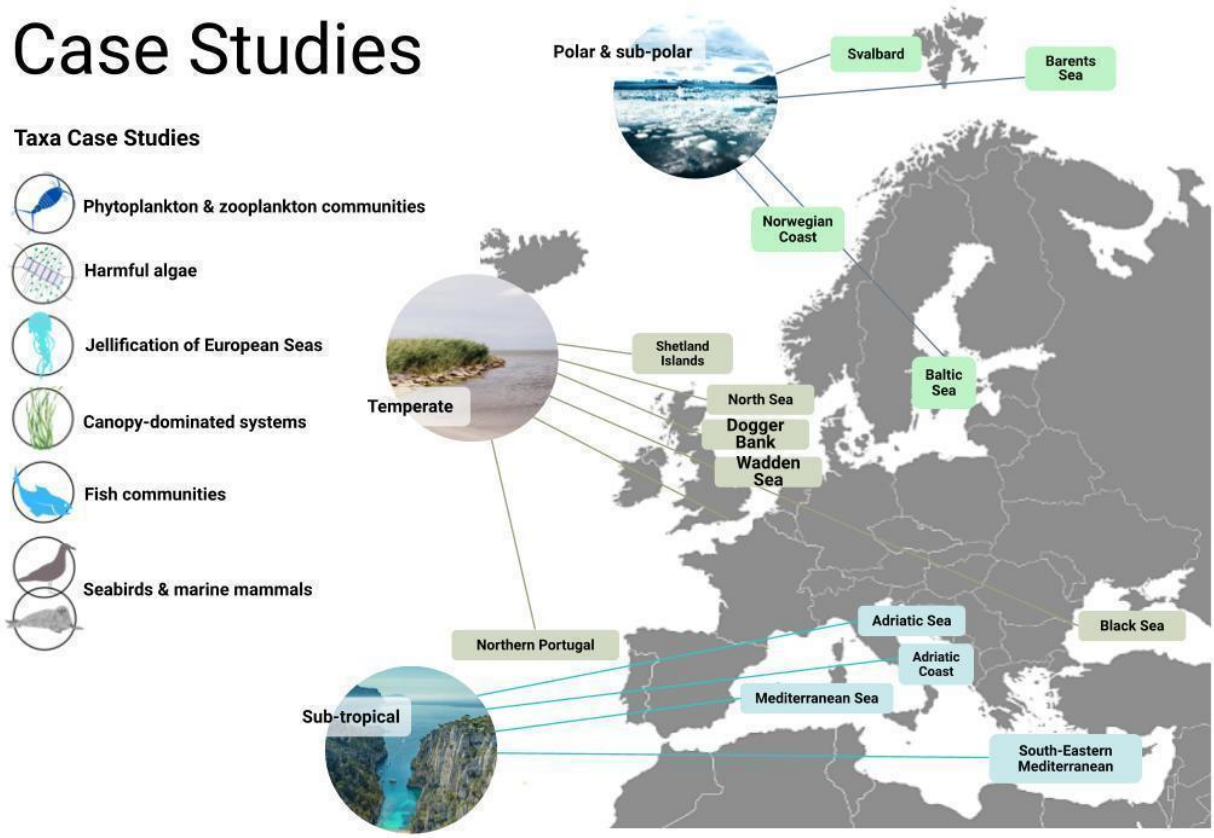
Case Study 10
Sub-tropical

Northern Adriatic Coastal Areas



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 10: Northern Adriatic Coastal Areas

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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 iconic groups of habitat formers (algal and animal forests, seagrasses, mussels), fish and jellyfish under different ecological contexts from shallow habitats to the mesophotic. The threats and opportunities involved in the conservation/management of key species (macroalgal forests, marine animal forests composed by corals, sponges, gorgonians and Posidonia oceanica) and their ability to provide ES will be examined by measuring the thresholds of functional tolerance to multiple drivers.

This CS aims to provide mechanistic evidence of physiological responses and health status of key Adriatic sea macrozoobenthos iconic species in relation to multiple environmental stressors through field work and laboratory experiments. Survival, growth, metabolism, immune function, reproduction, onset of stress-response mechanisms will be evaluated in single-species microcosm experiments under multiple stressors conditions reflecting scenarios of combined anthropogenic pollution and projected ocean changes, e.g. temperature, salinity, acidification. Nonetheless, field experiments will be oriented to the study of organisms' health status in relation to local environmental conditions in different areas of investigation, selected according to the magnitude of anthropogenic footprint and environmental variability.

Services

Adriatic coastal areas (sandy bottoms and rocky shores) offer the following ecosystem services:

REGULATING ES: carbon sequestration; coastal protection;

PROVISIONING ES: aquaculture (bivalves and whitefish) for nutritional purposes; industrial and artisanal fishery; sources of energy;

CULTURAL ES: coastal and marine recreative use (boating, diving, snorkeling), tourism and ecotourism, aesthetic and cultural value;

SUPPORTING ES: nutrient cycling; biodiversity hotspots offering habitat, shelter, feeding and nursery grounds to marine species;

Interacting Drivers of Biodiversity Change

Sea surface temperature (SST) and extreme warming events have been appointed among the main determinants of Adriatic macrozoobenthos fitness, especially in relation to the tolerance toward other stressors which include:

- nutrients availability
- harmful algal blooms
- ocean acidification (OA)
- sea surface salinity (SSS)
- chemical pollution from land (e.g. conventional, legacy and emerging, as pharmaceuticals, pesticides, PFAS, microplastics)

Regional Context

The Adriatic Sea is a highly valued and heavily used marine region, with a semi-enclosed morphology and peculiar oceanographic conditions that make it a distinct sub-region of the Mediterranean Sea. Recognized as a particularly productive basin, it provides natural resources and ecosystem services to approximately 30-50 million people. The basin is characterized by shallow depths in the north and deeper waters in the southern area, with highly differentiated habitats hosting several endemic and economically relevant species.

