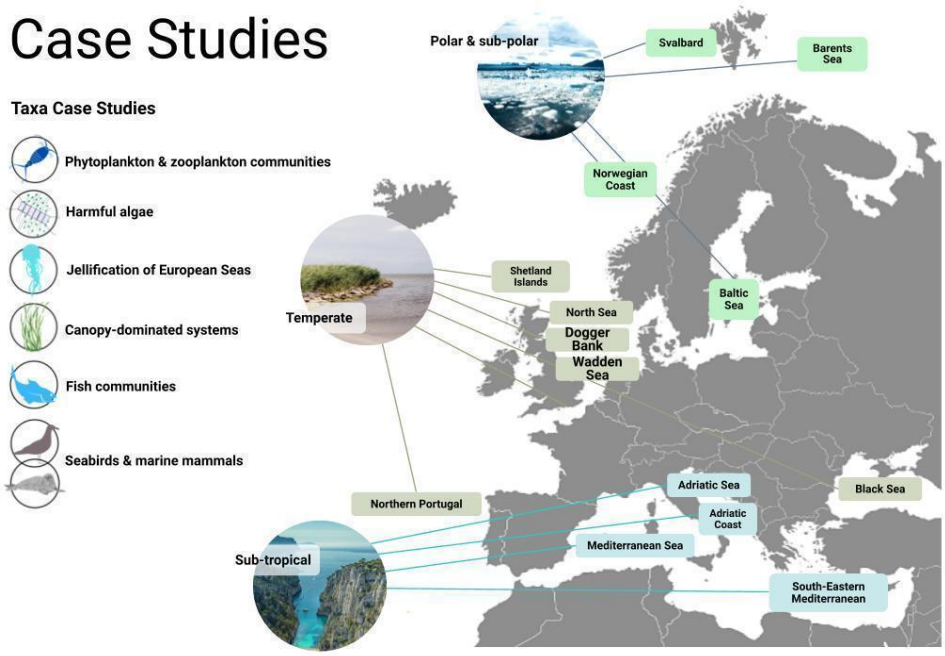
Case Study 12

Sub-tropical

Climate change, Bioinvasions and Pollution Impacts on SE Mediterranean Reefs



ACTNOW

ACTNOW is an EU-funded research project aimed at understanding the cumulative impacts on European marine biodiversity, ecosystem functions, and services for human wellbeing. The project equips regulators and decision-makers with essential knowledge and tools to combat biodiversity loss in coastal and marine habitats threatened by climate change and other regional drivers.

Conducted across various Case Study Regions in Europe, ACTNOW focuses on delivering scientific support for adaptation and mitigation measures, sustainable blue economy expansion, and contributions to the UNFCCC.

The project is structured into six Workpackages: WP1 (Data, Indicators and Scenarios), WP2 (Marine Organisms under Multiple Drivers), WP3 (Community, Food-Web and Ecosystem), WP4 (Cumulative Risks & Biodiversity Assessments), WP5 (Synthesis, Impacts & Solutions Options), and WP6 (Communication and Dialogue).

Objectives include developing 'what if' scenarios, understanding combined impacts on ecosystems, employing advanced biologging and molecular methods, and enhancing awareness of the links between marine biodiversity and human health.

ACTNOW has 17 CSs, 11 are regional CSs while 6 are pan-European (group / taxon) CSs. All are designed to deliver a cause-and-effect understanding, build predictive capacity in models, and to develop indicators and tools for decision-makers charged with the stewardship of European marine biodiversity under threats from multiple drivers (stressors in call) (see fig below). In each case, drivers examined represent the local/regional priorities from regulators who co-create what-if scenarios of interacting drivers including envisioned management actions.

Case Study 12: Climate change, Bioinvasions and Pollution Impacts on SE Mediterranean Reefs

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Description

The Mediterranean Sea is the largest semi-enclosed sea on the planet, and one of the main reservoirs of marine biodiversity; it contains between 4 to 18% of identified marine species while covering only 0.82% of the global ocean surface. However, at EU scale it is also the region with the strongest evidence of habitat loss, although with limited knowledge of the key drivers. The CSs in the sub-tropical area will test the effects of multiple drivers on macroalgal forests and key intertidal species (invasive mussels and snails), fish and jellyfish under different ecological contexts from the intertidal (i.e., the unique and threatened vermetid reefs) to shallow reef macrophyte communities. The threats and opportunities involved in the conservation/management of key species and their ability to provide ES will be examined by measuring the thresholds of functional tolerance to multiple drivers.

