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Supplementary Materials for

The Baltic Sea as a time machine for the future coastal ocean

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Background

The Baltic Sea is compared to six to various degrees enclosed costal seas from the tropic to the arctic. Below we describe the methods used to compare relevant anthropogenic threats and activities (Table 1) and research and governance activities (Table 2).

Ecosystem threats caused by anthropogenic activities (cf. Table 1 of main text).

System	Warming of surface water	Increased nutrient load	Oxygen depletion in bottom waters	Shipping intensity	Proportion of non-indigenous species	Organo-chlorines in organisms	Status of marine fish stocks
Baltic Sea	*121, 122*	*92, 123*	*92, 123*	*133*	*62, 134*	*24, 141*	*61, 153*
North Sea	*121, 122*	*123, 125*	*123, 125*	*133*	*134, 136-138*	*143, 144*	*61, 153*
Mediterranean	*121, 122*	*126-128*	*126-128*	*133*	*134, 139*	*145*	*61, 153*
Black Sea	*121, 122*	*126-128*	*126-128*	*133*	*134*	*146, 147*	*61, 153*
Gulf of Mexico	*121, 122*	*70, 124, 129*	*70, 124, 129*	*133*	*135, 140*	*148*	
East China Sea	*121, 122*	*130, 131*	*130, 131*	*133*	*134, 141*	*149-150*	
Barents Sea	*121, 122*	*132*	*132*	*133*	*179*	*151-152*	*61, 153*

Warming of surface temperature

Warming of annually averaged sea surface temperature was derived from the Extended Reconstructed Sea surface temperature (ERSST v5) observational data set (*121*, *122*) (See also Fig. 1B).

Increased nutrient load and Oxygen depletion in bottom waters

The classification of nutrient loads and concentrations, and in oxygen depletion (hypoxia/anoxia) in bottom waters are based on long-term monitoring data from semi-enclosed coastal seas and basins (Table 1), and evaluated on their documented ecosystem-wide impacts through eutrophication (nutrient over-enrichment leading to increased primary production, harmful algal blooms, and subsequent depletion of oxygen, i.e. hypoxia <4 mg/l O_2 and anoxia < 2 mg/l O_2).

- Baltic Sea: the trends of rapidly increasing nutrient levels from the 1960s to the 1990s have been described in (*93*, *123*) providing a clear classification based HEAT-index (*93*). For the oxygen depletion, long-term trends have been described in detail (*124*), describing the transition from short-term intermittent periodic hypoxia over small areas/volumes, increasing rapidly with the onset of eutrophication (*93*) and continuing to increase up until the current time (*124*).
- North Sea: long-term trends, classification and direct comparisons with the Baltic Sea are provided in ref(*123*), illustrating how both nutrient levels and trends, and long-term oxygen-conditions are not as immediately threatening for the ecosystem as in the Baltic Sea (*125*)

- Mediterranean Sea (in particular its marginal coastal sub-basins); increasing trends in both nutrient concentrations and periodic oxygen depletion have occurred, reaching levels of ecological concern, although not as drastic as for the Black Sea, which has experienced severe nutrient over-enrichment and long-term hypoxia/anoxia (*126-128*).
- The Gulf of Mexico experiences short-term seasonal hypoxia/anoxia in limited coastal areas effected by riverine inflow of nutrients, although on an ecosystem-wide scale the impacts are limited (*124, 129*) in comparison with several other coastal and marginal seas (*70*).
- East China Sea: the ecosystem threats from increased nutrient loading and oxygen depletion are severe, and the negative temporal trend is alarming (*130, 131*).
- The Barents Sea, being a sub-basin of the Arctic Sea, is historically marginally impacted by anthropogenic nutrient-input, and oxygen depletion has not been documented, and pose no immediate threats to the ecosystem (*132*).

The distinction between levels of impact (green: low impact, yellow: moderate impact, red: strong impact) is based on the rate of change over time and in space, as well as on frequency of occurrence of hypoxia/anoxia, and compared between sea areas based on expert assessments (*20*).

Intensity of shipping

Number of ships excluding recreational vessels were recovered from AIS information at Marine Traffic (*133*). Number of ships per km^2 were used to estimate shipping intensity where >1 ships/km^2 were considered high (red color), 0.1-1 ships/km^2 were moderate (yellow) and <0.1 ships/km^2 were considered low intensity (green). The levels distinguishing the three categories were arbitrarily chosen.

