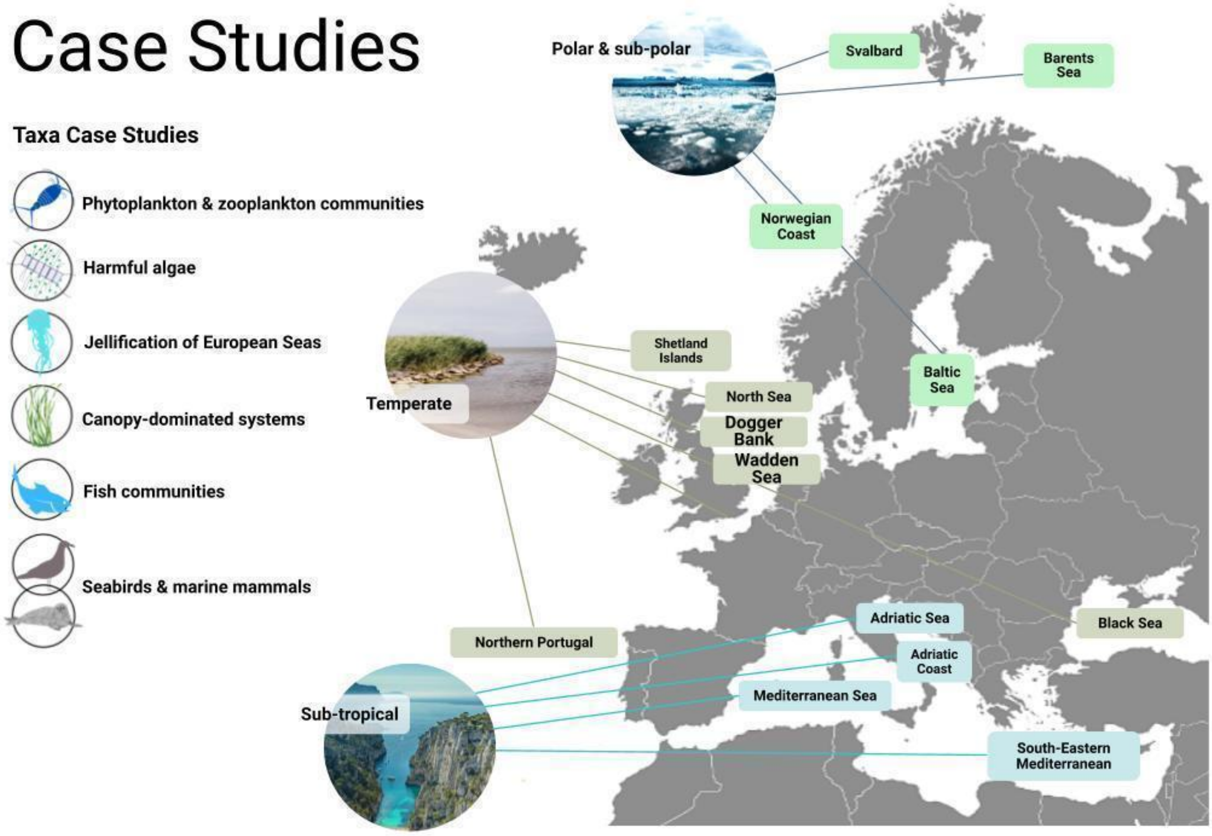
Case Study 7
Temperate

Black Sea Ecosystem



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 7: Black Sea Ecosystem

Leader

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Description

The Black Sea is the world's largest anoxic basin with limited connection to adjacent seas, and a large catchment area including some of the largest European rivers. Its ecosystems are particularly vulnerable, having gone through environmental collapse and partial recovery in the past (Kideys, 2002), with regime shifts from a pristine state with negligible human pressures before 1960 to environmental degradation in the 1980s-1990s as a result of eutrophication from intensive agriculture, overfishing and invasive species which disrupted both the benthic and pelagic food webs (Daskalov et al., 2017; Mee and Topping, 1998; Prodanov et al., 1997; Sukhanova et al., 1988). Since the late 1990s, nutrient loads have decreased, resulting in a gradual recovery of the ecosystem (Todorova et al., 2022).