The Levantine basin is the easternmost ecoregion in the Mediterranean. Within the Levantine basin, the south-eastern Mediterranean (SEM) corner, represents the trailing-edge of distribution of native Atlanto-Mediterranean and endemic Mediterranean species where they are exposed to the most extreme temperature and salinity conditions in this marginal sea. Many of the species that occur in the western Mediterranean or even in the northeast (e.g., the Aegean Sea) do not occur in the SEM. This means that the native biodiversity is generally lower in the SEM. There are also very few species that are known to be endemic only to the SEM (Coll et al. 2010), among them is the canopy-forming brown algae *Gongolaria rayssiae* (formerly *Cystoseira rayssiae*) (Mulas et al. 2022). The coastal areas (coastline and shallow shelf) are mainly sandy in the south and rocky in the north. The SEM also hosts a unique and fragile intertidal ecosystem named vermetid reefs (or aberration platforms) right at mid sea level (Fig. 1) that are threatened by both sea level rise (Rilov et al. 2021) and the increase in extreme desiccation events (Zamir et al. 2018).

Figure 1: *A vermetid reef in north Israel; a unique and endangered ecosystem. Credit: Gil Rilov*

The SEM is a hotspot for ocean warming and bioinvasions of non-native species, mostly of tropical origin (Coll et al. 2010, Edelist et al. 2013, Rilov et al. 2018, Rilov et al. 2019). Coastal waters are warming ca. four times faster in this region than the global average with an assessed increase by 1.5-3 degrees over the last three decades, and hundreds of mostly tropical non-native species have invaded in the past century and a half (many of which are invasive non-natives - INS, senso lato the revised very broad definition of Soto et al. (Soto et al. 2024) for invasive species) while dozens of native species populations have collapsed or completely disappeared (Rilov 2016). Marine heatwave index analysis shows that currently the entire summer period in the SEM region can be considered as one continuous and strong heatwave that has been intensifying over the past decade (Fig. 2). Invasion rates have also been accelerating in the past few decades, assumingly at least partly because of warming. There is also an increase in the synoptic systems that create extreme desiccation events in the rocky intertidal ecosystem (Zamir et al. 2018).

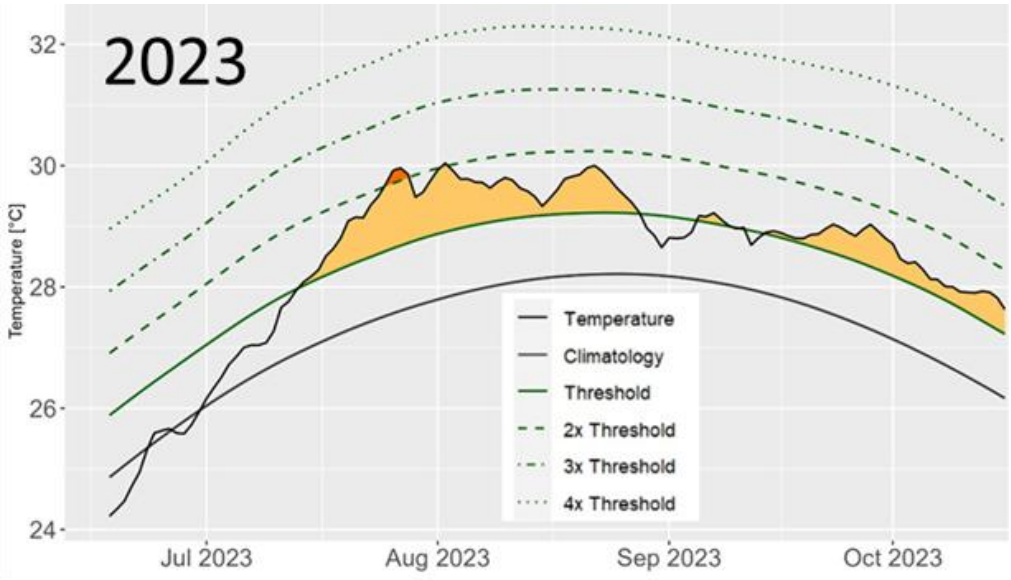

Figure 2*: Marine heatwave "events" in the coastal area near Haifa, Israel, detected from satellite SST data during the summer of 2023 by using the Hobday definition (Hobday et al. 2018) and the Marine Heatwave R program (Schlegel and Smit 2018).*

Furthermore, sea level rise is severe threat to the regional intertidal ecosystems because of the small tidal range and the topographic structure of the rocky intertidal zone in the region. Most of this zone is composed of flat vermetid reefs found in the low shore level, and they will permanently drown with only a small increase in sea level (Rilov et al. 2021). The community on this zone is highly seasonal, dynamic and is experiencing strong ecological shifts, some may be partly related to climate change (Rilov et al. 2020). On top of these global stressors, there is also a strong influence of overfishing by different sectors (Rilov et al. 2018). Other human impacts may include increase in the number and volume of desalination plants, a gradual increase in marine aquaculture (fish in cages, and macroalgae on land) and oil pollution threats, as was demonstrated in an extensive tar pollution event from a passing offshore tanker in February 2021, as well as consistent pollution of heavy metals, mainly mercury, mostly in the Haifa Bay area.

Services

provided by the intertidal and subtidal reef ecosystems include:

· Regulating: protection from beach erosion, carbon sequestration

· Provisioning: coastal fisheries, sea food

Cultural: coastal and marine tourism (diving, hiking, birdwatching, pleasure boating), culture heritage, sense of place, aesthetic values, educational values

· Supporting: biodiversity.