Proportion of non-indigenous species (NIS) present

Numbers of non-indigenous species for all seas except Gulf of Mexico were derived from AquaNIS information system (*134*). Information for Gulf of Mexico was from (*135*). Numbers of non-indigenous species were related to available estimates of native species for each area derived from the following sources: Baltic Sea (*62*), North Sea (invertebrates (*136*); macroalgae (*137*) microalgae (*138*)), Mediterranean (*139*), Gulf of Mexico (*140, and see http://e-gulf.org/biogomx/about.php*), East China Sea (*141*). For Black Sea and Barents Sea we did not find any accounts on total species diversity. Here we assumed species numbers to be about 10,000 species (which is higher than for the North Sea – 8,800, but lower than for the Mediterranean Sea – 17,000).

Proportions of non-indigenous species lower than 1% were classified as low (green), 1% - 4% moderate (yellow) and higher than 4% as high (red). Note that the scale was derived to allow relative comparisons of the systems and not to assess ecological status, i.e., the green category does not necessarily imply that NIS do not represent a problem, but only that the proportion is considered lower than in the systems classified as yellow or red.

Organochlorines in organisms

We focused mainly on data from fish species but in addition used supporting data from both higher and lower trophic levels when available. Importantly, variation is quite large within sea bodies, and literature data are furthermore reported based on different units (wet weight, dry weight and per lipid weight) that makes comparisons challenging. Some seas, e.g. the Baltic Sea and the Mediterranean have some extreme values, but in the table we try to indicate the overall picture with red color indicating the highest values overall, yellow medium values and green low levels of contamination. References used: Baltic (*24, 142*), North Sea (*143, 144*), Mediterranean (*145*), Black Sea (*146, 147*), Gulf of Mexico (*148*), East China Sea (*149, 150*), Barents Sea (*151,152*)

Status of marine fish stocks

Aggregate information on the different European seas, including the North-East Atlantic and the Black Sea was obtained from the European Environment Agency (*61*), and stock status and data availability classification followed the methodology in this publication, as follows; *Overall approach:* Fish stock status assessments followed Good Environmental Status (GES) criteria, as described in the EU Marine Strategy Framework Directive (MSFD) (*153*): criteria 3.1 - Level of exploitation (i.e. Fishing mortality - F) and criteria 3.2 - Reproductive capacity (i.e. Spawning Stock Biomass - SSB). A stock can be assessed with this approach if F and SSB information are available. The assessment of data availability was therefore based on the availability of F and SSB information.

Detailed methodology: Classification here followed the MSFD approach (Descriptor 3), using criteria 3.1 and 3.2 above to determine whether a stock is in GES:

- Sustainably exploited stocks: here defined as stocks for which F is at or below levels that deliver Maximum Sustainable Yield (MSY), i.e. $F \leq F_{msy}$. Thus only if values of F and F_{msy} were available we considered the stock assessed against this criterion and only if $F \leq F_{msy}$ was this stock considered to be in GES.
- Stocks with reproductive capacity intact: here defined as those for which SSB is above levels that can deliver MSY, defined as SSB > $MSY_{Btrigger}$ for the ICES area.

All assessed stocks were then categorized in to those for which both the fishing mortality ($F \leq F_{MSY}$) and the reproductive capacity ($SSB \geq MSY_{Btrigger}$) were in GES, those for which one of the two criteria was in GES, and those for which neither of the criteria was in GES.

We then classified the status for each sea based on the following categories:

- “good/green”: ≥75% of stocks with both F and SSB in GES.
- “medium/yellow”: ≥50% with either F or SSB in GES.
- “bad/red”: <50% of stocks with either F or SSB in GES.

Note that these are relative assessments – ideally good status would be defined as nearly 100% of stocks in GES, but we here chose to keep the whole range from good to bad to illustrate differences between regional seas.

Gulf of Mexico and East China Sea: Aggregate information summarizing stock status and data availability based on the categories above was not available for these two systems. Considering the different data foundation and the potential calibration error from using a second classification scheme for these two systems, only data availability was assessed for the heat map here (see below).

Research and governance activities (Table 2 of main text).

