EAS Congress 2009 Manila

Workshop on the Development and Advances on Marine Biosafety in the Context of the Convention on Biodiversity

Prospects for Research and Technology Development in Marine Biofouling Prevention

Presented by Dr Serena TEO

Tropical Marine Science Institute

National University of Singapore

What is Biofouling

- Biofouling is the undesirable growth of organisms on man-made structures
- What you use to kill fouling organisms will kill any other marine organism too
- Any organism can become a fouling organism in the “right” circumstances
- Marine biofouling occurs on ships, Port infrastructure, navigational instruments, seawater intake pipes (heat exchangers, cooling systems, desalination plants), oil platforms, etc.
- On vessels, they reside on unprotected surfaces, crevices and low flow areas such as sea chests

For most vessels with antifouling coatings in good condition, the fouling present is ~1%. But 1% of a large ship is more space than the same organisms can hope to find on a crowded reef!

SHIPS ARE VERY LARGE!

Hitch-hiking across the world's oceans

Types of organisms:

- Planktonic (primarily ballast water)
- Benthic mobile fauna and cryptic species (BW & Fouling)
- Sessile marine organisms (primarily fouling; larval stages also via BW)
- other terrestrial pests residing in cargo holds, etc

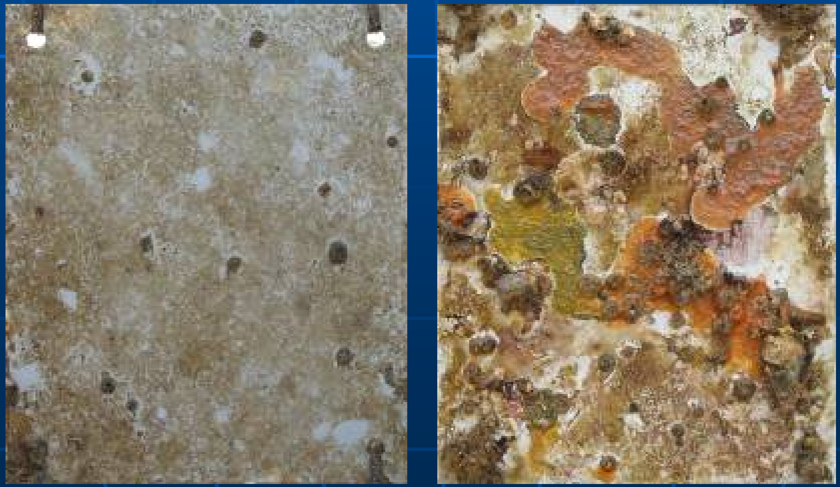
- Apte et al. (2000)[1] highlighted major ports as places where organisms may also transit to other Ports via by "jumping ship"

- The journey is much less hazardous now as ships travel faster than ever before, increasing survivorship

[1] *Apte et al. (2000) Biological Invasions Vol. 2(1):75-79*

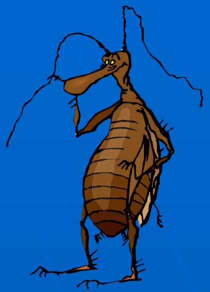
Fouling communities are diverse and vary across time and space

Fouling communities on navigational buoys from the East to West of Singapore (>20km)



Fouling community on a foul-release coating: Dec vs July

Life History Characteristics of "Successful' Pest Organisms



- Opportunistic, generalist, fast growing, hardy, not fussy about where they settle → able to colonize and adapt quickly to living in disturbed/polluted environments and on synthetic materials!

- Spawning events in many sessile invertebrates are triggered by stress – change in environment, stress of removal from surface – release of thousands of larvae increases the chance that the species does not get wiped out

Amphibalanus amphitrite, just 3- 5 days from spawning to settlement, and reaches full adult size in 2 weeks

Biofouling as a vector

- Molnar et al. (2008)[1]: 69% of invasives transferred via shipping, of which 39% occurred as hull-fouling
- Studies of alien species in Hawaii, NZ, Australia, North Sea and North America indicate that an average of 70% were introduced via biofouling, with 42% for Japan (IMO paper, BLG 12/11)[3]
- Risks from hull-fouling may exceed the threats from ballast water (Drake & Lodge, 2007[2])
- Few consolidated reports available for tropical Southeast Asia - due to lack of historic baseline survey data, poor taxonomic status of many tropical groups.

