CURRENT UNDERSTANDING OF MICROBIOLOGICALLY INFLUENCED CORROSION

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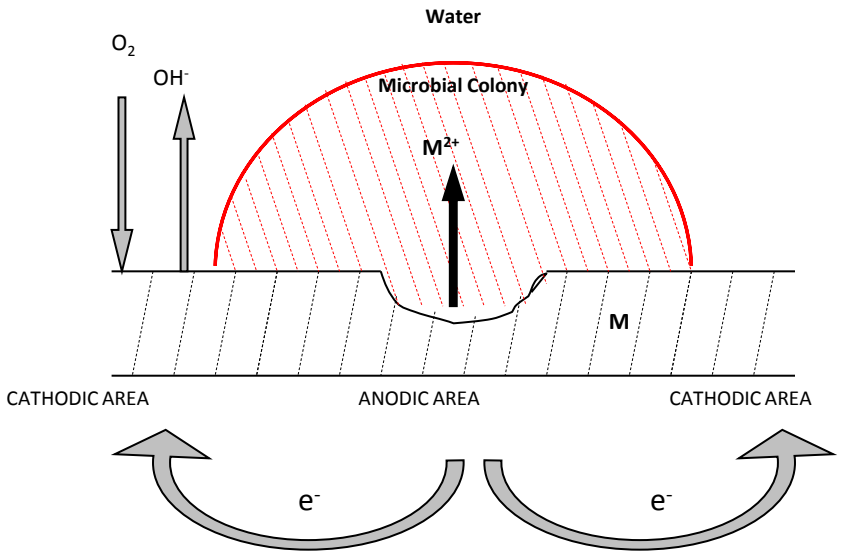
Presentation Outline

- Microbiologically Influenced Corrosion (MIC) Background
- Current Developments on MIC
- Case Study 1:
  - MIC of Duplex Stainless Steels
- Case Study 2:
  - MIC studies at Darwin Harbour
- Final Remarks/Recommendations
- Questions

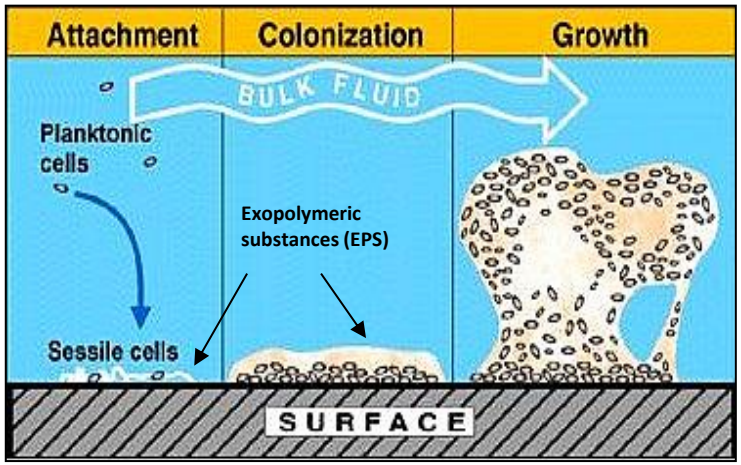
BACKGROUND

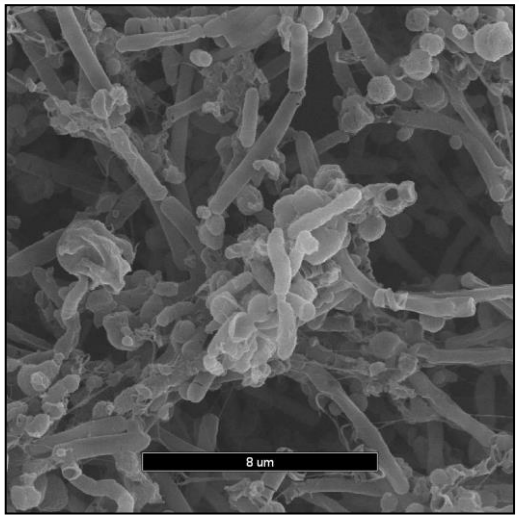


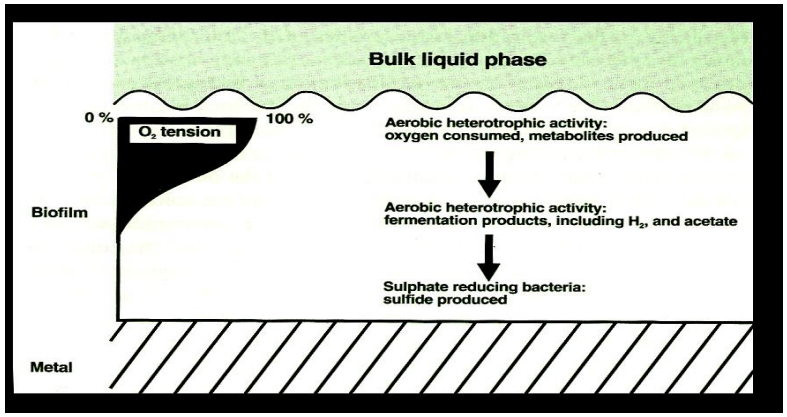
AERATION ZONE created by a microbial colony. Metallic cations (M2+) are released from the anodic area resulting in corrosion

