Marine Biofouling

“a process of adsorption, colonisation, and development of living and non-living material on an immersed substratum”
The fouling problem: Ships

Greenhouse gases
Air pollutants

Maintainance
costs
Paint

Fuel
Schedules

Marine pests

Drag
Reduced speed

Paint
solvents

VOCs

CO₂
NOₓ
SOₓ
PM

$$$

Water pollutants

Cu\textsuperscript{2+}

Cu\textsuperscript{+}

Paint
solvents

GHG Emissions & Fuel Efficiency

GHG Emissions & Fuel Efficiency
Air emissions

The latest information has international shipping contributing approximately 2.7% of global carbon emissions. Even considering the effects of the global financial crisis, predicted growth in global trade and likely future emissions reductions from land-based industries, means that in real terms and in terms of percentage, the industry's contribution is likely to significantly increase.

MEPC measures address GHG emissions

IMO's Marine Environment Protection Committee (MEPC) has agreed to disseminate a package of interim and voluntary technical and operational measures to reduce greenhouse gas (GHG) emissions from ships, as well as a work plan for further consideration of market-based instruments to provide GHG-reduction incentives for the shipping industry.

Energy efficiency regulations enter into force

New regulations aimed at improving the energy efficiency of international shipping entered into force on 1 January 2013. These regulations introduce a performance-based mechanism that leaves the choice of technologies to use to a specific ship design to the industry. For the control of emissions of nitrogen oxides (NOx), sulfur oxides (SOx) and particulate matter under regulations.

Ship Energy Efficiency Management Plan (SEEMP)

SEEMP template for owners and operators

<table>
<thead>
<tr>
<th>Measures for hull and propeller optimisation</th>
<th>Implementation actions</th>
<th>Monitoring and recording actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Hull resistance optimisation</td>
<td>a. Hull condition is assessed on a quarterly basis during port stays where this is practical through in-water inspection.</td>
<td>a. Keep records of in-water inspections and identify areas for underwater cleaning.</td>
</tr>
<tr>
<td></td>
<td>Responsible Person(s): Head Office</td>
<td>Responsible Person(s): Head Office</td>
</tr>
<tr>
<td></td>
<td>Company procedures: [insert #]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. In water hull cleaning is performed on a 1-year basis, in port stays where this is practical, in areas identified during inspections.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Responsible Person(s): Head Office</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Company procedures: [insert #]</td>
<td></td>
</tr>
</tbody>
</table>

Lloyd's Register
LIFE MATTERS
Invasive Marine Species

Sea creatures invade bay

Up to 400 exotic marine species may have been introduced into Port Phillip Bay. The Victorian Government says this poses a serious threat to the region's marine environment.
NZ Survey:
~70% of 500 commercial vessels had macrofouling
187 species identified; 128 non-indigenous, 10 cryptogenic
94 NIS not recorded from NZ
Non-NZ NIS on 30% of vessels

The Challenge
## Translocation Process

<table>
<thead>
<tr>
<th>Donor region</th>
<th>Translocation process</th>
<th>Selective filters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. COLONISATION</td>
<td>Propagule availability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Attachment / Entrainment</td>
</tr>
<tr>
<td></td>
<td>2. TRANSLOCATION</td>
<td>Survival</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environmental conditions</td>
</tr>
<tr>
<td></td>
<td>3. TRANSFER</td>
<td>Availability of suitable substrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biotic resistance</td>
</tr>
<tr>
<td></td>
<td>4. COLONISATION</td>
<td>Availability of suitable substrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environmental conditions</td>
</tr>
<tr>
<td></td>
<td>5. ESTABLISHMENT</td>
<td>Environmental conditions</td>
</tr>
</tbody>
</table>

**Recipient region**

- Environmental conditions / compatibility
- Environmental conditions
- Propagule release
- Availability of suitable substrate
- Biotic resistance
- Water currents, etc.
- Environmental conditions / compatibility
- Availability of suitable substrate
- Community instability
- Further inoculations
- Predation, etc.