The information in this document should help inform key stakeholders such as the Israeli Ministry of Environmental Protection; Israeli Ministry of Interior; Israeli Ministry of Energy; the Israel Nature and Parks Authority (INPA); and the Fisheries Department under the Ministry of Agriculture and rural development in how to consider climate change, bioinvasions and local stressors like pollutants of different kinds and sources in conservation and marine spatial planning strategies.

Interacting Drivers of Biodiversity Change

Ocean warming, marine heatwaves, extreme intertidal desiccation, bioinvasions, pollution (organic, hydrocarbons, heavy metals)

Regional Context

Monitoring and research in the past two decades in the region resulted in growing evidence that populations of dozens of non-harvested native species have already collapsed in the past several decades on the Israeli coast (Rilov 2016). For one (sea urchin, *Paracentrotus lividus*) we have experimental evidence that warming may have been the main driver (Yeruham et al. 2015), while competition with invasive rabbitfish for food has probably also contributed to its extirpation (Yeruham et al. 2020). The large tropical, invasive, urchin, *Diadema setosum*, gained a foothold in the Levantine region in 2006 in Turkey and was spreading on northern Levantine coast ever since. Only very recently, it has started to spread also on the Israeli coast (Zirler et al. 2023), and it is rapidly increasing in numbers with potential strong impacts on reef communities. The combination of warming and bioinvasions results in major reshaping of coastal benthic communities as well as fisheries stocks, and undoubtedly changes ecosystem functions and possibly services.

A decade of surveys indicated that intertidal (Rilov et al. 2020) and shallow reefs communities (Rilov et al. 2018), as well as trawl catch composition (Edelist et al. 2013, Arndt et al. 2018), have been heavily transformed from their original ecological state and will probably continue to do so. Overfishing has dwindled populations of predators and native assemblages of herbivores and fish are, in many places, dominated by alien species such as the mollusc assemblage (Rilov 2016). Macrophyte communities are dominated by turf “barrens” (probably caused by rabbitfish overgrazing) and, in many areas, there is an increasing cover of alien macroalgae, while native habitat-forming brown macroalgae, which are known to be a major reef component in the Mediterranean Sea with multiple functional roles, have very low cover, are very patchy (Rilov et al. 2018) and are also highly seasonal (collapse in early summer) (Mulas et al. 2022).

In the region, functional MPAs do maintain greater fish communities and predator biomass but alien species are a major component inside these reserves (Rilov et al. 2018, Frid et al. 2021). Preliminary data indicates that, inside a well-functioning MPA, the macrophyte community is more diverse (although dominated by alien species) and possibly with higher biomass than in areas outside the reserve thus benthic ecosystem functions may be more intact in the MPA. The question then rises, what is the role of tropical invaders in an area

where local biodiversity is rapidly shifting by warming and bioinvasions and should we protect them or remove them from MPAs.

Research Needs

Better understanding of the risks and cumulative impacts of global (warming, MHWs) and local (different relevant pollution types) on key species and communities.

Better understanding of the impact of old (e.g., rabbitfish) and new (lionfish, the urchin Diadema) invasive species on reef ecosystems, as well as the functioning of these invaders compared to native species under cumulative stressors.

Adaptive approaches for assessment of ecosystem (and biodiversity) health given high impact of global stressors (mainly ocean warming and bioinvasions).

Research Planned in ACTNOW

● T1.1 Communicate with stakeholders about the main risks to biodiversity and ecosystem functions that are relevant to the case study under the different scenarios and develop what if scenarios.

● T1.2 Participation in the indicator review and development and presenting relevant indicators existing from CS12

● T1.3 Shared existing datasets for the compilation list

● T2.1 Conducting multiple stressor experiments in the lab (with a major focus on the interactions of warming and MHWs with different types of pollution). Conduct fieldwork testing the impact of invasive species on reef communities. Testing the impact of temperature on different traits of endemic canopy forming macroalgae.

● T2.3 Develope scope for growth and/or DEB models for one or several species relevant to the CS

● T2.4 Participate in the meta-analysis development

● T3.1 the development of a HMSC for shallow reefs is considered depending of availability of relevant data and help from partners with expertise

● T3.2 the development of a food web model for shallow reefs is considered depending of availability of relevant data and help from partners with expertise

● T3.3 the development of key ecosystem-level indicators for shallow reefs is considered depending of availability of relevant data and help from partners with expertise

● T4.2 to be considered if applicable

● T4.3 to be considered if applicable

● T5.1 to be considered if applicable

● T5.2 to be considered if applicable

● T5.3 to be considered if applicable

● T6.2 Contributing to the development of the serious game "*Playing for change: Using experiential learning for bridging science and policy making to drive holistic understanding* "

● T6.3 organise stakeholder engagement activities relevant to risks and solutions for the CS

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