- Microbial metabolism (acids, sulphides, etc)
- Depolarization effect (acceleration of corrosion reactions)
- Effect of biofilm formation (ennoblement or activation of metal surface)

Biofilm Formation







Relevance of Microbiologically Influence Corrosion (MIC)

- Estimated cost of MIC in Australia: **> AU$10 billion in 2016**
- Microbes major players in Corrosion related failures in:
  - Oil Fields (Prudhoe Bay Oil spill, 2006)
  - Off shore Drilling Platforms (Failures of Duplex Stainless Steels)
  - Pipelines (On-shore gas internal corrosion)
  - Nuclear and Fuel Power plants
  - Gas Coolers
  - Water Supply Systems

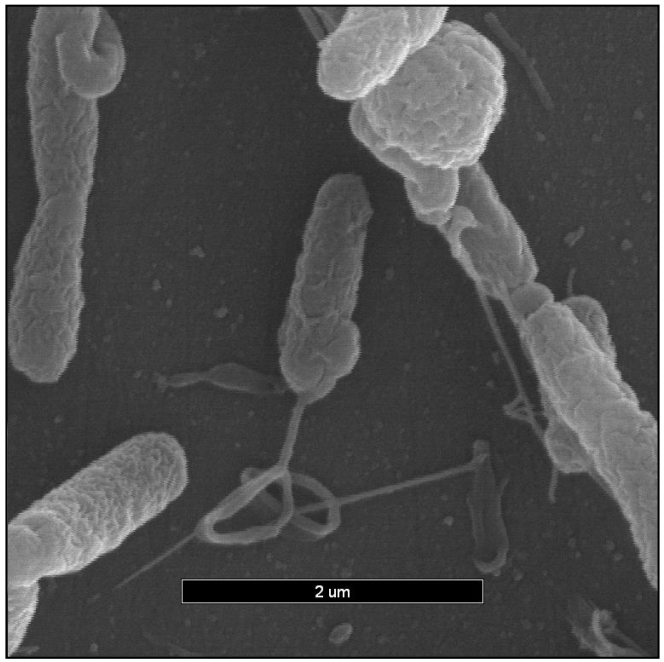

Material Substrate
Microbial Environment
Inspection Methods

Material Substrate	Microbial Environment	Inspection Methods
Stainless Steels	Marine Aerobic or Anaerobic	Potentiodynamic Polarisation Free Corrosion potentials Electrochemical Impedance Spectroscopy (EIS)
Duplex SS	Marine Anaerobic (Sulphate Reducing Bacteria SRB)	Electrochemical tests X-Ray Photoelectron Spectroscopy (XPS)
Aluminium (e.g. 2024	Fungus (Aspergillus Niger)	Pitting Corrosion Biofilm Thickness
Fuels (e.g Biodiesel)	Fungus (Moniliella wahieum)	Chemical Analysis
Concrete	Sulfur-oxidizing bacteria (SOB) (A. thiooxidans, A ferroxidans)	Microbial analysis Biofilm Thickness

Other MIC studies…

- Effect of flow rates (e.g. marine/tidal vs stagnant conditions)
- Effect of Climate Change
- Effect of Cathodic Protection
- Effect corrosion inhibitors and coatings
- Corrosion inhibiting capacity of bacteria or other microorganisms
- Corrosion Under Insulation
- Developing of MIC resistant Coatings

CASE STUDY 1
Sulphate Reducing Bacteria-Duplex Stainless Steels



SRB culture
Desulfovibrio salexigens

✓**SRB cause 50% of all instances of MIC**

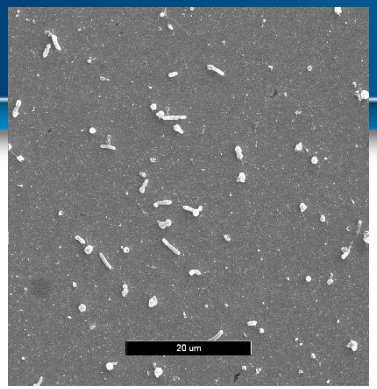
(anaerobic corrosion)

✓**SRB metabolism,**

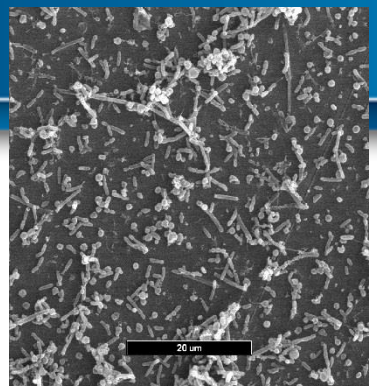
Metabolic reduction of sulphate to sulphide or hydrogen sulphide (H_2S).

