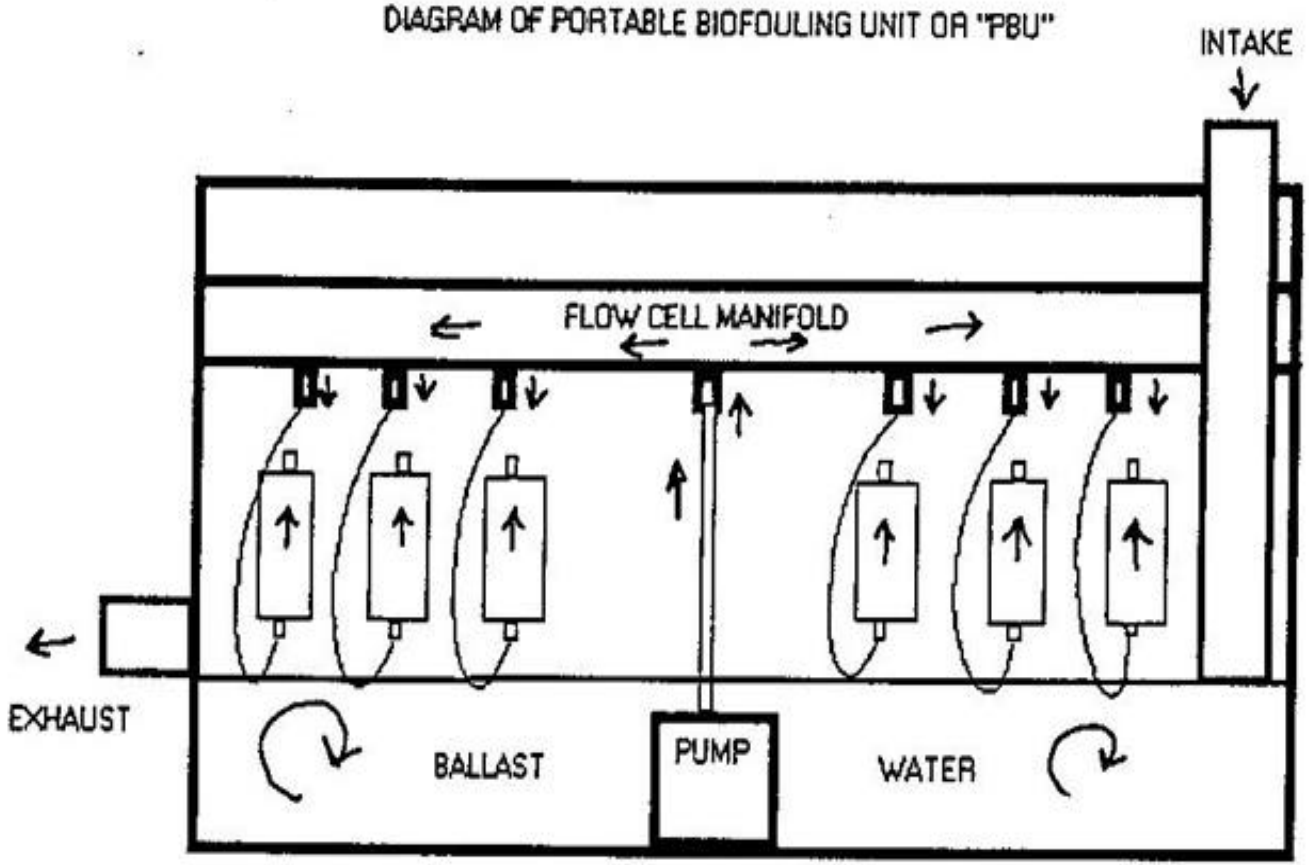
(Ref: Zambon, JJ, Huber, PS, Meyer, AE, Slots, J, Fornalik, MS and Baier, RE (1984) In situ identification of bacterial species in marine microfouling films by using an immunofluorescence technique. Applied and Environmental Microbiology, Vol. 48, No. 6:1214-1220.)

