

Warming Waters, Shifting Shores: How Malta's Seagrass Meadows Reveal the Hidden Impact of Climate Change

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What if tomorrow's ocean warming was already happening right now, in one quiet Maltese bay? By studying the thermal discharge from a power plant, researchers reveal how even local heat pollution mimics climate change, reshaping seagrass meadows and fish communities in ways that may foreshadow the Mediterranean's ecological future.

As sea temperatures continue to rise, the Mediterranean – a recognised climate change hotspot – is undergoing dramatic ecological shifts. But what happens when we focus on a single bay affected not by future warming, but by hot water discharged from a power plant? In my Ph.D. research with the Oceanography Malta Research Group OMRG), I investigated how this local thermal plume can mirror long-term ocean warming and its impact on ecological communities, focusing specifically on *Posidonia oceanica* meadows and fish communities.

My work, supervised by Prof. Alan Deidun and Dr Adam Gauci from UM's Department of Geosciences and

co-supervised by Dr Simone Mirto (National Research Council, Italy), was based in the twin embayments of Il-Hofra ż-Żghira and Il-Hofra l-Kbira. These near-identical bays, separated by a peninsula in south-east Malta, provided the perfect natural laboratory: one affected by thermal effluent, the other serving as a control site.

THE LOCAL BECOMES GLOBAL: WHY THERMAL EFFLUENT MATTERS

The Delimara power station, which provides over two-thirds of Malta's type of warming the Mediterranean is predicted to face in coming decades.

By analysing environmental data, seagrass health indicators, and underwater visual censuses ➔



Alessio Marrone

of fish over a two-year period, we were able to observe how species react to gradual increases in temperature. Unlike laboratory tanks or hydrothermal vents – commonly used to simulate warming – our site allowed us to study ecosystem-scale effects in the real world.

MALTA'S MARINE FOREST: THE CASE OF *POSIDONIA OCEANICA*

Posidonia oceanica, a seagrass species endemic to the Mediterranean, plays a vital role in coastal ecosystems. It stabilises sediment, supports biodiversity, and sequesters carbon. But it can also be highly sensitive to temperature shifts.

Closer to the thermal outfall, the meadows showed signs of stress. Leaves were shorter, rhizomes (underground stems) weighed less, and shoot density declined. Although the plants attempted to compensate by producing more leaves per shoot, overall photosynthetic capacity dropped. The health of the meadows deteriorated over the years of exposure to the thermal effluent, suggesting that even minor, chronic increases in temperature can have lasting impacts.

Interestingly, the shift also extended to the epiphytes (algae and microorganisms) growing on the seagrass. Calcareous species were replaced by more heat-tolerant turf algae, which offer lower ecological value. This change hints at a broader breakdown in the seagrass-associated microhabitat, with possible consequences for all species that depend on it.

FEWER FISH, AND DIFFERENT ONES TOO

The fish community also responded strongly to the temperature gradient. At the station closest to the effluent, species richness and diversity were lowest, yet fish abundance was



Top: View of Ras il-Fenek, the peninsula dividing the two bays under study. Bottom: General view of Il-Hofra ż-Żghira and the thermal effluent. Photos courtesy of Alessio Marrone

surprisingly high – mainly driven by thermophilic or opportunistic species like the native damselfish.

Traditional biodiversity indices only tell part of the story. To dig deeper, we grouped the observed species into functional groups – collections of fish that play similar roles in the ecosystem (eg, predators, grazers, detritivores). This approach revealed that transient predators and planktivores dominated the warmest area, while more sedentary species, such as ambush predators and temperate reef fish, were pushed to cooler waters.

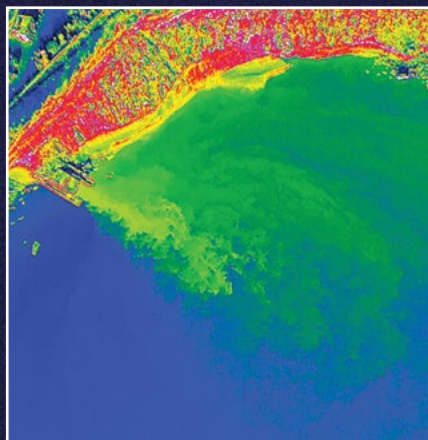
Of particular concern were the changes observed in herbivorous fish. Species like parrot fish were more common near the effluent and thrived in the warmer conditions, while others, such as salemas, were more abundant at control sites with healthier meadows. This shift could

alter grazing pressure on seagrass meadows, potentially destabilising an already vulnerable ecosystem.