**Prevention is Better than Cure**

...and less costly

## The fouling problems: offshore

- **Buoyancy**
- **Seawater intake / pipeline blockage**
- **Corrosion**
- **Undersea instruments**
- **Heat transfer**
- **Structural drag**
- **Fuel Schedules**
- **Marine pests**
- **Sensor/Optical Windows**
The Offshore Fouling Environment

DePalma 1972: "Fearless Fouling Forecasting"

Platform Fouling Growth Profile

Currie & Jenkins 1994

What about here?
Deep water communities - Bass Strait

Invasive Marine Species

Ocean Patriot
How do we manage biofouling?

Biofouling management

Antifouling coatings
- Biocidal (Toxic)
- Foul release

Cleaning
- Careening
- Slipping/dry-docking
- In-water

Isolation
- Dry-berthing

Historically, biofouling management is a response to economic & operational impact:
- Cost/benefit basis: docking intervals, fit for purpose (not necessarily best for purpose)
- Focus: (tolerable) hull fouling
How do we manage biofouling?

Antifouling paints

Antifouling paint development

- Pre-18th C: Beaching, careening, pitch & tar
- 1758: Copper sheathing
- 1860s: Copper “paints”
- 1950s: Copper, mercury, arsenic paints
  Soluble matrix, Contact leaching
- 1960s: Organotin biocides
- 1970s: Self-polishing copolymer paints
- 1990-2000s: TBT banned
- 1990s: Foul release coatings
- 21st C: Copper SPCs, safer co-biocides

- Effective life:
  - 18 – 24 mth
  - 36 – 60 mth*

* Except for aluminium hulls

*Copper has been a mainstay of antifouling for 250 years
Antifouling biocides need to be:

- Toxic, yet non-toxic
- Stable, yet unstable
- Broad spectrum, yet not too broad
- Leachable, but not too fast, nor too slow

Co-biocides:
- Diuron, Irgarol, DCOI, ZPT, CPT, Dichlofluanid, Tralopyril
Antifouling paint types

Minimum effective release rate

Antifouling paint types

Minimum effective release rate
Non-toxic, fouling release coatings

- Also known as minimally adhesive coatings
- Surface character prevents adhesion or minimizes adhesion strength of fouling organisms
- Based on silicone or fluorinated polymers
- Only suitable for continuously active, higher speed (> 15 knot) vessels
- Prone to abrasion damage, problematic to clean in-water

What is an effective antifouling?

Biocidal:
- Continuous copper release rate from stationary hull:
  - > 10 µg Cu/cm²/day
- Short half life co-biocide (algaecide/slimicide)

Non-biocidal:
- Self-cleans @ ≥ 15 knots on high activity vessels

*Hull niches cannot always be effectively antifouled
Niche fouling

Natural Antifouling ??

- Minimal adhesiveness
- Microtopography
- Mucous secretion
- Sloughing
- Hydrophobic or hydrophilic?
- Filtration
- Chemical deterrence
- Toxic metabolites

Natural product antifoulants:

- classed as biocides
- registration cost € 7-9 million
- registration process ~10 yrs
Novel methods for biofouling control

Nano-scale superhydrophobic coatings
Extreme water repellency copied from nature – For rapid drain down

Natural products from mussel shells: Potential for novel antifouling coatings

Air bubble curtains to protect vessels in dock

Biomimetic surfaces
a-f - Surface macrotopographies on marine molluscs; source: Scardino, 2006.
g, h - Bioinspired shark skin topography; source: Schumacher et al. 2007.

Biomimetic surfaces

Fouling control using vibration effects – PZT embedded panels
deter barnacle cyprids at specific frequencies

Antifouling Options – Paint type

<table>
<thead>
<tr>
<th>Paint Type</th>
<th>Effective life (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper-based conventional</td>
<td>12 – 24</td>
</tr>
<tr>
<td>Copper-based erodible</td>
<td>36</td>
</tr>
<tr>
<td>Copper-based SPC</td>
<td>60</td>
</tr>
<tr>
<td>Biocide-free fouling release</td>
<td>&gt; 60 but….</td>
</tr>
<tr>
<td>Novel technologies “natural products”, fibre coatings etc.</td>
<td>unproven</td>
</tr>
</tbody>
</table>

*except for aluminium

$
How do we manage biofouling?
In-water cleaning

Australia & New Zealand Environment Consultative Council (ANZECC Code, 1997):
No part of a vessel's hull treated with antifoulant is to be cleaned in Australian waters……

“On 26 June 2013, the Standing Council on Primary Industries endorsed the “Anti-fouling and in-water cleaning guidelines”:
Controlled in-water cleaning:
To clean or not to clean?