✓**Anaerobic corrosion mechanism:**

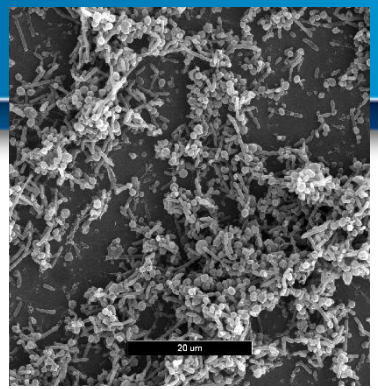
$$4Fe + SO_4^{2-} + 8H^+ \leftrightarrows FeS + 3Fe^{2+} + 4H_2O$$



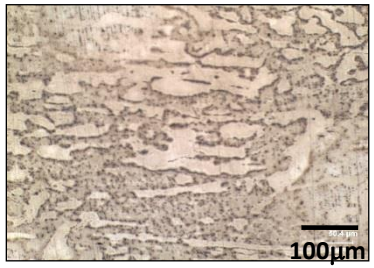
4 days

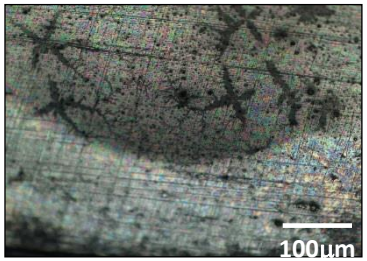


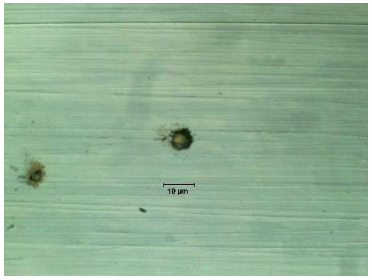
7 days



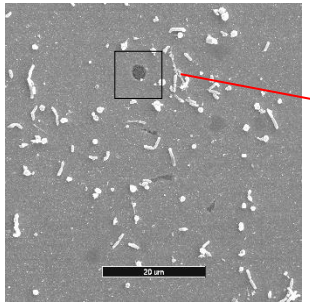
10 days

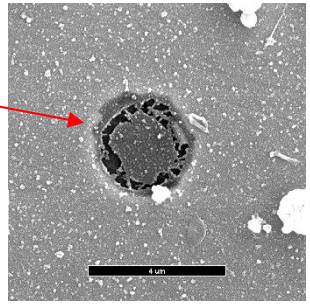


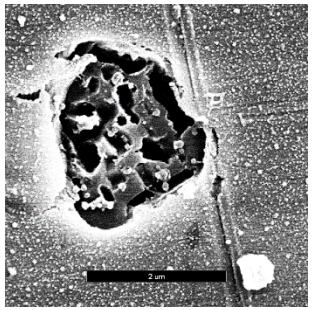


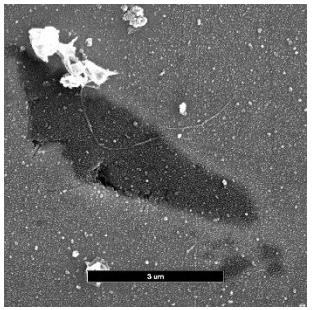


Optical Microscopy





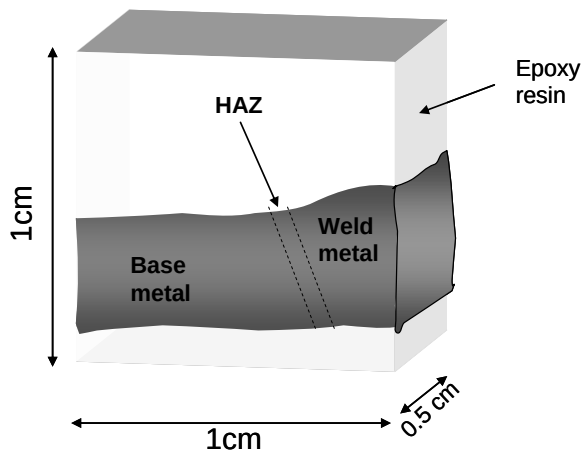


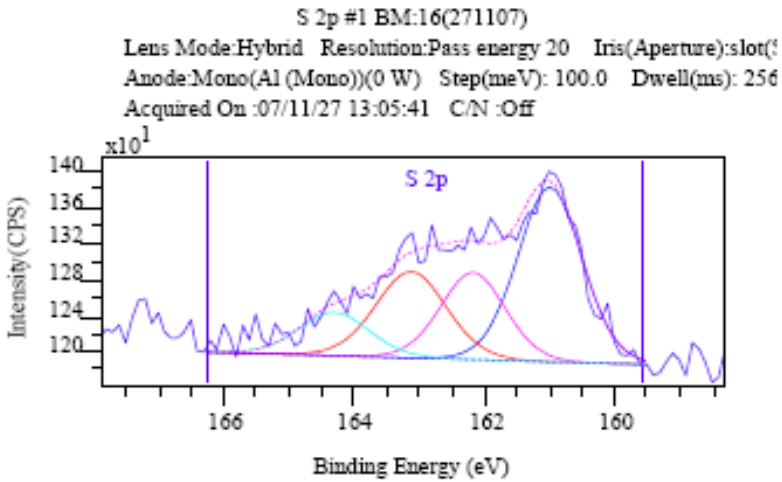


SEM

Post-corrosion characterization
X-ray photoelectron spectroscopy (XPS) analysis

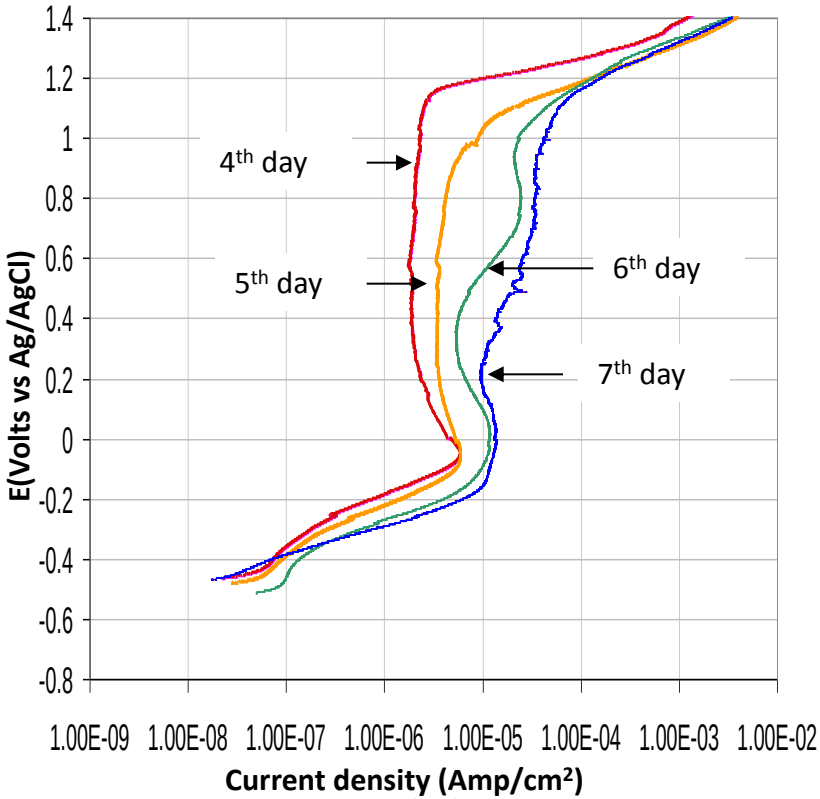
- Identification of Fe, Cr, Ni sulphides and oxides on metal surface.
- Formation of various types of sulphides: FeS, FeS_2, Cr_2S_3, NiS
- Penetration of passive film, diminished passivity of metal.