The western part of the Black Sea is also subjected to multiple natural and anthropogenic stressors like large river discharges and related nutrient and pollutant loads, continuous land use change and urbanisation of the coastline, tourism, overfishing, aquacultures, maritime transport. Anthropogenic activities and pressures are often in conflict with marine protected area management plans aiming to maintain biodiversity, ecosystem functions and ecosystem services.

With the continuing overexploitation of fish stocks (Daskalov, 2012; FAO, 2022), and increasing seawater temperature due to climate change leading to reduced vertical water mixing and increase of the hypoxic zone (Capet et al., 2020), the study of biodiversity changes, ecosystem processes and services in the area is especially urgent.

Services

Key ecosystem services provided by the Black Sea ecosystem include:

- Provisioning: wild capture fisheries and aquaculture
- Regulating and maintenance: carbon sequestration, water filtration and element/matter cycling, primary production, habitat provision incl. fish nursery habitats
- Cultural: coastal and maritime tourism

Interacting Drivers of Biodiversity Change

<u>Key direct and indirect stressors:</u>

Point and diffuse sources of pollution (rank 5);

Continuous urbanisation (rank 3);

Overfishing (rank 5);

Climate warming (rank 3);

Eutrophication (rank 5);

Invasive species (rank 4).

<u>Impact of multiple stressors (field time series availability)</u>

Eutrophication (rank 5)

Overfishing (rank 5)

Spatial distribution, biodiversity and ecological status of benthic communities (rank 4)

Persistent pollutants (rank 2)

Research Needs

Basin-wide ecosystem model studies:

At present climate related indicators and predictions of biological production are too simplistic and apparently inconsistent with food web/ecosystem data and theory, as they rarely account for complex interactions between bottom-up and top-down effects (Lynam et al 2017). We will work toward developing climate related indicators reflecting food web interactions and hierarchies (Heath et al 2014; Daskalov et al. 2017). End to end (from hydrography to top-predators and fishing) data and trophic models (EwE) will be used to explore, model and simulate food web indicators of climate change, fishing and non-indigenous species. As a first stage, exploratory statistical data analyses will be performed to reveal mechanisms and provide explanations of climate and anthropogenic (fisheries, introduced species) effects on hierarchically structured marine food webs (WPs 1&2). Next, series of EwE models and scenarios will be built to account for different historical states of the Black Sea ecosystem and related climate forcings (WP3). Finally, forecast simulations will be run using moderate/extreme climate and anthropogenic change scenarios, and implications for ecosystem management will be accounted for (WP5).

Coastal ecosystems studies- in-situ and microcosm laboratory experiments:

Multiple stressor impacts on coastal rocky reef benthic ecosystems

We will investigate the combined effects of various pressures on the structure, distribution and functions of Black Sea infralittoral rocky reefs dominated by a mixture of Cystoseira macroalgal 'forests' and Mytilus galloprovincialis black mussel reefs. Cystoseira communities have been under a continuous eutrophication impact since the 1970s and have suffered a severe decline in their distribution and structure, followed by a period of recovery and stable structure since the early 2000s. M. galloprovincialis communities co-inhabit coastal reefs together with macroalgal communities with preferences towards more exposed coasts and areas with increased organic matter inputs. They have been under predatory pressure from the invasive Rapana venosa whelk since the 1960s, suffering severe decline in recent years, with areas that have completely lost their black mussel populations in recent years, and areas that have recovered from the impacts. On top of that, Mytilus reefs are impacted by bottom trawling and illegal mussel harvesting. Both Cystoseira and M. galloprovincialis communities are vulnerable to extreme summer temperatures (heat waves), where sea water temperatures above ~30° C could result in rapid die outs of benthic organisms. Local hypoxia events, resulting from eutrophication cascades and increased temperatures, have also been observed to have impacts on these communities. Possible future pressures from NIS (herbivorous fish species etc.) entering the Black Sea through the Bosphorus channel with the ongoing increase in sea water temperatures should also be taken into account.