This Work

- Compare PBU with BOB (Ballast Organic Biofilm) sampler
- Examine ballast exchange events
- Assess influence of port location and sequence on biofilm complexity

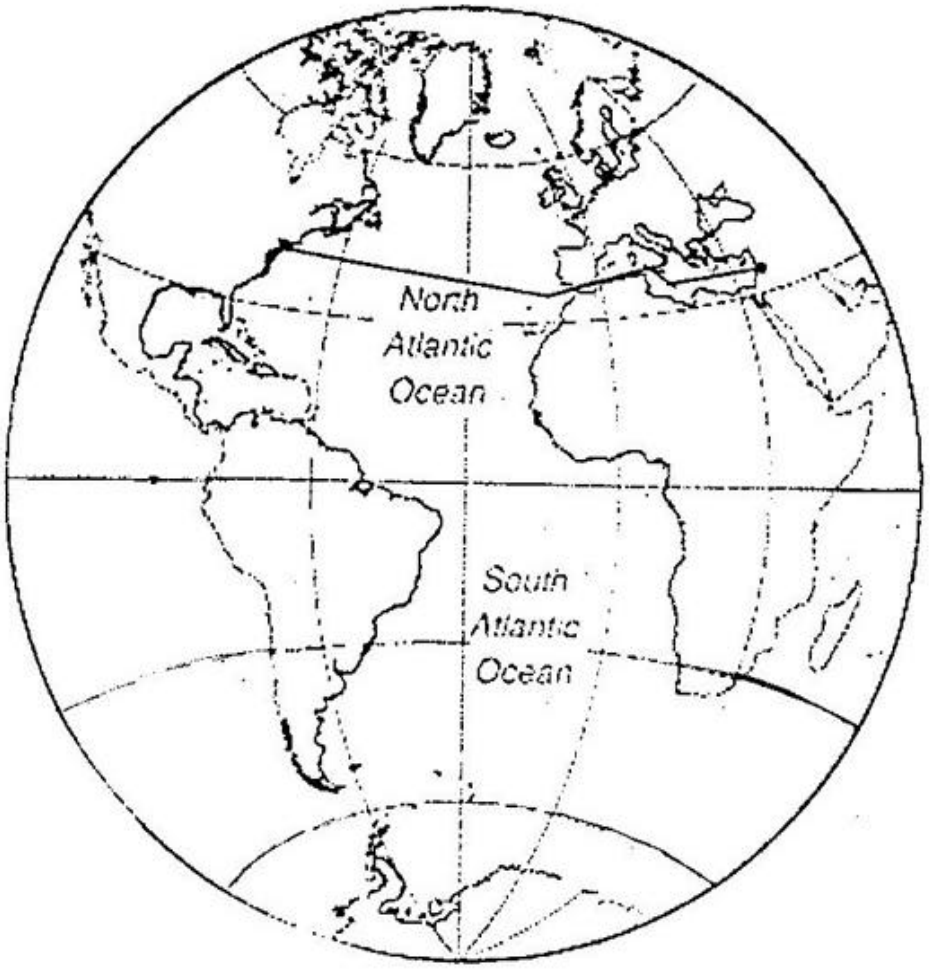
Portable Biofouling Unit

DIAGRAM OF PORTABLE BIOFOULING UNIT OR "PBU"



