Centennial-scale records of water quality in the sub-tropical South Atlantic (Ref IAP2-18-109)

Heriot-Watt University, Institute of Life and Earth Sciences, Lyell Centre

In partnership with the University of Glasgow

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Overview

Background:
Industrial activity and land use change has increased the input of nutrients, organic carbon and toxins into coastal oceans around the world over the past several decades and is of major ecological concern. Ecotoxicological and eutrophic impacts lead to complex and undesirable effects on marine ecosystems, including shifts in species dominance, increased susceptibility to other pressures and degradation of the ecosystem. In recent years, many regions have imposed tighter restrictions on industrial discharge and increased efforts to restore damaged ecosystems. One emblematic example of efforts to control pollution is the case of Cubatão (Figure 1), an industrial region adjacent to the São Paulo metropolis and one of the biggest ports in the southern hemisphere.

In the 1970-80's, Cubatão was recognized by the United Nations as "the most polluted city in the world". Eighteen large industrial plants were responsible for extensive air and water pollution. Every day, approximately 237 metric tons of particulate matter, 78 tons of sulphur dioxide, 61 tons of nitrogen dioxide, and 90 tons of hydrocarbons were discharged. In 1983, the local environmental agency (CETESB) successfully implemented a pollution control program that, ten years later, was recognized as one of the most successful pollution control program in the world.

Figure 1. Location of Cubatão, São Paulo state, Brazil

The historical consequences of Cubatão's pollution to the human health have already been widely documented. However, the effect of this pollution on the adjacent coastal and marine ecosystems remains unknown. Understanding how pollutant exposure changes over time is important for long-term management strategies because the legacy of environmental pollution often persists for many years, even when management and 'clean-up' strategies have been put in place. This requires historical datasets that often do not exist. An alternative method is to use biological archives: calcifying marine organisms (e.g corals, coralline algae) are known to be effective monitors of environmental pollution over decadal timescales with high (sub-annual) resolution. Importantly, since these records come directly from the ecosystem, they provide information on the specific region of interest, which long-term monitoring stations may not be able to.

Current state of the art:

The South-eastern Brazilian coast is dominated by crystalline rocky shores, estuaries and sandy beaches, with hundreds of coastal islands that were gradually isolated from the mainland during the Pleistocene and Early Holocene. The most southerly coral reef in the Atlantic Ocean has recently been identified as Queimada Grande island, São Paulo state at 24°29'S (Figure 1). Here, coral reefs are dominated by two species: *Madracis decactis* and *Mussismilia hispida*, as well as extensive beds of free-living red coralline algae (Figure 2).

How these habitats respond to acute pressures (e.g. pollution) remains unknown. Interestingly, the corals here appear to be especially resilient to high turbidity waters – which naturally occur in the area because of land run-off. Understanding the extent of pollution in these ecosystems over the past 50-100 years will provide invaluable information on the link between the land and sea, past and present-day pollutant exposure and the effectiveness of implemented marine management and clean-up strategies.

Figure 2. Queimada Grande - the southern-most reef in the Atlantic Ocean

Aim: This project will reconstruct a history of water quality in the marine environment adjacent to Cubatão industrial area and Santos Port. This is important as it will tell us how coastal marine ecosystems have been affected by industrial activity and the effectiveness of recent management measures.

Methodology

The scholar will have the opportunity to spend up to one year at the Universidade Federal de São Paulo (Unifesp) in the first 18 months of the project. During this time, coral and coralline algal samples will be collected from Queimada Grande reefs, and an analysis of local and regional land-use change will be conducted.

Coral / coralline algal samples will be analysed using LA-ICP-MS to reconstruct in situ environmental conditions in terms of pollutants and physico-chemical parameters such as temperature or pH. These data will allow the scholar to reconstruct, with high temporal resolution, the change in pollutant exposure at a centennial time-scale.

Comparison of historical land use change and implemented management practice with pollutant reconstructions will tell us how effective management strategies have been in reducing pollutant exposure to the coastal marine environment.

Collaborators:
Dr Guilherme Pereira-Filho, Universidade Federal de São Paulo

Timeline

	Y1	Y2	Y3	Y3.5
Sample collection				
Land use analysis				
Growth band analysis				
Pollutant reconstruction				
Dissemination				

Training & Skills

The student will benefit from being actively engaged with an international team throughout the PhD, including dedicated time overseas. This research is also highly topical at the policy level, thus the student will complete their PhD highly prepared for a career in academic, industry or policy.

This project will equip the student with a range of skills including numeracy, proficiency in the translation of science to policy, fieldwork and analytical science. Specific research skills will include:

- Paleoenvironmental reconstruction
- Advanced techniques in GIS
- Marine, coastal, terrestrial and freshwater fieldwork
- Interdisciplinary analysis, combining geology, marine biology and terrestrial ecology within the policy and industrial landscape
- Environmental statistics and calculations of uncertainty

Project support: The facilities and instrumentation available within the supervisors' institutions provide a combination of leading laboratory, field and analytical capability and technical support that will be ideal for

this proposed research, maximising PhD training and research advance.

Scholar support: The Lyell Centre, Heriot-Watt University has a large research student cohort that will provide peer-support throughout the studentship. The scholar will participate in the annual post-graduate research conference within the School of Energy, Geoscience, Infrastructure and Society (EGIS), providing an opportunity to present their research to postgraduates and staff within the School, and to also learn about the research conducted by their fellow postgraduate peers. All project supervisors are highly research-active: the scholar will interact with all members of their research groups, providing an opportunity to learn about other techniques and research areas which may be applicable to their research. Additionally, the supervisors are all based in research-active departments that span a broad range of geoscience, ecological and environmental research, exposing the scholar to a range of other research areas. To facilitate this, the scholar will actively participate in meetings with the 'Benthic Ecology & Biogeochemistry' group at the Lyell Centre, the 'Marine Global Change' group at the University of Glasgow and the 'Marine Ecology and Conservation' group at Unifesp. This will provide the opportunity to discuss cutting-edge topics in the field, review recent papers and to present current research plans to academics with a common research interest in an informal and supportive atmosphere.

Where required, and to maintain continued professional development, the scholar will be encouraged to attend specialist courses directly aligned to the project:

- Palaeo-environmental reconstruction techniques and interpretation (time-series analysis)
- This project will involve some fieldwork, thus the scholar may attend a field first aid course in the first 6 months of the project.
- If desired, the scholar may attend diving orientated courses
- Analytical training will be provided by the supervisors and / or specialist technicians for each piece of instrumentation required for analyses.
- The project supervisors will also support and encourage the scholar's attendance on transferable skills training such as data management, scientific writing and science communication. These are provided for free by Heriot-Watt University.

References & Further Reading

Pereira-Filho et al (in press) The Southernmost Atlantic coral reef in the subtropical island of Queimada Grande, Brazil. Bulletin of Marine Science

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Further Information

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