Our long-term data on the community structure of these two ecosystems since 2009, combined with continuous monitoring of the physical and chemical properties of marine coastal waters (nutrients, chl-a, oxygen concentration) will allow us to study the dynamics in the impacts of these combined pressures and to develop scenarios for future changes in coastal ecosystem structure and functions (WP 1 & 2). We plan to compare recent data from our study sites (species diversity and abundance, biomass and spatial structure of macroalgal and Mytilus populations) with 'historical' and decade-old biological and environmental data, run experimental in-situ nutrient enrichment experiments and exclusion experiments(WP2, T2.1, T2.2), and develop different scenarios based on multivariate statistical analysis and habitat suitability models (WP3).

Multistressor impacts on the functional diversity of soft-bottom ecosystems and sediment-water interactions

Soft-bottom ecosystems have the widest distribution of all ecosystem types along the Black Sea coast and shelf. Their characteristic macrobenthic communities perform important ecosystem functions such as bioturbation and bioirrigation, through which they regulate and influence biogeochemical processes and benthic-pelagic coupling, Rising coastal pressures in the region and climate change are likely to severely impact soft-bottom ecosystems, and the services they provide. However, in the Black Sea, the functional aspects of soft-bottom biodiversity, and the cumulative impacts of climate change and anthropogenic stressors on them, are currently understudied.

We will investigate the effects of multiple stressors (temperature, hypoxia, organic matter loading (eutrophication)) on key Black Sea soft-bottom communities through laboratory and in situ micro- and mesocosms, and quantify the changes in bioturbation rates and nutrient and oxygen sediment-water fluxes (WP2, T2.1). We will attempt to estimate critical loads/thresholds leading to significant reduction in ecosystem function, and apply trait-based analyses to identify particularly vulnerable traits/communities (WP2, T2.3).

Existing data on coastal benthic communities, and national WFD and MSFD monitoring wider-scale data will be used to extrapolate the experimental results and model the responses to future change scenarios, and develop predictive maps of traits/species abundance changes (WP3). The trait-based analyses will be supported by a database of functional traits on Black Sea invertebrate fauna, currently under development at IBER-BAS.

Marine plastic pollution and food webs

Building on previous data on water and sediment microplastic pollution in the coastal Black Sea, we will attempt to quantify/identify the possible transfer of microplastics over the food web, from benthic primary consumers with different feeding methods – filtrators/suspension feeders (e.g. bivalves), surface and subsurface deposit feeders (e.g. benthic polychaetes, some clams), to higher-level consumers such as benthic-feeding fish (WP1 & 2). We will sample locally abundant/important benthic invertebrate species characterized by their predominant feeding method, and benthic-feeding fish, and quanitfy and analyze the possible microplastic content in their tissues. The samples will be collected in areas with higher identified plastic pollution, and other, relatively clean areas. The results will contribute towards filling the knowledge gaps in microplastic pollution impacts on marine food webs, and developing and refining MSFD GES indicators.

Research Planned in ACTNOW

● T1.1

Regionalization of “What if” scenarios for the Black Sea using stakeholder inputs from previous projects (BRIDGE-BS Living labs, SOMBEE)

METU: Results from the stakeholder workshops organised under the Biodiversa-Belmont Forum funded project Scenarios of Marine Biodiversity and Evolution under Exploitation and climate change (SOMBEE) are used for the What-If scenarios. Scenarios were co-created for IPCC’s RCPs and SSPs and stakeholders from Turkey, namely Turkish Marine Research Foundation, Central Union of Fishers Cooperatives, Ministry of Environment, Urbanisation and Climate Change, Ministry of Agriculture and Forestry and the Commission for the Protection of Black Sea against Pollution, attended the two workshops organised in February 2020 and October 2022. Further, questionnaires were distributed to the members of the stakeholder organisation to collect data about their perception on climate change and anthropogenic stressors impacting the Black Sea ecosystem.

● T1.2

Reviews of biodiversity and ecosystem health metrics and indicators used in the Black Sea - benthic and pelagic ecosystems.

● T1.3

Inventory of long-term time series and monitoring datasets available for the Black Sea.

