

Acidification of Europe's seas: an overview based on the European Climate Adaptation Database

Summary

European marine regions range from open oceans to almost entirely land-locked. The European Union member States are responsible for more than half of the regional seas surrounding the European continent and outermost regions (> 5 700 000 km²). 206 million people (41% of EU population) lives in coastal regions (2011)¹. European seas include a wide range of marine and coastal ecosystems, ranging from the stable environment of the deep ocean to highly dynamic coastal waters.

European Union policy initiatives that focus on the sustainable exploitation of marine resources are:

- Common Fisheries Policy (CFP)
- Integrated Maritime Policy (IMP) → maritime spatial planning (MSP)
- Thematic Strategy on the protection and Conservation of the Marine Environment (includes the Marine Strategy Framework Directive (MSFD))
- European Strategy for Marine and Maritime Research
- EU Biodiversity Strategy
- Blue Growth Strategy

The pH of ocean surface waters has already decreased from an average of about 8.2 to 8.1 since the beginning of industrial revolution. If the atmospheric CO₂ level be over 936 ppm² this would result in 0.3-0.4 pH unit decreasing by 2100 which means that the ocean would be about 100-150% more acidic. Measurements at time-series stations near the Canary Islands confirm a 0.02 pH drop over the last decade and corresponding decreases in saturation states of both calcite and aragonite. The average surface pH of the Black Sea is substantially higher than that of the Baltic and Mediterranean Seas. Differences in surface pH between these seas are largely explained by differences in carbonate ion concentrations. The relative change in the pH is slightly more in the Baltic Sea where the carbonate ion concentration is lowest, and it is slightly less in the Black Sea, where carbonate ion concentrations are highest.

10% of the Arctic Ocean may become corrosive to calcium carbonate already by 2020.

Surface-waters of the Baltic Sea could become corrosive to all forms of calcium carbonate well before the end of the century.

No danger of surface waters becoming corrosive to CaCO₃ before 2100, but sharp reductions in CO₂⁻² concentrations (Med Sea: -37%, Black Sea: -45%).



Anikó ZSENI and Éva V. Pestiné RÁCZ
Széchenyi István University, Győr Hungary (EU)
zseniani@sze.hu racev@sze.hu