“When do the environmental costs of releasing non-indigenous species and chemical contaminants during in-water cleaning outweigh the risks of no action?”

Report 1
In-water hull cleaning and filtration system: In-water cleaning trials 26-28 November 2012

How do we manage biofouling?
Marine Growth Prevention Systems
Marine Growth Prevention Systems

- Direct chemical dosing
  - Sodium hypochlorite
  - “Antifoulant” solution
- Electrochemical dosing
  - Copper (+aluminium) anodes
  - Hypochlorite generation
- Other
  - Ultrasound

Questions:
- Do they work?
- Should they work?
- How should they be worked?
- How do they compare?

How do we manage biofouling?
Rules & Regulation
Regulations & requirements

IMO
- Biofouling Management Guidelines (2011)

Western Australia
- Ministerial conditions on projects (Current)

California
- Biofouling management regulations (2015)

New Zealand

Australia
- Sectoral guidelines
- Quarantine Act ["Quarantineable pests" / Species of concern] (?)
- Marine Growth Risk Assessment

What is antifouling & biofouling management best practice?
Objective: “a clean ship” = slime layer only [?]
How are risks best reduced?

Proactive antifouling prevention:

- External - Effective antifouling coatings
- Internal - Marine Growth Prevention Systems / antifouling material (e.g. CuNi)
- Prescribed dry-docking intervals

Additional hull husbandry

- Controlled in-water cleaning
- Internal - Chemical (acid, disinfectant), physico-chemical (temperature, salinity, deoxygenation)

Good biofouling management is not a single strategy, but a combination of strategies

How do we manage biofouling?

Offshore
**Subsea coolers**

**Offshore Gas Fields**

- Well heads remote from production platforms
- Gas flow recovered at ~80°C; corrosive within standard pipelines
- Coolers on well heads to reduce temperature
- Heat exchange through cooler walls critical
- ~100 m depth
- Projected cooler life- 25 years

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**To coat, or not to coat...**

Why coat?
- Corrosion protection
- Biofouling reduces heat transfer/cooler efficiency

But...
- Thick coatings also reduce heat transfer/cooler efficiency
- Heat will kill/prevent biofouling?

However...
- No heat during wet storage/down time
- Growth on "cool" end
## Coating Options

<table>
<thead>
<tr>
<th>Paint Type</th>
<th>Effective Life (months)</th>
<th>Cost</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soluble matrix/ablative</td>
<td>24-36</td>
<td>$</td>
<td>✗</td>
</tr>
<tr>
<td>Contact leaching</td>
<td>24</td>
<td>$</td>
<td>✗</td>
</tr>
<tr>
<td>CDP</td>
<td>36</td>
<td>$$</td>
<td>✗</td>
</tr>
<tr>
<td>SPC</td>
<td>60</td>
<td>$$$</td>
<td>✗</td>
</tr>
<tr>
<td>Metallic copper epoxy</td>
<td>120+*</td>
<td>$$$$</td>
<td>?</td>
</tr>
<tr>
<td>Foul release</td>
<td>60 +</td>
<td>$$$$$</td>
<td>✗</td>
</tr>
<tr>
<td>Mechanically resistant</td>
<td>3**</td>
<td>$$</td>
<td>✗</td>
</tr>
</tbody>
</table>

* scattered biofouling may occur
** coatings are durable and long life is achieved through regular cleaning

## Metallic Copper / Epoxy Coatings
**The Burden of Bio fouling**

Specific density

Conventional wisdom:
- Soft fouling \(1.0\)
- Hard fouling \(1.4\)
- Calcite = \(2.7\)

Measured:
- Soft fouling \(1.06\)
- Hard fouling \(1.74\)

How do we manage biofouling?

…better!
Needs, wants, uncertainties

Coatings:
- Better, safer, cheaper
- Niche areas
- Structures

Maintenance practices:
- Hull/structure husbandry

Engineering design:
- Prevention (not accommodation)

Offshore:
- Growth rates & characteristics

In-water cleaning:
- Waste capture
- Efficiency
- Safety

Regulations:
- Certainty, uniformity
- Uptake

Thank you
...over to you