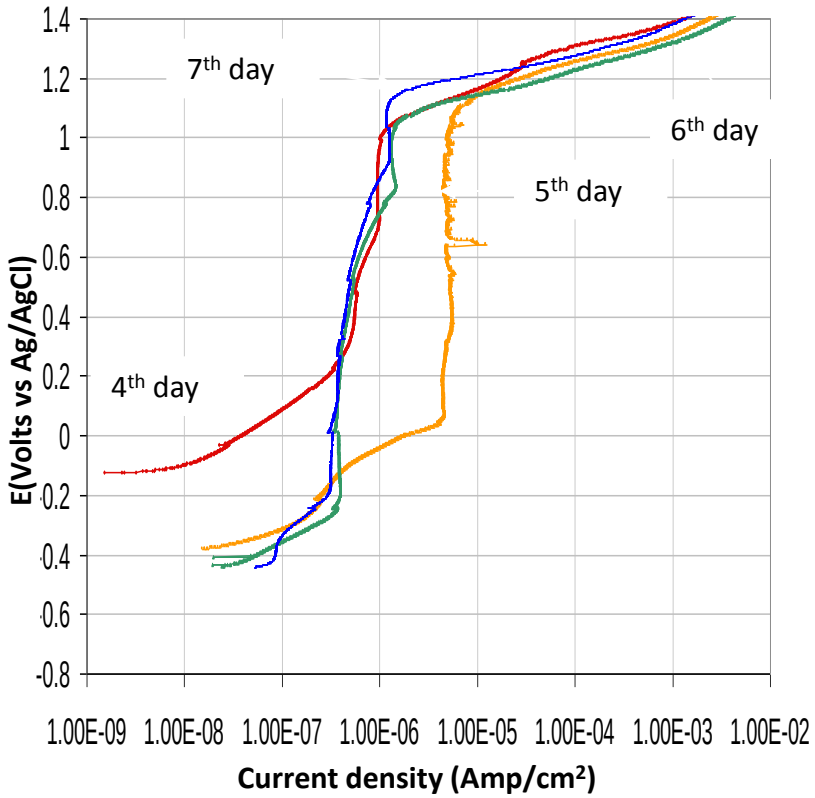


Depassivation of Steels

SRB environment



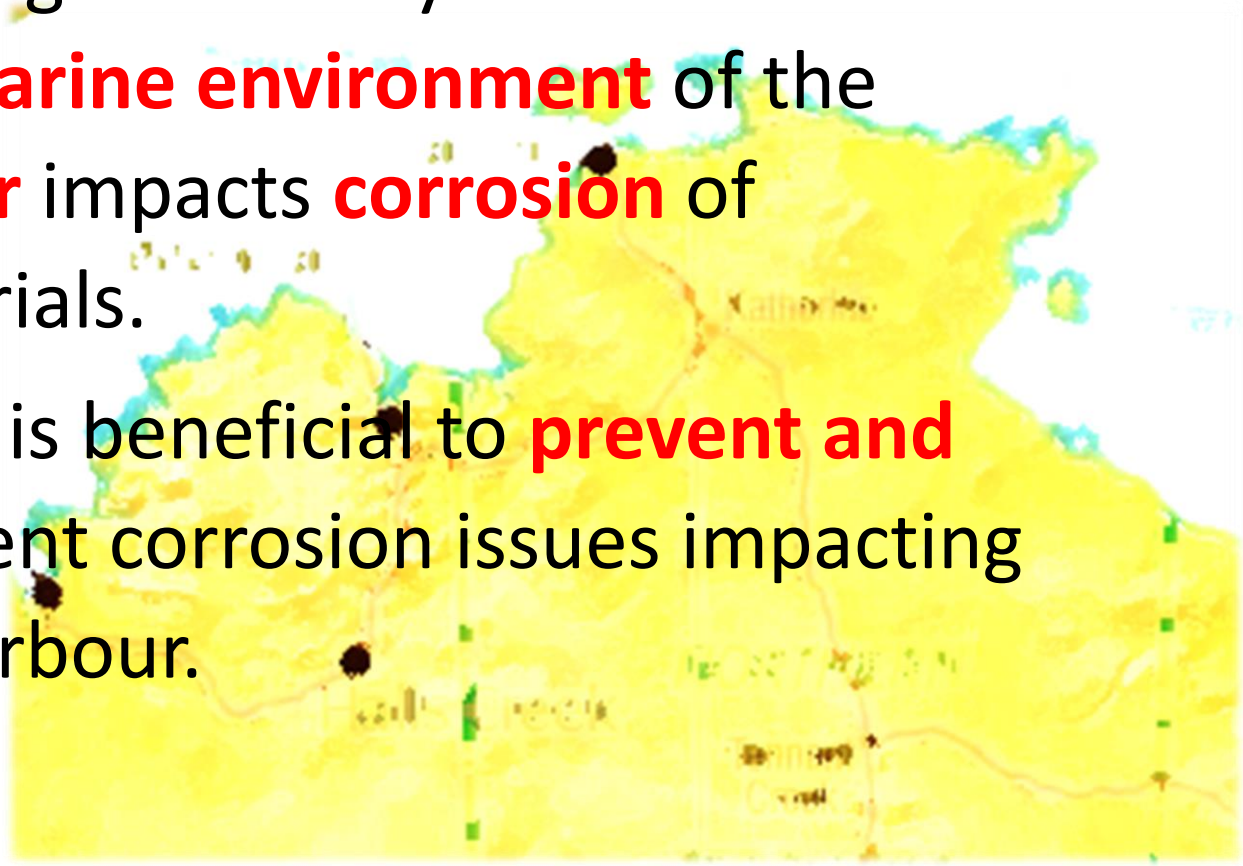
Abiotic environment



CASE STUDY 2
Corrosion studies in Darwin Harbour

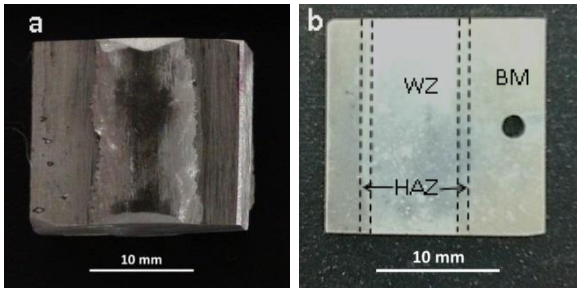
An understanding of the way in which the **local tropical marine environment** of the **Darwin Harbour** impacts **corrosion** of structural materials.