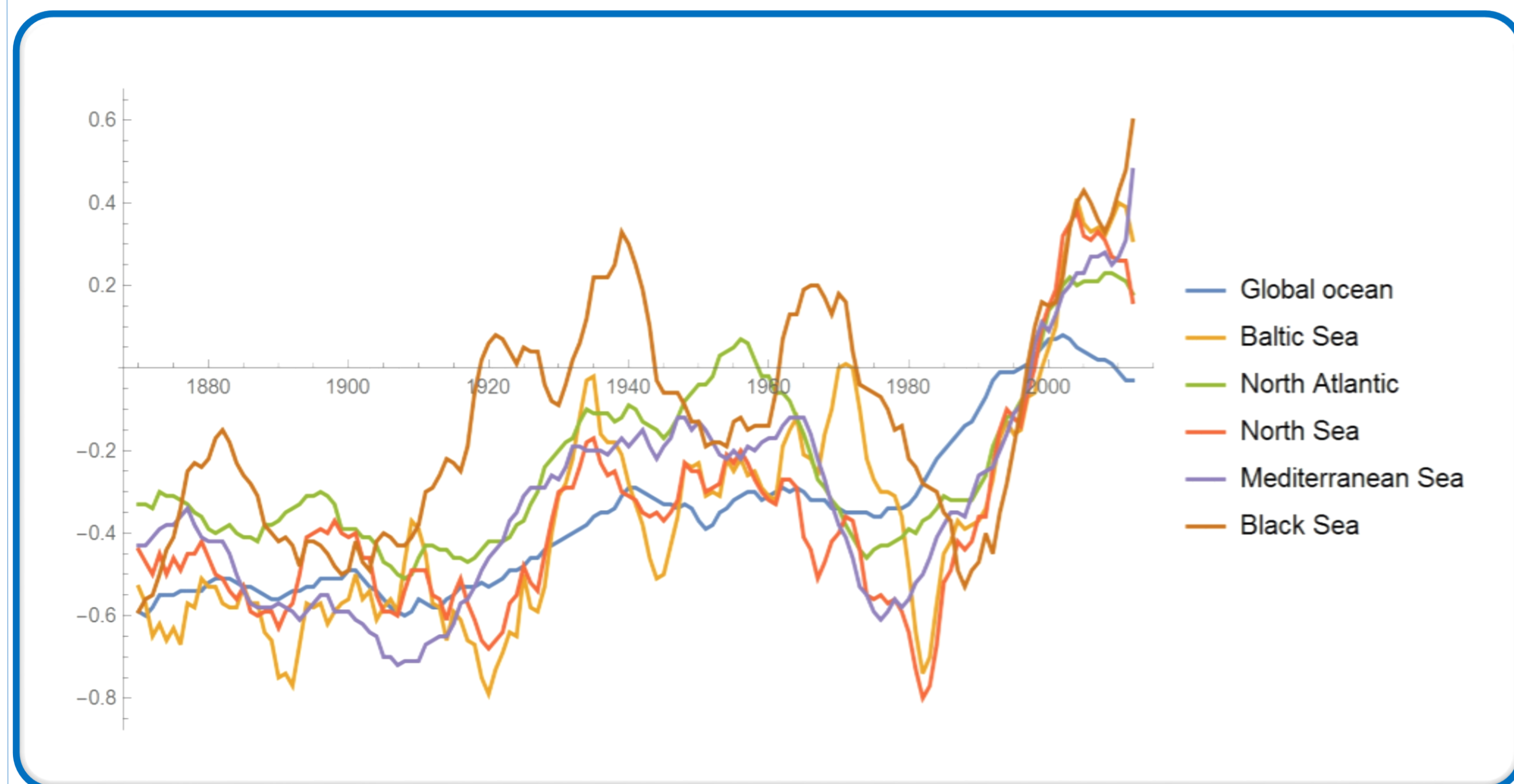


Figure 1. Annual average sea surface temperature anomaly, referenced to the average 1970-2012

North Atlantic (Arctic ocean, Baltic sea)

- Has the highest proportion of the anthropogenic carbon distributed throughout the whole water column
- The loss of sea ice of Arctic has implication for ocean acidification since open waters absorb more CO₂ from atmosphere
- Arctic surface water is already close to undersaturation with respect to aragonite
- the Arctic may experience corrosive surface waters in the near future
- interactive effects with warming and expanding hypoxia
- certain calcareous taxa (e.g. planktonic foraminifera) are actually increasing in abundance, a trend associated with climate shifts in Northern Hemisphere temperature
- ocean warming may increase general productivity in the North Atlantic, which increase in fish catch
- ocean acidification could constrain this increase in catch potential
- bivalves are likely to be impacted by ocean acidification
- effects of acidification on adult fishes may be small and indirect
- The long-term resilience of cold water coral reefs to ocean acidification is a concern and their continued role as a nursery habitat for fishes is unknown.
- fisheries and aquaculture:
 - major regional political, social and cultural importance in coastal European countries
 - a large fraction of the economies of Greenland, Iceland and the Faroe Islands
- The people most vulnerable to the impacts are Arctic indigenous people who depend critically on fisheries for their diet and income.

In April 2013 the European Commission adopted the EU strategy on adaptation to climate change (known as White Paper) which aims at making Europe more capable to face climate change by reducing the vulnerability of its sectors, systems, people and assets. It sets out a framework and mechanisms for taking the EU's preparedness for current and future climate impacts to a new level. The White paper is accompanied by several working documents, one of it concerns water, coasts and marine issues including ocean acidification. Based on the European Climate Adaptation Database the poster presentation provides an overview of research and knowledge projects deal with the acidification of Europe's seas.