Ballast Organic Biofilm Samplers

Hadera cruise path



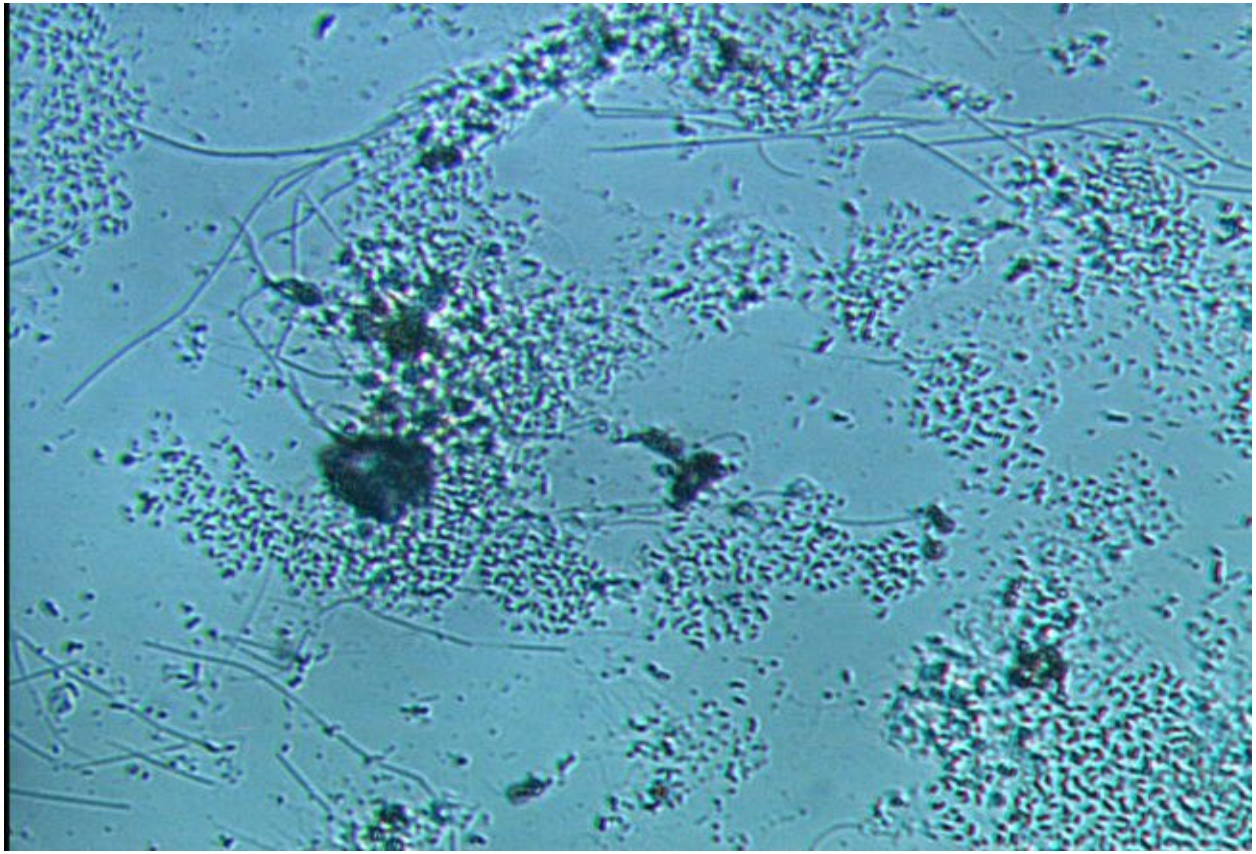
Hadera References

- Hulsmann N, Baier RE and Galil BS (2000) The Hadera Study: Effects and limitations of open-ocean exchange concerning the dispersal of heterotrophic protists, American Society of Limnology and Oceanography (ASLO), Oral Presentation

- Drake LA, Ruiz GM, Galil BS, Mullady TL, Friedmann DO, and Dobbs FC, (2002)

  Microbial ecology of ballast water during a trans-oceanic voyage and the effects of open-ocean exchange, Marine Ecology Progress Series, Vol. 233:13-20

Biofilm on glass from BOB sampler deployed aboard Hadera for 17 days, light microscope image



(Meyer et al., ASLO 2000)

- Risk assessment, prediction, and limitation of transport of bioinvaders in biofilms. American Society of Limnology and Oceanography

(Ref: Meyer, AE, Baier, RE, Hulsmann, N, Friedmann, D, Forsberg, RL (2000) Risk assessment, prediction, and limitation of transport of bioinvaders in biofilms. American Society of Limnology and Oceanography (ASLO), Poster Presentation.)

ASLO Conclusions (Meyer et al., 2000)

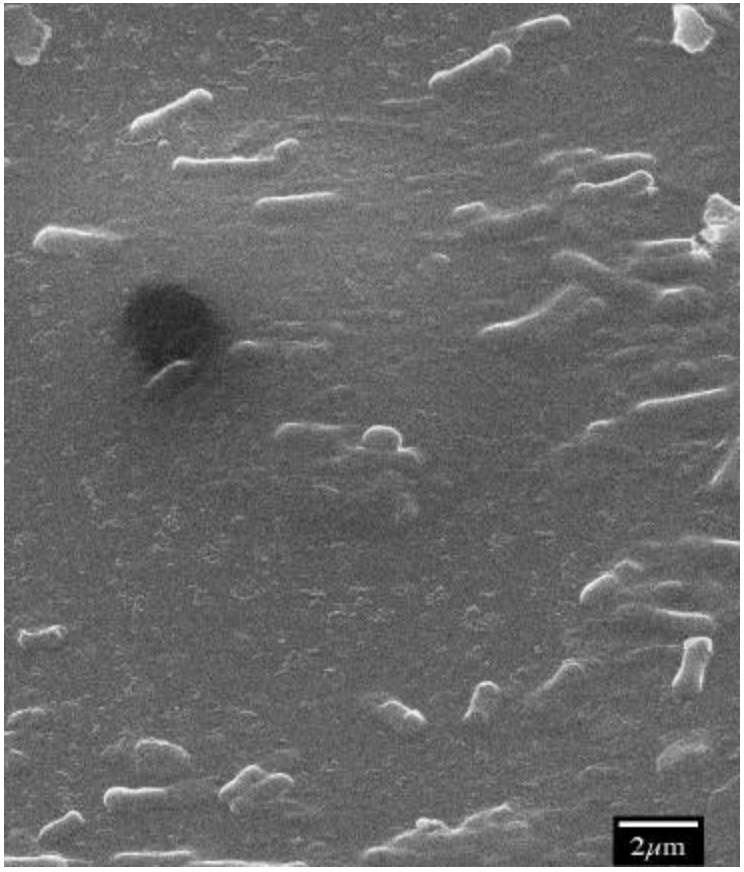
- viable biofilms were formed on all test materials placed in the ballast tanks of the coal carrier *Hadera*
- Biodiversity was different on different test surfaces; methylsilicone polymeric coatings supported the least diverse biofilms
- biofilms formed on surfaces in the ballast tanks of the Hadera “seeded” secondary biofilms in artificial seawater environments in the laboratory