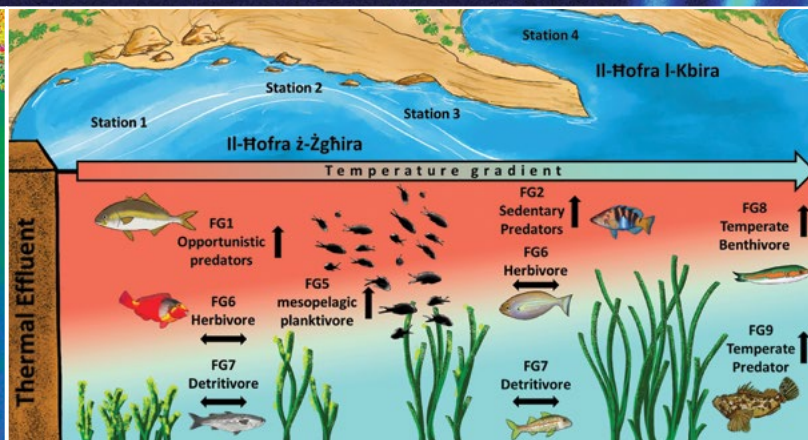
FUNCTIONAL COMPENSATION OR ECOLOGICAL RED FLAG?

In ecology, 'functional compensation' refers to one species stepping in to perform the role of another when environmental conditions change. While this can initially mask ecosystem degradation, it often signals a looming shift.

In our study, detritivores like red mullets were replaced by more heat-tolerant fish, such as grey mullets, near the effluent. This switch may preserve sediment turnover in the short term, but represents a move towards less ecologically specialised and potentially less commercially valuable species. It's a warning that ecosystem services –



Thermal image of the thermal effluent within Il-Hofra ż-Żghira.



Graphical abstract of the manuscript being published featuring the main highlights concerning the seagrass and Functional Groups being analysed.

Images courtesy of Alessio Marrone

like biodiversity support and fishery yield – could decline even if overall fish abundance appears stable.

THE DISAPPEARANCE OF SEASONS?

Another striking finding was the loss of seasonal variation. In the control bay, fish communities changed noticeably between spring and autumn, following expected ecological cycles. But near the thermal plume, this seasonal rhythm was disrupted. Communities remained relatively stable across seasons, hinting at a climate future where warming ‘flattens’ natural fluctuations and may reduce ecosystem resilience.

WHY STUDENTS AND RESEARCHERS SHOULD CARE

Our research shows that even localised warming – from a single power plant – can destabilise critical marine habitats. These findings serve as a proxy for broader climate change impacts, especially in semi-enclosed seas like the Mediterranean, which is warming 20% faster than the global average.

For students and early-career researchers, this work underscores the value of integrating fieldwork, functional ecology, and data-driven modelling to understand environmental change. It also highlights how local observations

can contribute to global understanding.

Furthermore, the research journey – conducting underwater surveys, managing international collaboration, and integrating marine biology with environmental monitoring – offers a blueprint for interdisciplinary science that can drive meaningful environmental policy and conservation.

FINAL THOUGHTS

The twin bays of Il-Hofra ż-Żghira and Il-Hofra l-Kbira may seem like quiet corners of the Maltese coast, but they offer a compelling glimpse into the Mediterranean’s ecological future. As ocean temperatures rise, ecosystems are already beginning to shift – some species thrive, others retreat, and the crucial services these habitats provide may be at risk.

This study is just one part of my broader Ph.D. journey with the OMRG. Beyond seagrass meadows and fish communities, I am also investigating other components of the ecosystem, such as benthic macrofauna (sediment-living organisms located on the seabed, with sizes ranging from 0.5 to 2 mm), to gain a more holistic view of how thermal stress cascades through marine food webs.

Importantly, we are embracing novel and cutting-edge technologies to make

climate change modelling and thermal effluent monitoring more cost-effective and efficient. These include the use of environmental DNA, which enables the detection of species by analysing genetic traces they leave in seawater, and infrared drone surveys, which help map thermal gradients from above with remarkable precision.

By integrating traditional field ecology with advanced tools, we are building a more scalable and responsive approach to monitoring environmental change – one that could be deployed across other vulnerable Mediterranean regions. The hope is not just to understand what is happening, but to develop the capacity to respond quickly, smartly, and sustainably. **T**

Further Reading

Marrone, A., Rinaldi, A., Montalto, V., Gauci, A., Ape, F., Ringear, H., Spoto, M., Martinez, M., La Marca, E. C., Mirto, S., & Deidun, A. (2025). Surviving in a warmer marine world: A study on the impact of thermal effluent on *Posidonia oceanica* meadows and associated fish assemblages in the Maltese Islands. *Journal of Marine Science and Engineering*, 13(3), 475. <https://doi.org/10.3390/jmse13030475>