System	Research activities	Monitoring activities	Data availability for fish stock assessments	Governance structure
Baltic Sea	see method text	see method text	*61*	see method text
North Sea	"	"	*61*	"
Mediterranean	s	"	*61*	"
Black Sea	"	"	*61*	"
Gulf of Mexico	"	"	*154, 155*	"
East China Sea	"	"	*156-158*	"
Barents Sea	"	"	*61*	"

Research activities

Estimated from Web of Science search made 2 October 2017. Search was done on the full name of the sea in the title of the publications, and using all years and all databases. Green color indicated >10 studies per 1000 km^2 of sea area in total, yellow indicated 4-10 studies, and red <4 studies.

Monitoring activities

Based on data from http://www.st.nmfs.noaa.gov/copepod/time-series/index.html (accessed 2 October 2017), the number of regularly visited monitoring sites for hydrography, zooplankton and phytoplankton time-series were compared among seas. High monitoring intensity/green were used for seas with a total >0.1 sites per 1000 km^2, yellow color for seas with 0.01-0.1 sites per 1000 km^2, and red color for seas with <0.01 sites per 1000 km^2.

Data availability of fish stock assessments

Data were retrieved from European Environment Agency (*61*). We checked the availability of information on the level of exploitation F and reproductive capacity SSB available for a given stock ("yes" or "no"?). For each sea, we then estimated the proportion of stocks falling into "yes" or "no" for data availability, and classified the status based on the following categories:

- "good/green": ≥75% of landings with both F and SSB information available.
- "medium/yellow": ≥ 50% of landings with either F or SSB information available.
- "bad/red": <50% of landings either F or SSB information available.

Gulf of Mexico: Recent assessments indicate that the status of less than 50% of 60 US stocks in this area could be determined based on the available data (*154*, *155*), and that the data foundation was considerably worse for stocks in waters of the other bordering nations, Cuba and Mexico (*154*). This leads to a classification as "red".

East China Sea: More than 200 species are exploited commercially in this region (*156*). The stock status of the majority of stocks is not assessed systematically, F and SSB estimates are largely inexistent, and landings of the majority of commercial species are aggregated into an aggregate category "mixed fishes" (*157*, *158*). The data foundation is sub-optimal, but the scarcity of species level information for stock status assessments appears evident, leading to a classification as "red".

Governance structure

We divided the coastal areas into three categories describing different levels of governance:

- Strong governance - a large majority of the bordering countries are part of a governance system that comprises both: a) international agreements in the form of regional sea conventions and b) intergovernmental structures with supranational elements – holding the mandate to make legally binding decisions as well as the authority to enforce these decisions and take legal actions in cases of non-compliance.
- Medium strong governance – some of the bordering countries are part of a governance system that comprises both international agreements and intergovernmental structures with supranational elements (se *strong governance* above) while a significant number of countries stand outside the latter.
- Weak governance – the bordering countries are part of a governance system that comprises, more or less monitored and enforced, international agreements while common intergovernmental structures with supranational elements (se *strong governance* above) are missing.

table S1A. Detailed assessment of the qualitative status of environmental pressures/drivers in the Baltic Sea region compared to other worldwide coastal seas. The possible time machine aspect and where applicable use of each parameter is characterized in more detail. Given are also all relevant literature references.

Parameter	Baltic Sea - current status	Time machine can be applied to	Similar changes expected in other coastal areas	Type of time machine	Use of the "time machine" - examples
Temperature (surface)	1°C > baseline (*7*)	Coastal seas generally	2030-2050	Ahead of time	Temperature effects on biogeochemical cycles and rates (*20*), extreme event effects on species survival (*159*), changes in phenology and seasonality of species (*160*).
Salinity	Permanent gradient 2-24 psu (*161*)	Continental shelf areas affected by melting ice or increased precipitation and river run-off	Locally now or ahead	Space-for-time	Long-term effects including adaptation of marine species and/or ecosystems to decreased salinity, for example in marine seaweeds (*162*) and marine fish (*163*).
Carbon dioxyde pressure	Locally yearly average >700 µatm (Fig. 1C)	Coastal seas generally	Most areas >2100	Ahead of time	Long-term effects of shifted pH on marine species growth and survival (*164*).
Nutrient loads	4.5x baseline phosphate, 3.5 x nitrogen in river runoff (*18*)	Coastal seas generally; estuaries specifically	Point sources now, large-scale ahead	Ahead of time	Effects on increased plankton blooms and turbidity on depth distribution of macrophytes (*165*) (see below for effects of hypoxia and algal blooms). Effects of nutrient reduction (*166*)
Bottom area of Hypoxia	10x area early 1900 (*167*)	Coastal seas generally	Locally now, regionally ahead	Ahead of time	Effects on spawning and growth of fish (*117, 168*) Short and long-term ecosystem effects of hypoxia (*169, 170*).