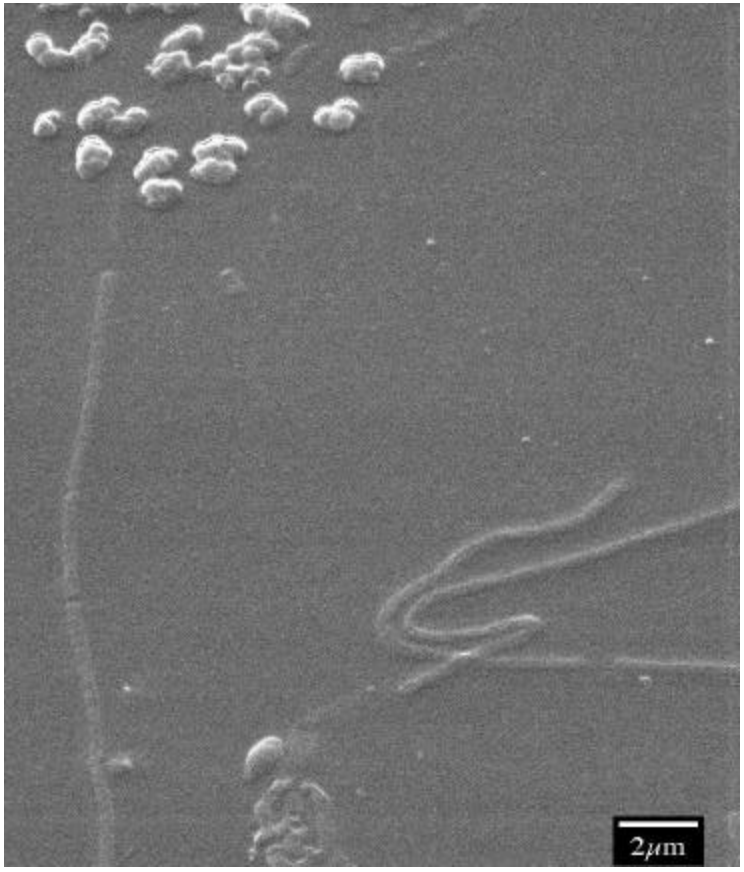
Forsberg, Patel, GLRC 2000

- High surface-energy materials showed the most attached colonizers
- Flow cells installed after mid-ocean ballast exchange showed new attached filamentous colonizers

- Ballast water biofilms roughly follow the nonlinear biofouling vs. surface energy curve established for hull fouling and other types of biological adhesion
- Mid-ocean ballast water exchange increases the apparent biodiversity of some biofilms

SEM images of biofilms on surfaces before ballast exchange (left) and after ballast exchange (right)





First Conclusion

- Ballast exchange can increase biodiversity and biocomplexity of biofilms, and therefore is not always a good idea.

Second Conclusion

- Minimal biodiversity & clumping on low-energy surfaces, recommend use of similar ballast compartment wall coatings for ease of re-suspension of biofilm organisms into volume phase

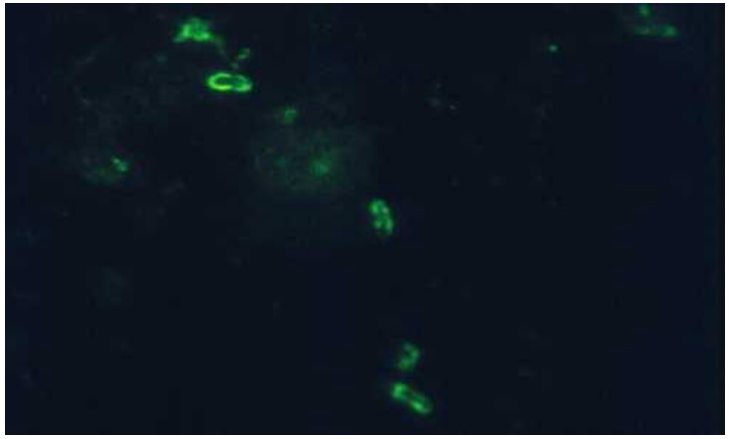
Immunofluorescent stained “benchmark” organisms in oceanic biofilms