This knowledge is beneficial to **prevent and remediate** current corrosion issues impacting assets in the Harbour.



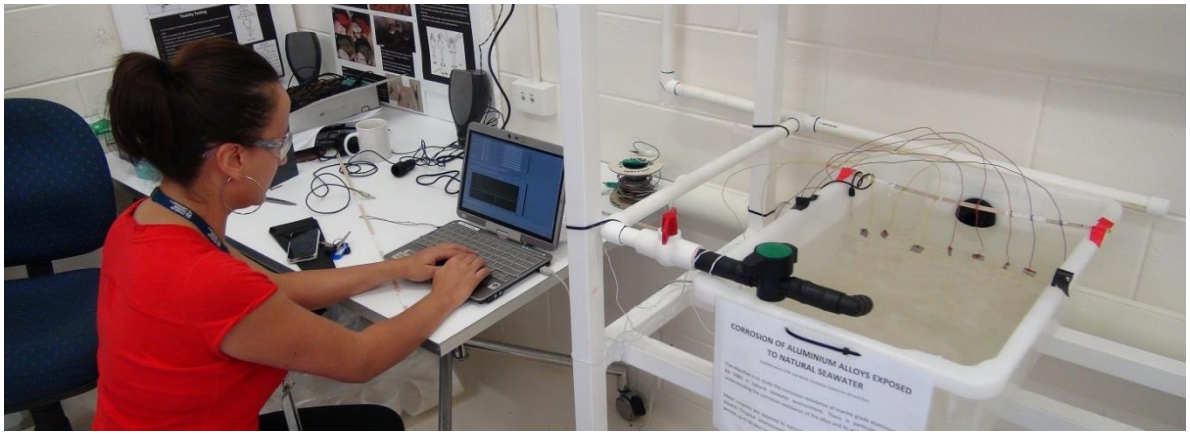
Preliminary Research

Corrosion behaviour of marine grade aluminium alloys and their weldments in natural seawater from Darwin Harbour