[1] *Molnar et al.(2008) Frontiers Ecol Environ Vol 6(9): 485-492*
[2] *Drake & Lodge (2007) Aquatic Invasions Vol 2(2): 121-131*
[3] *http://www.gisp.org/publications/reports/BiofoulingGuidelines.pdf*




Invasions in tropical marine ecosystems

- While there are records for introductions, there are few records of marine invasions for tropical Southeast Asia
- Yeo et al (2009)[2] found that >50% decapod species on a semi-submersible oil platform brought into Singapore for cleaning were non-native (and one new species!).
- *Megabalanus coccopoma* have been observed on ships brought in for cleaning, but as yet not observed in local fouling communities.
- Hutchings et al. (2002)[1] hypothesized that high biodiversity and low endemicity offer fewer niches for NIS to become established and become invasive.
- On the other hand, stressed marine ecosystems and man-made environments are vulnerable and starting points for invasions into a new region.

Carijoa riisei, originally Atlantic and now found in the Pacific and Southeast Asia

Watersipora subtorquata is tolerant of copper coatings and now found in most ports

[1]*Hutchings et al. (2002) Pacific Science Vol 56(2): 223-233*
[2]*Yeo et al (2009) Biofouling 26(2):179-186*

Variables contributing to amount of fouling observed on vessels

1. Vessel characteristics
   - Age of vessel
   - Typical speed and voyage profile
   - Typical duration in port
   - Duration since last dry dock
   - Antifouling systems, vessel design

2. Operation history & travel routes
   - Characteristics of the "Donor" vs "recipient" ports

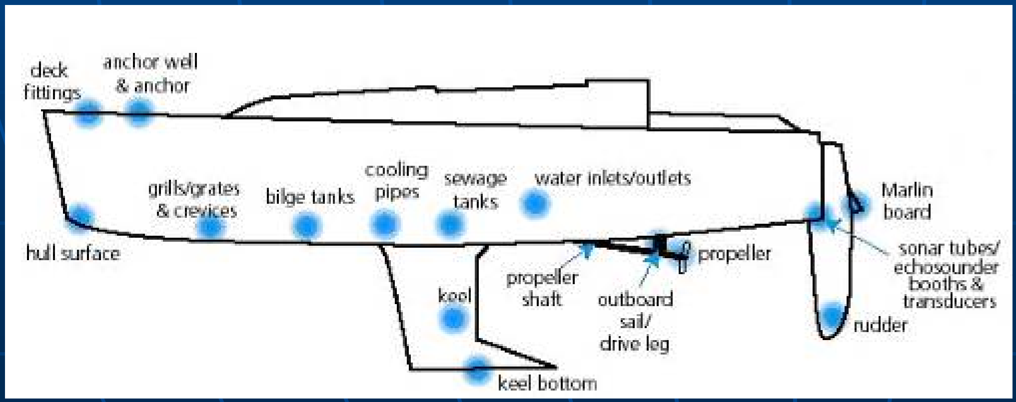
3. Biology and physiology of fouling organisms

[1]Davidson et al. (2009) Biofouling Vol. 25(7): 645-655
[2]Floerl & Inglis(2005) Biological Invasions Vol. 7(4):589-606

Ships as vectors

- More fouling present in crevices and non-hull areas[1,3]
- Vessels that spend more time in Port and/or travel at lower speed (due to longer time at pierside or in near-coastal waters, shorter port-to-port/regional voyages) have more fouling[1,2]
- Longer time between dry docking increases the extent and diversity of fouling present[1]

[1]Davidson et al. (2009) Biofouling Vol. 25(7): 645-655
[2]Coutts & Taylor (2004) NZ J Mar Freshw Res Vol 38(2):215-229
[3]ASA(2006) Commercial Vessels Biofouling Project Final report. Australian Shipowners Assocn



High risk areas on a recreational vessel
(Diagram courtesy of AQIS/West Coast Ballast Outreach project)

Photo courtesy of ASA

Impacts of Biofouling

- Direct economic cost for shipping

- Cost of AF application (new VLCC, USD 150-400k); Cleaning and maintenance costs (Hull cleaning, approx USD 35k) – average about 10% total cost of vessel
- Fuel costs account for 50% of operational cost of a ship, and slime alone will cause a 4% drop in speed[1]

- Biodiversity and ecological impacts

  Once introduced, eradication is nearly impossible. The real cost is a large annual budget for pest management

- Cost of eradication of *Mytilopsis sallei* from Darwin Harbour - US$1.6m excluding manpower costs
- Management of zebra mussels in the Great Lakes - US$100m/yr