● T2.1

- Field studies of macroalgal communities long-term change in eutrophication gradients and increasing SSTs
- Canopy thinning experiment in *Gongolaria barbata* canopies
- Field studies of predation of invasive whelk *Rapana venosa* on black mussel *Mytilus galloprovincialis* reefs
- Field studies - microplastics in coastal food webs
- Field studies - in situ measurements of community metabolism/oxygen fluxes
- Laboratory microcosm experiments exploring heat wave effects on seagrass and sand community metabolism and nutrient and oxygen sediment-water interface fluxes.

● T3.1

Attempt to develop HMSC model for coastal macrobenthic communities and drivers for the Black Sea based on available datasets

● T3.2

Estimation of key indicators of food-web structure for the Black Sea, and their responses to future changes using regional scenarios, based on EwE and OSMOSE models.

<u>METU:</u>

METU: Climate and fishing scenarios are being simulated using the Object-oriented Simulator for Marine Ecosystems (OSMOSE) Black Sea model (OSMOSE-BS) using IPCC scenarios until 2100. The OSMOSE-BS model includes eight fish species: three small pelagic fish species: European anchovy (*Engraulis encrasicolus; Linnaeus, 1758*), European sprat (*Sprattus sprattus; Linnaeus, 1758*), Mediterranean horse mackerel (*Trachurus mediterraneaus; Steindachner, 1868*), three demersal fish species: red mullet (*Mullus barbatus;* Linnaeus, 1758), whiting (*Merlangius merlangus;* Linnaeus, 1758), turbot (*Scophthalmus maximus*; Linnaeus, 1758), and two pelagic piscivorous fish species: bluefish (*Pomatomus saltatrix; Linnaeus, 1776*) and bonito (*Sarda sarda*; Bloch, 1973). The OSMOSE-BS model was offline and one-way coupled to the Geophysical Fluid Dynamics Laboratory's Earth System Model (GFDL-ESM4), which contributed to the sixth phase of Coupled Model Intercomparison Project (CMIP6) (Dunne et al., 2020; Stock et al., 2020). Currently, preliminary outputs from climate scenarios are available using IPCC scenario (SSP 3.70), which is a combination of the Shared Socioeconomic Pathway 3 (SSP3) and the Representative Concentration Pathway 7.0 (RCP 7.0) scenarios, and fishing scenarios are underway. Two scenarios were used. The first scenario represented the historical period of the Black Sea from 2000 to 2014, and the second scenario represented the future climate change scenario, representing the impacts of climate change for the period 2086 to 2100. Once Black Sea downscaled products from FutureMARES are ready, the scenarios will be updated.

Future biomasses and catches of the commercially important fish species are predicted to decrease under the climate-only scenario (Figure 1).