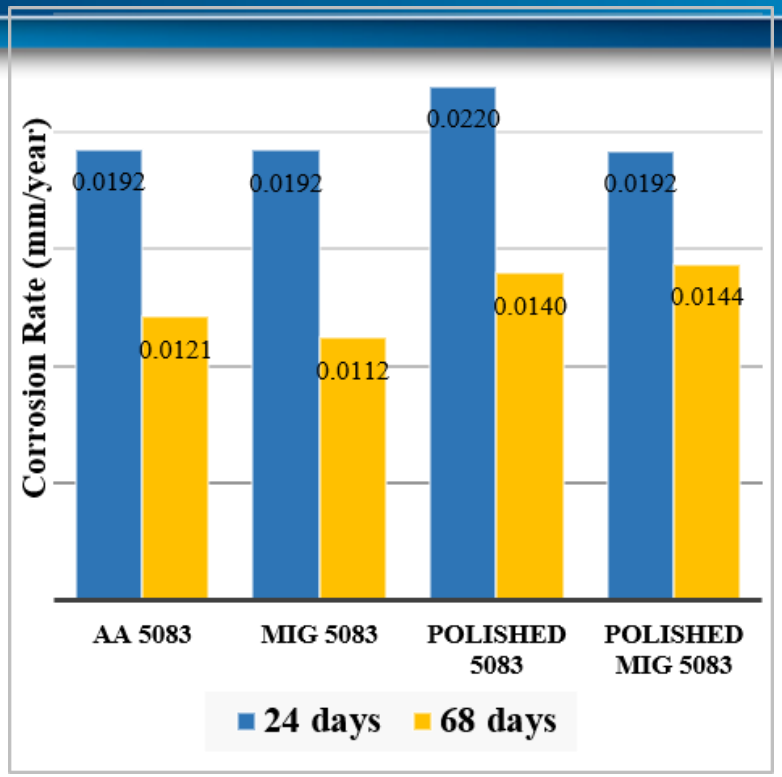


MIG welded AA5083 specimens for total immersion tests (a) unpolished, (b) polished indicating WZ, HAZ and BM

Set up of Corrosion tests in natural seawater at the Aquaria at Australian Institute of Marine Science (AIMS)



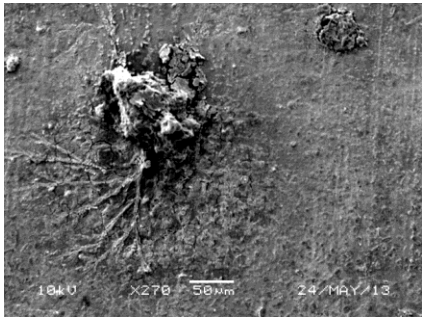
Corrosion rate by weight loss

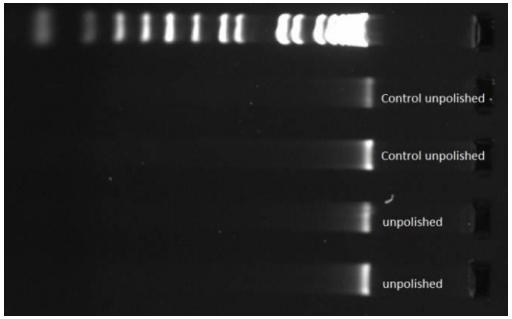


Corrosion rate of AA5083 and MIG welded AA5083 in unpolished and polished condition after immersion in natural seawater.

Corrosion rate at least 7 times higher than the reported in temperate environments

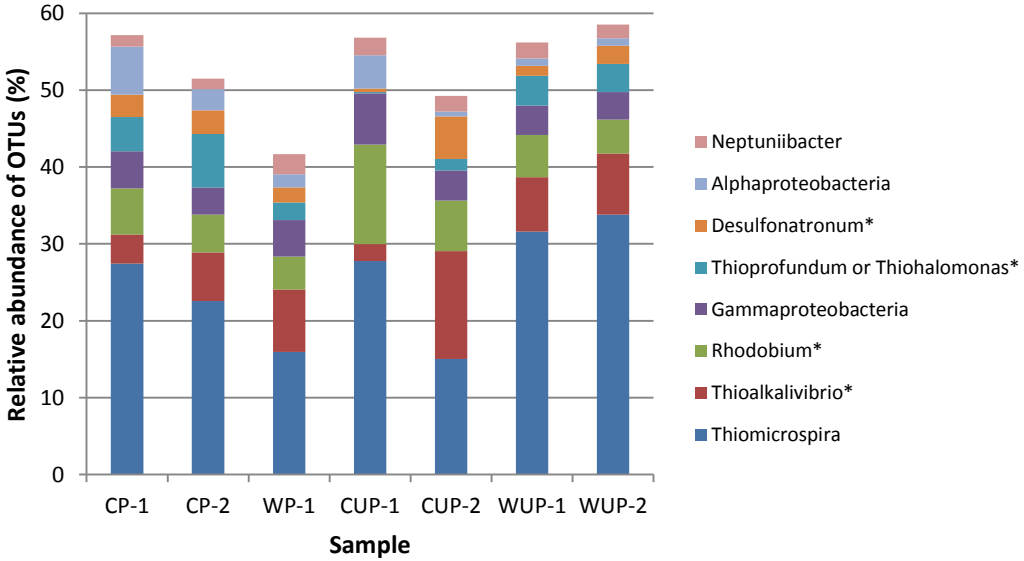
Biofilm Identification by DNA Extraction