Table 1. Recent research projects on acidification of Europe's seas

Project name	Duration	Funding	Key words	Geographic characteristics	Partners	Description	Websites
MEECE: Marine Ecosystem Evolution in a Changing Environment	2008-2013	EC Seventh Framework Programme (FP7)	Decision support systems, guidelines, impact assessment, indicators	Europe: Baltic Sea, North Sea, Atlantic Area, Mediterranean	22 partners lead: Plymouth Marine Laboratory (UK)	How marine ecosystems respond to combinations of multiple climate change and anthropogenic drivers. Special work packages on ecosystem response to climate change and acidification	www.meece.eu/
VECTORS: Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors	2011-2015	EC Seventh Framework Programme (FP7)	Marine ecosystems, human pressure, biodiversity, invasive species, outbreaks, fisheries, ocean acidification, ecosystem service, ecosystem goods, ballast water	Europe: Baltic Sea, North Sea, Mediterranean	37 partners lead: Plymouth Marine Laboratory (UK)	How environmental and man-made factors are impacting marine ecosystems now and how they will do so in the future.	www.marine-vectors.eu
VECTOR: Vulnerability of the Italian coastal area and marine ecosystems to climatic changes and their role in the Mediterranean carbon cycles	2006-2001	Various Italian Ministries, Integrated Special Fund for Research (FISR)	Coastal areas, biodiversity, carbon cycle, sea level rise, fishery, Mediterranean, impact scenarios, wetland	Europe: Mediterranean	8 partners, lead: CoNISMA – National Inter-University Consortium on Marine Sciences (IT)	Most significant impacts of climate change on the Mediterranean marine environment and the role of this basin on the planetary CO ₂ cycle. Possible future impact scenarios on the Italian coasts.	vector.conismambi.it/sito%20inglese/e-index.htm
MedSea: Mediterranean Sea acidification in a changing climate	2011-2014	EC Seventh Framework Programme (FP7)	marine ecosystems, acidification, scenarios, economic effects, Mediterranean	Europe: Mediterranean	16 partners, lead: Universitat Autònoma de Barcelona (ES)	Projections of Mediterranean acidification under the influence of climate change as well as associated economic impacts. Projections based on new observations of chemical conditions, new observational and experimental data on the responses of key organisms and ecosystems to acidification.	medsea-project.eu/
SUSFISH	2009-2012	EU INTERREG-IVA Ireland/Wales Programme	environmental conditions, productivity, oceanographic modelling, environmental parameters, scenarios	Europe: Atlantic Area	5 partners, lead: Bangor University Wales (UK)	Guidelines for future (50-100 ys) fisheries management, ensuring sustainable development of the shellfish industry in Ireland and Wales. How current commercial shellfish productivity in the Irish Sea will respond to changes in temperature, salinity, water quality (eutrophication, acidification), sea level rise and changes in ocean current regimes.	www.susfish.com/
UKOA: UK Ocean Acidification Research Project	2010-2015	Various UK ministries and councils	ocean acidification	global	lead: 6 organisation other partners: 17 (each from UK)	Reduce uncertainties in predictions of carbonate chemistry changes and their effects. Understand the responses to ocean acidification, and other climate change related stressors, by marine organisms, biodiversity and ecosystems and to improve understanding of their resistance or susceptibility to acidification. Provide data and effective advice to policy makers and managers.	www.oceanacidification.org.uk
EPOCA: European Project on Ocean Acidification	2008-2012	EC Seventh Framework Programme (FP7)	Modelling, acidification, carbonate, ocean biochemistry	Europe, Caribbean Area, Macronesia, Indian Ocean Area	29 partners, lead: Laboratoire d'Océanographie (FR)	Fill the numerous gaps in our understanding of the effects and implications of ocean acidification.	www.epoca-project.eu
CARBOCHANGE: Changes in carbon uptake and emissions by oceans in a changing climate	2011-2015	EC Seventh Framework Programme (FP7)	Modelling, carbon exchange, acidification, climate change, carbon cycle	Europe, Caribbean Area, Macronesia, Indian Ocean Area	28 partners, lead: Geophysical Institute and Bjerknes Centre for Climate Research, University of Bergen (NO)	Best possible process-based quantification of net ocean carbon uptake under changing climate conditions. The actual observations of the changing ocean carbon sink will be integrated with the ocean carbon models, a coupled land-ocean model, an Earth system model of intermediate complexity, and fully fledged Earth system models.	carbochange.b.uib.no/
BIOACID II: Biological Impacts Of Ocean Acidification	2012-2015	Federal Ministry of Education and Research (Germany)	pelagic ecosystems, benthic assemblages, natural reefs, species interactions, ocean services	Arctic, North Atlantic ocean, Baltic sea	15 partner (each from Germany), lead: GEOMAR Helmholtz Centre for Ocean Research, Kiel (DE)	More encompassing assessment of future biological responses to ocean change and their possible socio-economic consequences. Better understanding of the chain from biological mechanisms, through individual organism responses, through food web and ecosystem effects, to economic impacts.	www.bioacid.de