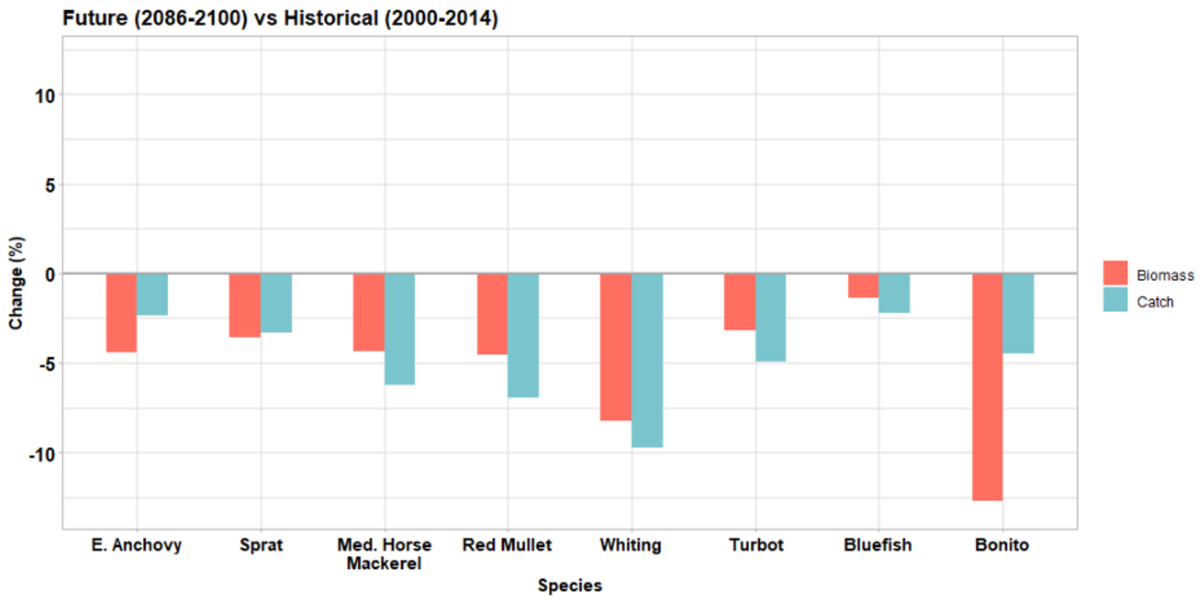


Figure 1. Relative change in biomass and catch between future climate and historical scenarios.

The proportion of biomass in the species populations considering their allowed minimum landing sizes was analysed. Smaller sizes are predicted to increase and larger sizes are predicted to decrease within the populations (Figure X2).

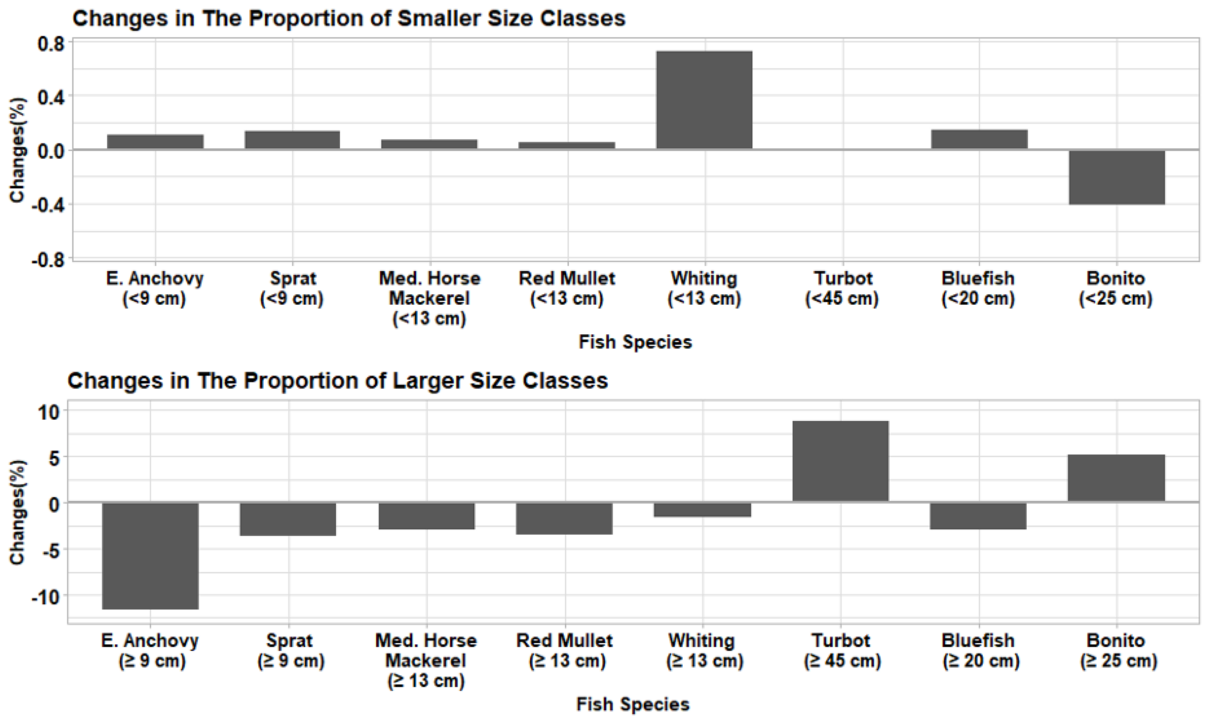


Figure 2. Percentage changes in the proportion of biomass of species smaller and larger than their minimum landing size between future climate and historical scenarios.