Yet, the Adriatic sea and its northern area in particular, has been highlighted as one of the most vulnerable sub-basins in the Mediterranean sea to climate-related changes, affected by increasingly marine heatwaves, acidification and freshening, due to the aforementioned semi-enclosed morphology and shallow depths that amplify these processes. Nonetheless, the basin is among the most threatened and impacted regions of the Mediterranean sea due to a consistent anthropogenic footprint arising from exploitation of resources through fishery and aquaculture, oil and gas extraction, maritime traffic, but also tourism and riverine effluents and waste water treatment plants discharges delivering relevant loads of conventional, legacy and emerging contaminants.

The Mediterranean mussel *Mytilus galloprovincialis* represents a fundamental species along rocky coastal Adriatic areas, key for ecosystem functioning by supporting the benthic-pelagic coupling of nutrients and energy and acting as ecosystem engineer. Nonetheless, this species is the main cultured in the basin, representing a significant socio-economic asset. Specifically, along Conero Riviera rocky coast, wild mussels ("mosciolo") contribute with provisioning and regulating ecosystem services, but also cultural due to the historical and traditional aspects in the Marche region connected to this species. Due to their nutritional and cultural peculiarities, wild mussels in Conero Riviera have earned the endorsement of the Slow Food Movement as protected product. Unfortunately, despite its tolerance toward abiotic stressors, the vulnerability of this species toward ongoing changes has been highlighted under multiple stressors scenarios, including marine heatwaves, acidification and pollution (Giuliani et al., 2020; Mezzelani et al., 2021; Nardi et al., 2022, 2021, 2018, 2017), and mass mortality events of wild mussels are increasingly being documented (Brachetti et al., 2024; Garrabou et al., 2022).

In such a context, there's an urgent and growing interest in understanding thresholds of tolerance of this species to climate change related stressors and pollution, also in relation to biotic and abiotic factors that may modulate such threshold as host-microbiota interactions, ecological history and reproductive cycle. Unravelling mechanisms of action and interaction of stressors, and the factors influencing the magnitude of effects, is crucial in order to predict the impacts on socio-economic and ecological assets, provide solutions for their conservation, and support stakeholders and policy makers in coastal resources use and management.

Research Needs

Identify pressures on wild and cultured bivalves and on iconic species in the area, the threshold of tolerance of selected species towards multiple environmental stressors, and explore mitigation and conservation strategies.

Research Planned in ACTNOW

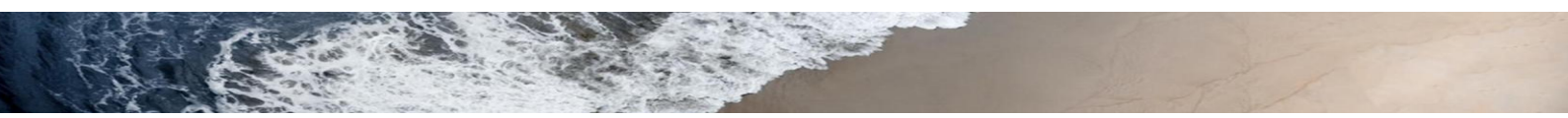
Manipulative experiments will be performed on selected species reflecting ecological and economically relevant assets of Adriatic sea, including bivalves *Mytilus galloprovincialis* (native) and *Ruditapes philippinarum* (invasive, intentionally introduced for aquaculture purposes) and the sea anemone *Anemonia viridis*. Single-species microcosm experiments will be used to identify organisms' responses at various levels of biological organisation (molecular, cellular, physiological) to multiple environmental stressors, as marine heatwaves, salinity stress, hypercapnia, and chemical pollution (pharmaceuticals, pesticides, PFAS). In parallel, field experiments will be aimed to study selected species health status in different sites in relation to environmental conditions (temperature, salinity, background pollution, …) and explore mitigation and conservation strategies, as heat hardening and priming techniques.

- T2.1 - Lab experiments with mussels (*Mytilus galloprovincialis*), clams (*Ruditapes philippinarum*) and sea anemones (*Anemonia viridis*) aimed to evaluate organisms' responses at various levels of biological organisation (molecular, cellular, physiological) to multiple environmental stressors, as marine heatwaves, salinity stress, hypercapnia, and chemical pollution (pharmaceuticals, pesticides, PFAS).

Strategies to ameliorate the performance of organisms under multiple stressors scenarios will be explored: use of heat hardening and priming techniques will be tested in lab experiments and successful approaches will be then transferred to the field.

Field activities in Conero Riviera, central Adriatic sea, will be aimed to evaluate organisms' health status in relation to environmental condition: periodic activities (4-6 weeks) will involve the sampling of wild and translocated mussels, to study the bioavailability of chemicals and their health status throughout the year and in relation to the occurrence of possible extreme events. Nonetheless, the susceptibility of mussels early-life stages (gametes and embryos) toward selected stressors will provide insights on shellfish stocks vulnerability. This activity will allow to explore possible mitigation and conservation actions to counteract the decline of wild mussels population, with implications for both biodiversity and fishery.

All the results produced in this task will be also used and valorized in T2.3



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