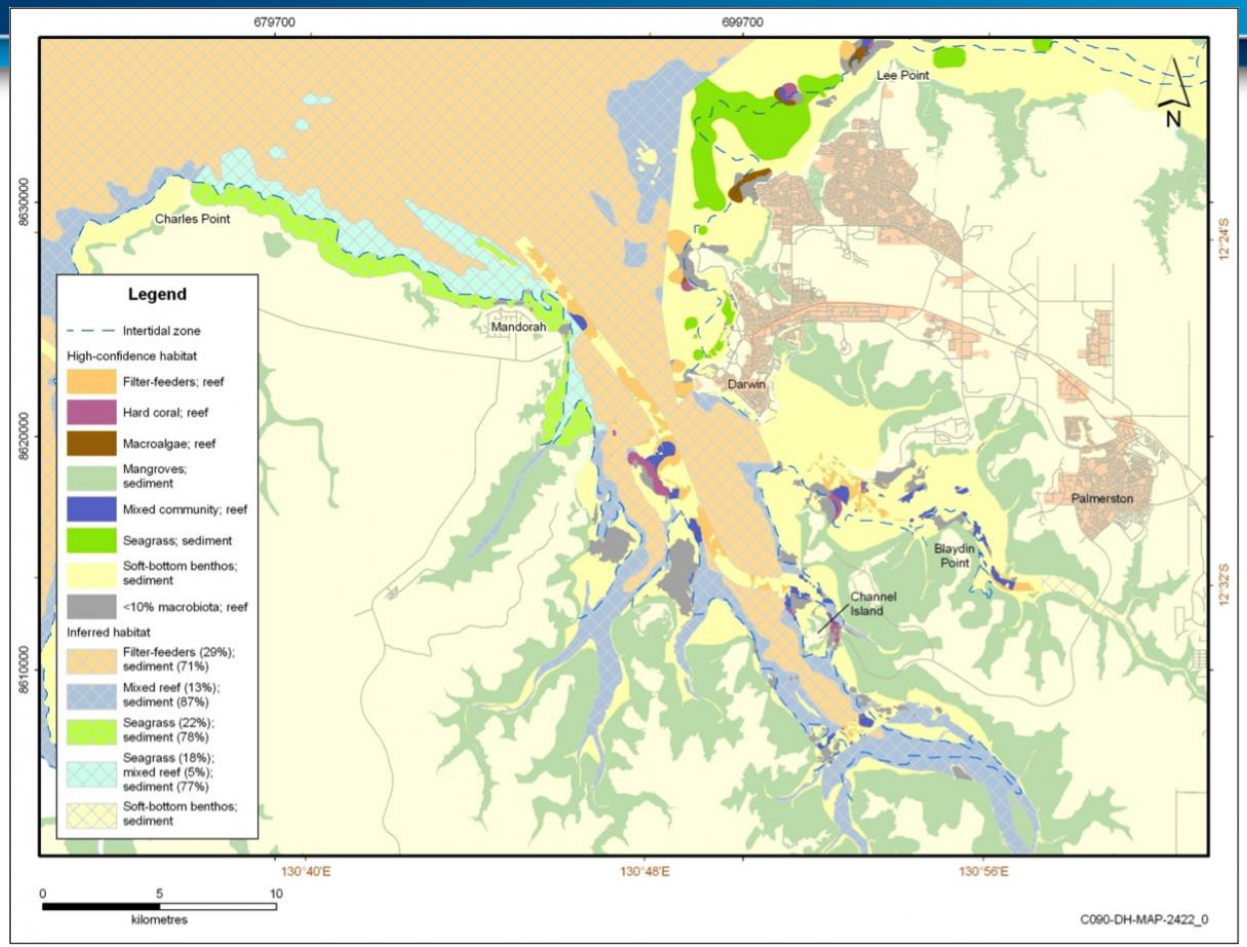
Left, Scanning electron micrograph (SEM) of corrosion product and biofilm formed on the surface of AA 5083 after 30 days of immersion.