Mytilopsis sallei is very tolerant of low salinity and pollution conditions

[1]*Schultz, 2007. Biofouling Vol 23(5): 331-341*

Marine Fouling Prevention

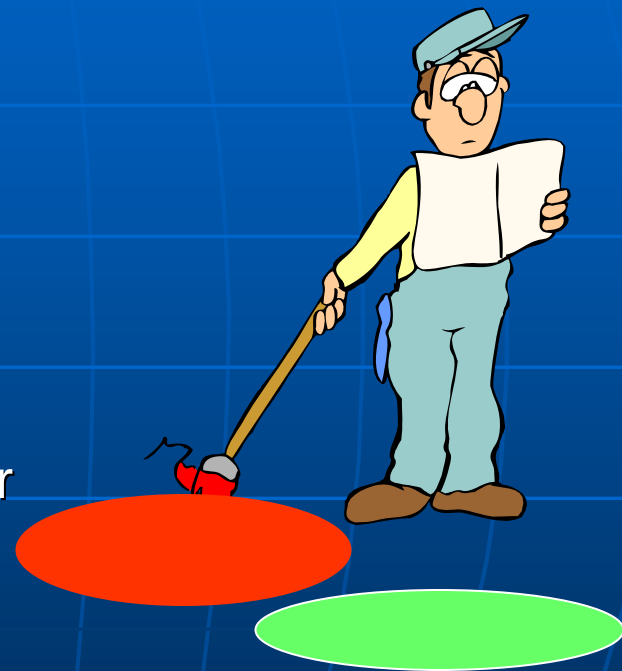
- Antifouling Coatings & Treatment Systems
- Environmental impacts from the use of toxic antifouling substances
- Management Practices to reduce fouling on ships

ANTIFOULING

A) BIOCIDES

- Coatings
  - Metal sheathing
  - Contact leaching/Diffusion
  - Controlled Depletion Polymers
  - Self-Polishing Copolymers

- Chemical based dosing systems
  - Electrochlorination
  - Dosing of biocides used in water treatment systems



- Non-foul bioactive materials
  - non-leaching biocides
  - “non-toxic” organic “repellents”

TBT → Copper → Cu/Zn+ “¤” → ??

Balancing Environmental Costs

- Switch from TBT to copper paints has increased incidence of biofouling and the frequency of dry docking
- SPC coatings require vessels to be active 70% of the time; 5-7 days in anchorage is sufficient for fouling to establish
- But use of more toxic coatings increases the risk of bioaccumulation of toxic substances in the environment, thus reducing fitness of native biodiversity, resulting in native habitats becoming more susceptible to invasions
- Existing compounds are not degrading fast enough: note how regulation against compounds seem to correspond with their attaining larger market share (TBT, Copper, Irgarol, Diuron..)
- Biological degradability is key!

ANTIFOULING

B) Methods employing non-chemical physical properties of materials

- Fouling release coatings
- Surface properties that minimize fouling adhesion

- Use of thermal shock and heat treatments
- Use of ultrasound/acoustic methods

Intersleek® 900 for U.K. Navy's Flagship

SpecialChem - Sep 9, 2009
http://www.specialchem4coatings.com/news-trends/displaynews.aspx?id=12017

Technology Gaps

- Existing marine AF coatings were invented to improve ship performance: reduce fouling so there is less drag and better fuel economy and engine performance. They do not specifically address biosecurity concerns.


10 home

thesundaytimes October 25, 2009

ALL AT SEA

Overbuilding and global recession moor more than 500 ships, along with their crew

Robin Chan

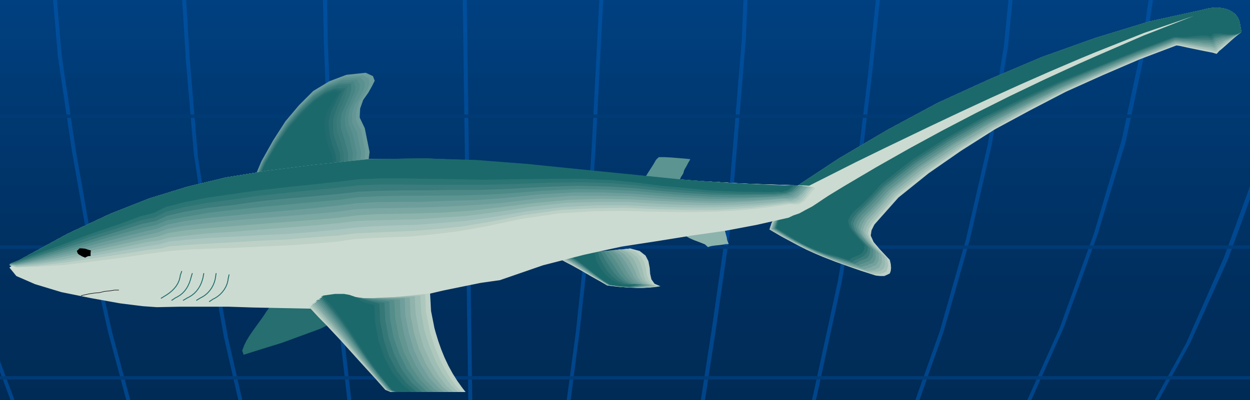
Ablative and foul-release coatings only work when ships are moving, and moving fast!