IBER - BAS: Several EwE models of the Black Sea have been developed, including time and space dynamics and time-dynamic coupled with biogeochemical models. The present EwE model covers the period 1995-2020. It is upgraded with data from the last Black Sea stock assessments up to 2020, most of which are prepared within the Horizon 2020 project EcoScope (GA 101000302 EcoScope). The model structure is set to 35 trophic groups including phytoplankton (2 groups), macrophytobenthos (4 groups), protozoans (2 groups), invertebrates (zooplankton and zoobenthos, 12 groups), fish (11 groups), dolphins (1), and detritus (1 group, Fig. 1). Fisheries consist of 5 fishing fleets. Three functional groups were added based on new stock assessments: bonito, bluefish, and red mullet. The EwE model is coupled with the LTL phytoplankton biomass for the hindcast years 1995-2020.

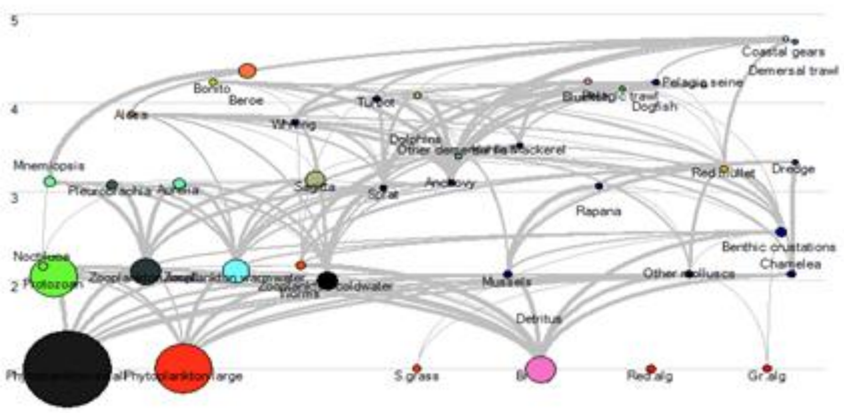


Figure 3 Black Sea EwE model structure: trophic group size correspond to relative production, groups are ordered by trophic level (on Y axis).

THe Ecospace basin-scale model was updated from Daskalov 2015 by adding a new 10 x 10 km grid. Five habitats were defined based on depth and productivity of the Black Sea waters: Habitat 1 (coastal waters), Habitat 2 (inner shelf), Habitat 3 (outer shelf), Habitat 4 (slope), Habitat 5 (deep sea, Fig.2). Functional groups may occur in more than one habitat, and some groups (e.g. plankton, dolphins) are expected to occur in all habitats. The fishery is represented in Ecospace by assigning fisheries fleets to habitats, i.e. defining in which habitat(s) a fisheries fleet may operate.

Figure 4. Representation of Black Sea Ecospace 'habitats' (lighter to darker blue): Habitat 1 (coastal waters), Habitat 2 (inner shelf), Habitat 3 (outer shelf), Habitat 4 (slope), Habitat 5 (deep sea).

The time-dynamic model Ecosim was validated by fitting to empirical time-series of biomass and catches (Figs. 3 & 4). The fit is carried out by numerically adjusting the so-called vulnerability parameters (v's) that are responsible for dominance of top-down (v~5-1000), intermediate (~2) ot bottom-up (~1) control over the groups feeding interactions. The fitted model over 1995–2020 shows good resemblance to empirical time-series data (Fig. 3 & 4).

