

Economical, social and environmental impacts of marine biofouling in the Sultanate of Oman

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Executive Summary

Objectives:

This study had the following objectives:

- To identify biofouling communities in Oman's waters;
- To investigate the effect of biofouling organisms on the efficiency of fishing gear;
- To estimate the environmental impact of biocides and their accumulation in marine organisms;
- To investigate the socio-economic impact of biofouling;
- To evaluate the effectiveness of current antifouling defences and to provide recommendations for their improvement.

Methods:

Fouling communities' composition, their wet weight and dynamics of on artificial and natural substrata were analysed during field experiments. The effectiveness of commercially available biocidal (copper and zinc-based) and non-biocidal (silicon-based) antifouling coatings from four leading antifouling companies was investigated in static experiments in the marina Bandar Al Rowdah and Shangri La. Biofouling communities were identified and quantified using light, epifluorescent and electron microscopy (SEM) and 454 pyrosequencing. The concentrations of heavy metals in marine organisms and water were estimated using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Toxicity analysis of paint leachates was performed using microfouling organisms and nauplia of *Artemia salina*. The impact of biofouling on fishermen operations were investigated through questionnaires in the Al Sharkiya region in Oman.

Results:

The research team identified 27 different fouling invertebrate species belonging to 7 phyla. For the first time four invasive invertebrate species were detected in Muscat waters. Microbial communities mostly dominated by unknown species of the class *Alphaproteobacteria*. The type of fouling organisms, the duration of the experiment and type of fibers affected the life span of fishing gear adversely. The biomass of biofouling communities formed on wooden, aluminum, fiberglass and acrylic panels were not different. Biocidal antifouling paints leached Cu and Zn ions into the environment, which accumulated in marine organisms. From the questionnaire survey 89% of the fishermen's boats had biofouling on their boat hulls and the waterline, which reduced the speed of

the boat and increased consumption of fuel and oil. Pyrosequencing of biofilms from antifouling coatings revealed the presence of 31 different bacterial classes with *Cyanobacteria*, *Flavobacteria*, *Alphaproteobacteria* and *Gammaproteobacteria* accounting for >90% of all sequences on all coatings. All tested antifouling paints reduced macrofouling in comparison with the control. The best antifouling performance for >1 year was for copper-based antifouling coatings. Antifouling performance of the non-toxic paints was different in both marinas. During this project three MSc students graduated and one PhD student is at the final stage of her thesis writing. Five students were employed as research assistants and two special problems projects have been completed by the UG students.

Conclusions:

- Biomass of biofouling communities in Oman waters is 5-10-fold higher than the recorded for other Gulf regions and is a serious problem.
- 27 different invertebrate species belonging to 7 phyla were found in biofouling communities.
- For the first time, the presence of three invasive bryozoan species and one tunicate species were detected on hard substrata in Oman waters.
- Microfouling were represented by 31 different bacterial classes with *Cyanobacteria*, *Flavobacteria*, *Alphaproteobacteria* and *Gammaproteobacteria* being the most common ones. Most microbial species were unknown and need to be properly identified in future studies.
- The type of fouling organisms, duration of the experiment and the type of fibres affected the life span of fishing gear negatively.
- Most fishermen had biofouling on their boats, which reduced the speed of the boat and increased consumption of fuel and oil.
- All antifouling coatings reduced macrofouling in comparison with clean surfaces.
- The best antifouling performance for >1 year was recorded for biocidal antifouling coatings. However, these coatings leached Cu and Zn ions in the environment and were accumulated in marine organisms, which is harmful to humans.
- Non-toxic antifouling paints prevented biofouling but their performance was highly variable in different marinas. Further research is required in this regard.