Right, DNA analysis result indicating the strong presence of biofilm after 30 days of immersion,



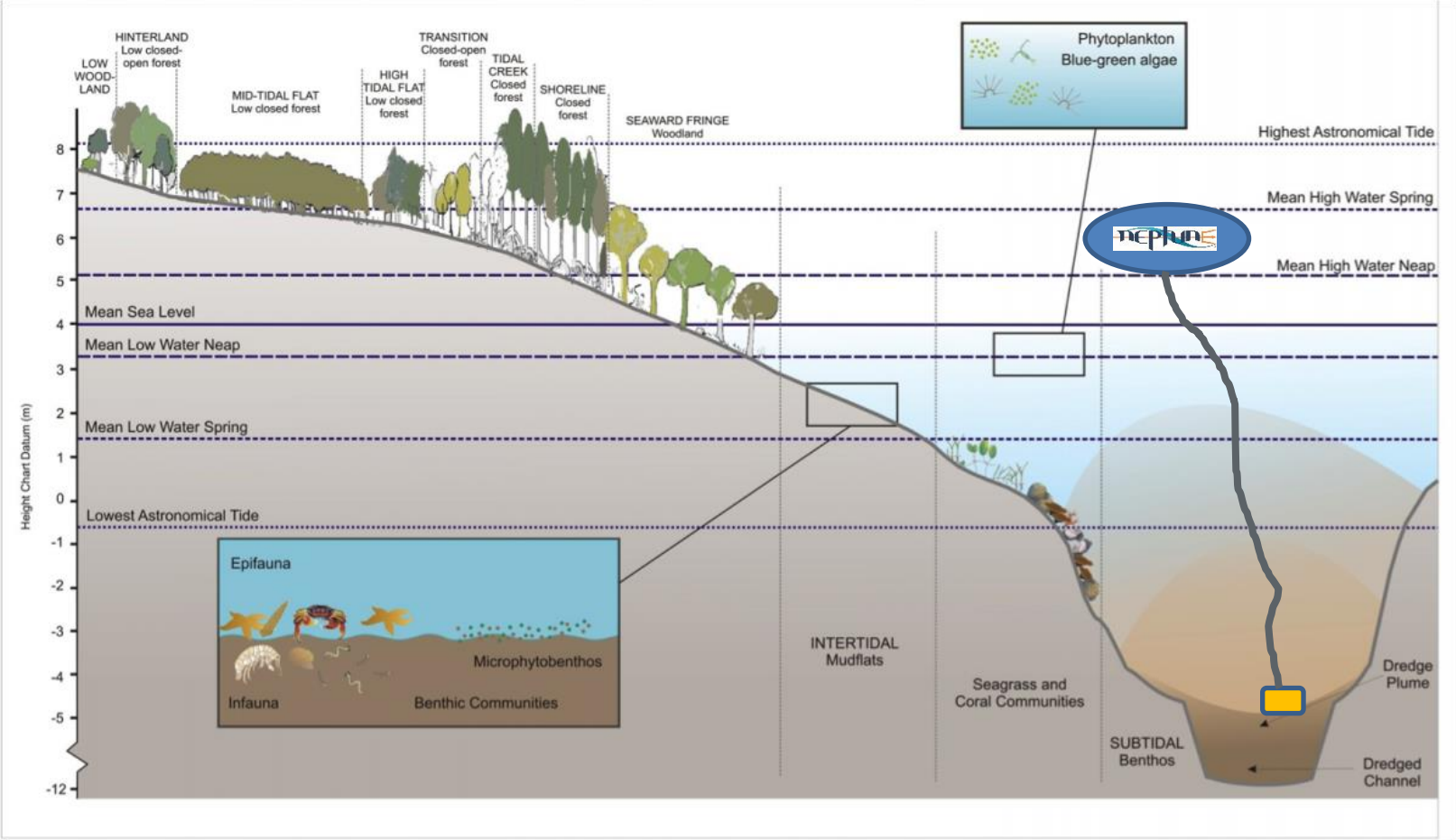
Preliminary identification of bacteria present by DNA sequencing

In-situ Corrosion Darwin Harbour



Monitoring of the corrosion rates for long periods of exposure (i.e., measurement of corrosion potentials, weight loss and surface analysis).

Research Station-Schematics



MIC Estimated Testing Schedule (5 years)

Preliminary Planning
- Collection of available field data and navigation maps (location of buoys)
- Integration of research program with Darwin Port Maintenance Schedule
- - Field recognition
  - Estimation of sampling and testing logistics
- Identification of tidal zones and environmental habitats

Material Selection and identification
- Mooring chain material selection (based on DPC experience) , Consider design and weight
- Procurement of materials supplies (detailed in a separate schedule)
- Characterization of material previous to immersion (Chemical and microstructural)
- Record of initial weight

Setting up of Research Stations
- At locations consulted with DPC and stakeholders

Monitoring/data collection required Quarterly or Biannually
- Corrosion visual inspection
- Environmental monitoring
- Microbiological testing
- Wall thickness measurement (corrosion rate)

Removal of material from Research Station
- Characterization of corrosion products
- Record of final weight (weight loss-corrosion rate measurement)

Interim annual and final report to Stakeholders
- Test results with recommendations provided to stakeholders

Final Remarks

- Requirement of interdisciplinary collaboration for IMR of structures attacked by MIC
- Different depassivation and corrosion attack mechanisms
- Importance of including MIC management in overall Asset Integrity Programs