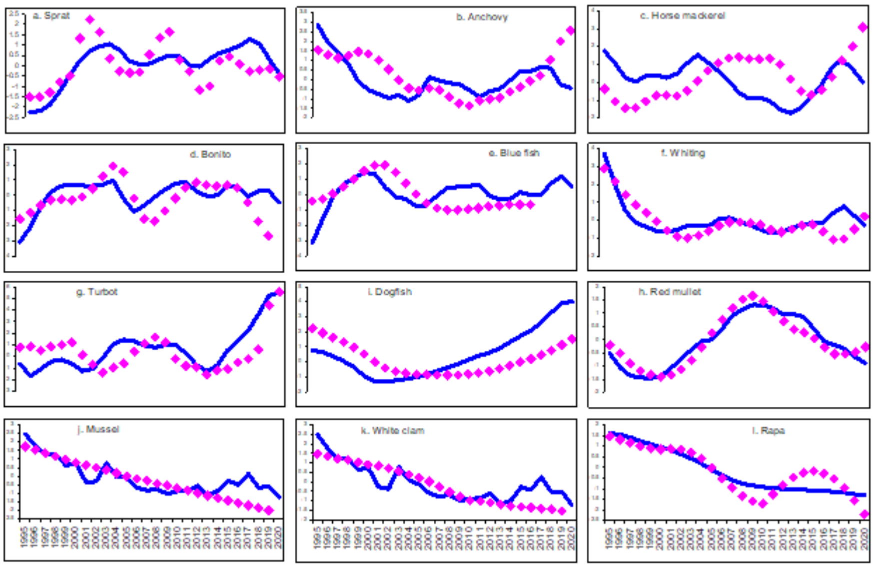


Figure 5. Fitted Ecosim model: lines are estimated and dots are empirical time series of relative biomass

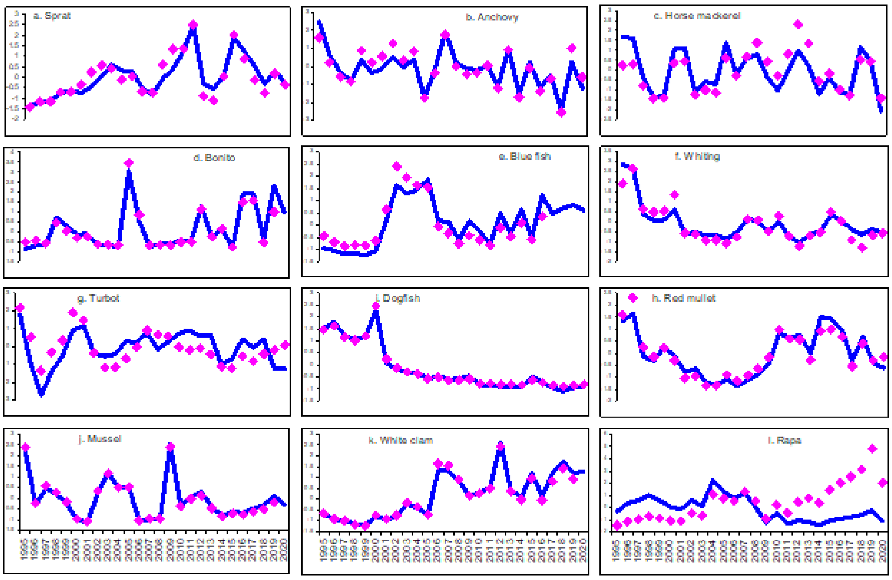


Figure 6 Fitted Ecosim model: lines are estimated and dots are empirical time series of fisheries catches

- T3.3

Estimate key ecosystem-level indicators and compare their responses to multiple drivers and future changes using regional scenarios for the Black Sea based on EwE and OSMOSE models. Comparison with indicators derived from other models/case studies.

<u>METU:</u> The OSMOSE-BS model and Black Sea Ecopath with Ecosim hindcast models are ready. Preliminary climate scenario simulations from OSMOSE-BS are ready and presented under T3.2. Once the FutureMARES downscaled products for the Black Sea are ready, the collaborative modelling approach defined in the GA in May 2024 will be followed for scenario simulations.

● T4.1

Inventory of existing biodiversity assessment tools in the Black Sea.

● T4.2

Support for the development of cumulative risk and biodiversity framework, with focus on the Black Sea case study regional context and stakeholder views/needs collected in other projects.

● T4.3

Application of biodiversity risk frameworks to assess the current biodiversity status and risk in the Black Sea.

● T6.1

Compilation of stakeholder inputs for the Black Sea regional problems, needs, drivers, from other recent projects (BRIDGE-BS, SOMBEE).

● T6.2

Participation of PhD students (N. Bobchev) in Actnow early career scientist network and trainings. 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

Preparation of publications with the results, presentation of results at international conferences, interviews and media presentations of Actnow work in the coastal Black Sea.