¹ European Environment Agency,(2014): Marine messages. Our seas, our future — moving towards a new understanding. <http://www.eea.europa.eu/publications/marine-messages>

² RCP8.5 in IPCC(2014): Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schöner, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Mediterranean Sea

- surrounded by 22 countries
- coastline of 46 000 km
- 480 million people (1/3 along coastal regions)
- 175 million tourists
- 10 000-12 000 marine species in the Mediterranean Sea, 20-30% are endemic
- Mediterranean Sea has already warmed 0.67°C over the last 25 years
- the acidity of NW Mediterranean seawater has increased by 10% since 1995
- far the largest driver of the acidification of Mediterranean Sea is the absorption of atmospheric CO₂.
- if we continue to emit CO₂ at today's rate, acidity will increase another 30% by 2050, and 150% by 2100
- important sectors that could potentially be affected by ocean acidification:
 - tourism (gorgonians and other corals disappear, and jellyfish outbreaks increase)
 - fisheries (1.4 million tonnes, primarily small pelagic fish)
 - aquaculture (marine and brackish aquaculture produces 180 thousand tonnes of shellfish and more than 1 million tonnes of fish annually. Harvest of shell-forming species, including mussels, clams, oysters had a value about 225 million EUR in 2012).
- the ecosystems of the area are already stressed by increased temperature, overfishing, invasion of alien species and eutrophication
- Mediterranean Sea region has been identified as one of the main climate change hotspots
- warming and acidification are rapidly altering marine life in Mediterranean Sea :
 - SE (south eastern) Mediterranean species are already shifting northward to cooler waters
 - many organism die during summer due to combine effect of extreme warming and acidification.
- Impacts of ocean acidification and warming on marine organism varies, because of differences in sensitivity:
 - marine bacteria and viruses appear less sensitive
 - some planktonic organism are more directly harmed by acidification, while others by warming
 - the combined effects can strengthen their impacts on some species
 - acidification and warming modify the abundance and functioning of both phytoplankton and zooplankton groups living in the Med. Sea. Including those of shell-forming organism like pteropods and coccolithophores.
 - fish larvae (eat such plankton) could be at risk of starvation in the future; this can have a negative impact of fisheries population
 - ocean acidification on fish are not well-studied, but may occur through changes in essential fish habitats or on other parts of the food web
 - acidification may lead to harmful algae blooms
 - warming and acidification may increase negative impact on shellfish, especially early life stages
 - acidification affect jellyfish distribution patterns (certain species of jellyfish thrive in a warmer, more acidic ocean. Increased jellyfish outbreaks on the southeastern Med. coast would considerably decrease annual tourism revenue.)
 - acidification impact major contributors to habitat building such as reefs
- acidification causes reduction in the ability of coastal marine organism to resist corrosion of their shells or skeleton
- Three iconic ecosystems in the Mediterranean particular vulnerable to changes in ocean chemistry:
 1. Seagrass (*Posidonia oceanica*) meadows: known as a hot-spot of biodiversity in the Med. sea, supporting hundreds of species as a shelter and nursery. Seagrass thrive well at increased CO₂ levels, but major groups such as corals, sea urchins and calcified algae are removed from the ecosystem and can be replaced by invasive species of algae.
 2. Vermetid reefs: structured built by living organism (such as marine snails) that rises from the bottom towards the surface of the sea. Equally important for their biodiversity and shore protection.
 3. Coralligenous reef: accumulation of calcareous encrusting algae. Major touristic attraction covering large sections of the Med. coastal waters from the depth of a few meter to over a hundred meters. The highly diverse community of these reefs hosts one of the most iconic and commercially important species, the Red Coral (*Corallium rubrum*), which are at particularly high risk.
- What can we do to mitigate the impact of acidification and warming on the Mediterranean Sea?
 - reduce other environmental stresses (pollution, overfishing, habitat destruction)
 - create effective marine protected areas
 - use marine spatial planning to promote the conservation and sustainable management of coastal ecosystems as major carbon sinks
- Implementation of ecosystem-based adaptation strategies is needed.

Acknowledgement

This research was supported by the research project „Green Energy” – Higher educational sector specific cooperation to improve rural economy in the field of energetics (TÁMOP-4.1.1.C-12/1/KONV-2012-0017) - The Project is supported by the Hungarian Government and co-financed by the European Social Fund.