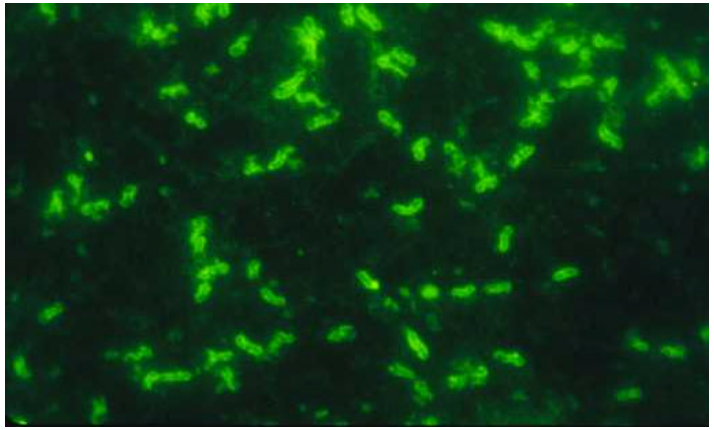
Top Left – Comamonas terr.

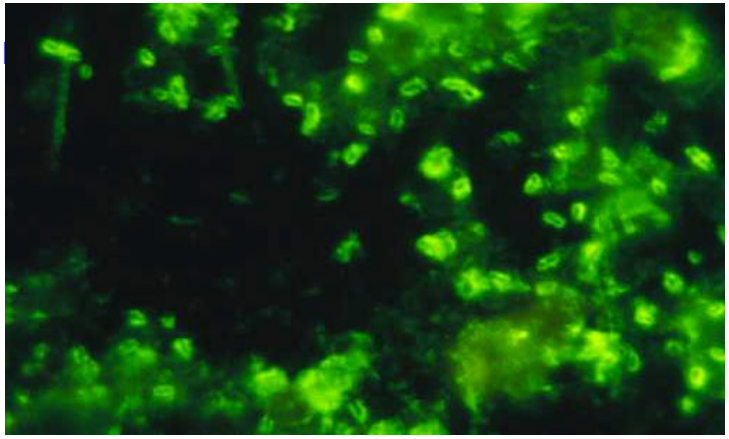
Top Right – Vibrio alginolyticus

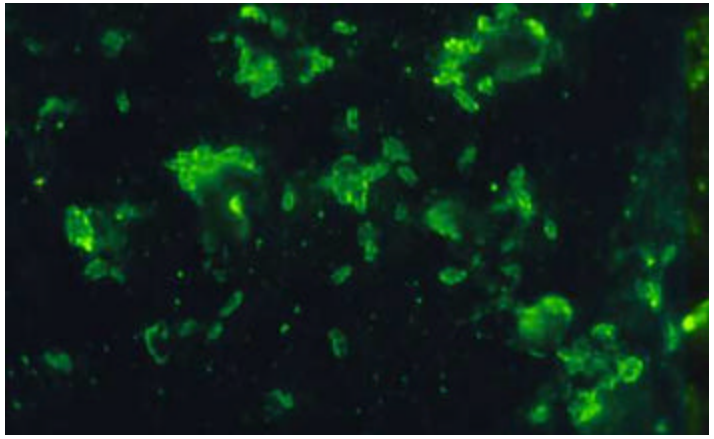
Bottom Left – P. putrfaciens

Bottom Right – Pseudomonas sp.









BOB deployments on ZIM cruises

- ZIM China - 1 biofilm sampler
- ZIM Pacific – 3 biofilm samplers, 2 cruises
  BOB A & B – cruise I
  BOB B & C – cruise II
- Identical travel routes, different ballast histories
- Mediterranean Sea >>> Atlantic Ocean >>> Caribbean Sea >>> Pacific Ocean >>> South China Sea >>> Reverse >>>

Statistical analysis of numbers of benchmark organisms

- No material dependence
- No BOB position dependence
- No up/down dependence
- Yes – select port dependence
- Yes – “prior” exposure dependence

New Observations

- Up/down inorganic sedimentation difference
- Ballast history and port differences
- Different compartment (corrosion?) conditions noted

Work in Progress: Biofilms as “vertical seed beds” in North American Great Lakes where NOBOB vessels are energetically re-ballasted, re-suspending sediments into biofilms