ANTIFOULING R&D

NEXT GENERATION SOLUTIONS

- Stimuli-responsive
- Bio-mimetic
- Rapidly degradable

→ Combination of methods with synergistic properties that will deliver good performance at a lower environmental cost



Technology Gaps

- Existing coatings R&D is conservative as development costs are very high.
- Lack of international coating performance standards make it difficult for new technologies to enter a marketplace dominated by a few large players.

- New R&D is needed to tackle ship fouling
  - Better ship design to reduce fouling in niche areas
  - Better designs to facilitate maintenance activities
  - Better coatings and tools that allow regular maintenance

Management of fouling

- Appropriate use of AF coatings
- Regular service and maintenance of coatings – in water cleaning and dry-dock
- Hull-grooming
- Appropriate waste disposal measures

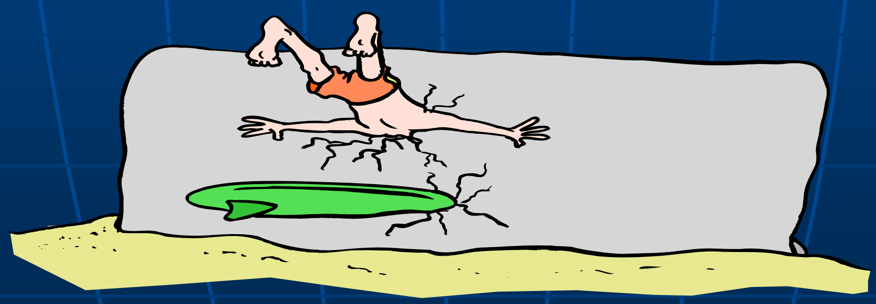
- R&D to enable better quality risk assessments
- Regulatory frameworks and/or uniform codes of practice
- Inspections, appropriate border controls and quarantine measures
- Risk management systems

Image courtesy of Triton Diving Services, Ltd. /West Coast Ballast Outreach

Risk Assessment

- Risk = likelihood x severity
- Perception of risk varies between individuals
- Risk can be managed, by reducing likelihood or severity through better knowledge, vigilance, and implementing appropriate controls

- Most biosecurity risks on vessels can be reduced with better fouling management



Moving forward

- PUBLIC EDUCATION, AWARENESS

- Taxonomic impediments – shortage of trained personnel for monitoring programs – being able to identify species correctly is important for invasives detection!

- Antifouling R&D has been driven primarily by industry and regarded in academia as applied research.

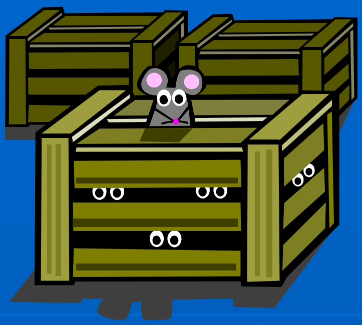
  Need for funding agencies to recognize relevance of basic biology research:

  - Biology and physiology of organisms, biological mechanisms of adhesion, invasives ecology → basic principles for pest and disease control

  This kind of information is needed to conduct credible risk assessments, for the development of viable management strategies and effective treatment technologies

- Poor knowledge leads to the use of excessively heavy handed methods which are invariably detrimental to the environment

In summary



The wish-list of every shipowner is a pest-free vessel!

- Greater awareness of the economic and societal costs associated with fouling and invasions is needed, especially in Asia.
- New knowledge of the biology of marine pests organisms, especially for tropical Asian seas, to enable technology to advance significantly
- More multi-disciplinary collaboration between biologists and engineers, industry and academia is needed to enable effective biofouling management

Acknowledgements

Thank you to all, especially:

- The organizers, PEMSEA & IMO for the opportunity to present our perspective at this workshop
- The many industry people who have contributed their ideas and feedback for this presentation
- Colleagues at the Tropical Marine Science Institute, Prof Dan Rittschof (Duke University), and the US Office for Naval Research Coatings Program