Pictures, graphs and maps

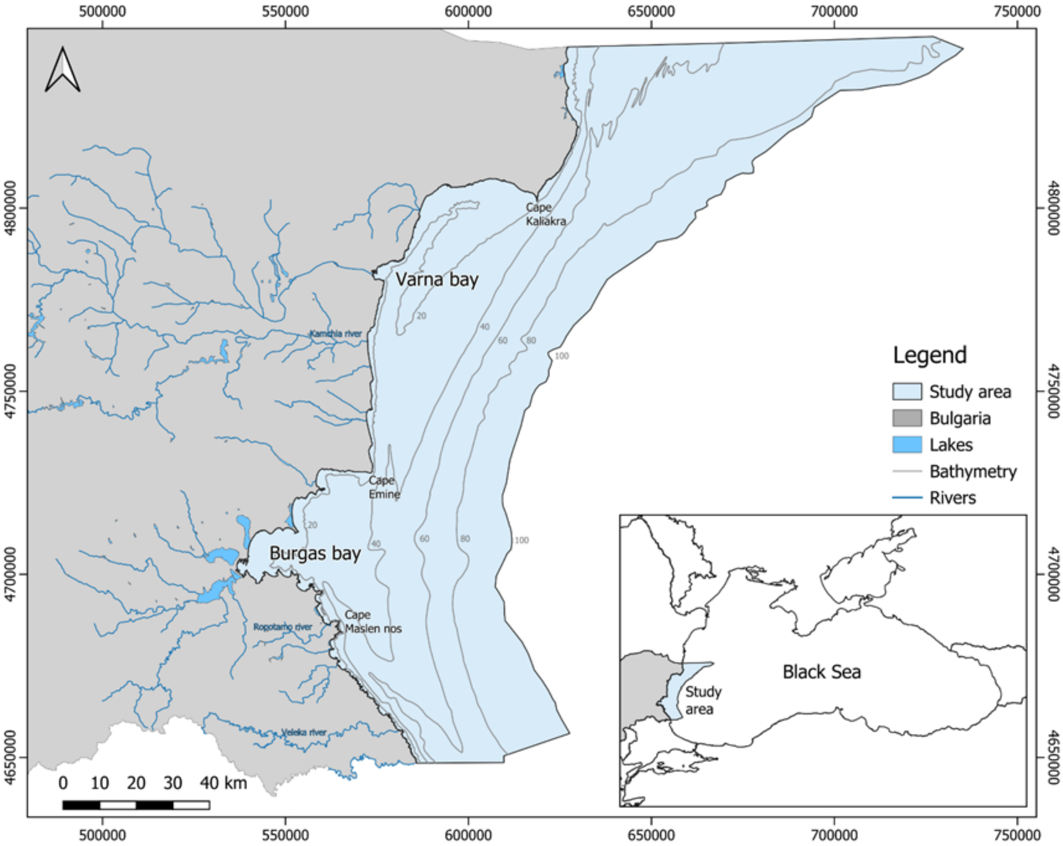
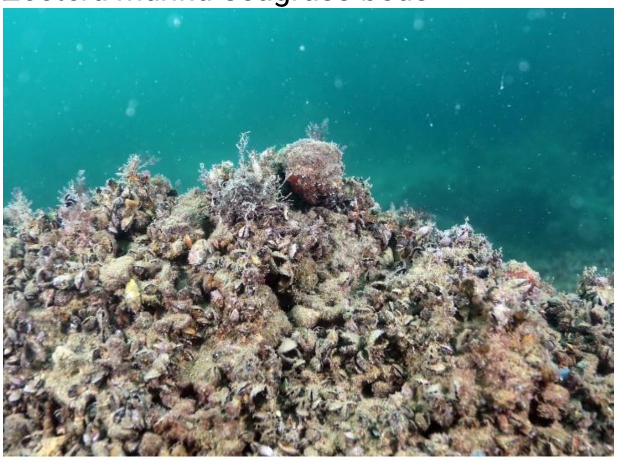


Figure 7. SW Black Sea coastal and shelf area and Bulgarian Black Sea coast

Coastal shallow-water sandy seabeds

Cystoseira spp. communities

Zostera marina seagrass beds



Mytilus galloprovincialis reefs and *Rapana venosa*

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