Sea ice	Maximum cover reduced by 20% since 1970-ies (*7*)	Arctic, subartic coastal seas	2030-2040 (or sooner)	Ahead of time	Effects on population dynamics of marine mammals breeding on the ice sheet (*171*).
Multiple stressor interactions	Combination of above listed stressors	Coastal seas generally; estuaries specifically	Locally now, globally ahead	Ahead of time	Assessment of the effects of multiple stressors on whole ecosystem shifts ("regime shifts") (*31*).
Loss of habitat-forming species	Local loss of seagrass meadows (*37*) and seaweed forests (*165*)	Coastal seas generally	Locally now, regionally ahead	Ahead of time	Effects on fish-recruitment on loss of habitat-forming macrophytes and shallow soft bottom substrates (*172*).
Nonindigenous species	130-150 alien species out of 6000 (*41, 62, 134, 173*)	Coastal seas generally; estuaries specifically	Locally now, globally ahead	Ahead of time	Effects of introductions of nonindigenous species to species-interactions and ecosystem function (*174*).
Fish stock	40% of fish stocks lack good environmental status (*61*)	General for oceans and coastal seas	Locally now, globally ahead	Ahead of time	Cascading effects of removal of large fish (*38, 175*), socioeconomic effects of non-sustainable management of fish stocks (*176*).
Algal blooms	3x baseline (1970) net primary production (*35*)	Coastal seas generally	Locally now, regionally ahead	Ahead of time	Socio-economic effects of increased algal blooms (*177*). Cascading effects of fish removal on algal blooms (*34*).
Diversity of marine macrozoobenthos	Spatial range 25 - 773 km (*62*)	Coastal seas generally	Locally now or ahead	Space-for-time	Relationship between species diversity and ecosystem production (*178*).
Genetic diversity	Loss of 10%-50% of genetic variation (*103*)	Coastal seas generally	Ahead	Ahead of time	Effects of loss of genetic variation on population tolerance to environmental change, ecosystem productivity and ecosystem function

table S1B. Detailed assessment of scientific knowledge, management regimes, and governance structures in the Baltic Sea region compared to other worldwide coastal seas/areas. The possible time machine aspect and use of each parameter is characterized in more detail. Given are also all relevant literature references.

Parameter	**Baltic Sea - current status**	**Time machine can be applied to**	**Similar changes expected in other coastal areas**	**Type of time machine**	**Use of the "time machine" - examples**
Monitoring programs	>100 y of monitoring, high density of sites (www.ices.dk, http://www.st.nmfs.noaa.gov/copepod/time-series/index.html)	General for oceans and coastal seas	Locally now or ahead	Ahead of time	Use of monitoring data to understand causes of ecosystem perturbations (*179*), raise awareness of new hazards and support science-based management (*180*).
Regional models	Baltic Nest (www.balticnest.org), NEMO Nordic (*181*), socioeconomic models (*177*), drainage models (vattenwebb.smhi.se)	Coastal seas generally	Ahead	Ahead of time	Modeling socioeconomic costs of nutrient reduction (*79*) and socioeconomic effects of climate change (*177*). Modelling sizes and positions of marine protected areas (*182*).
Regional marine environment policy institutions	HELCOM (*183*) (www.helcom.fi), Baltic Sea Advisory Council 2006 (www.bsac.dk)	Coastal seas generally	Ahead	Ahead of time	Success and failures in international collaboration for improved environmental management (*53, 57, 184*).
Regional multi-disciplinary research programs and platforms	BONUS 2006 (*55, 185*), Baltic Sea Science Conference (www.io-warnemuende.de/bssc2017-home)	Coastal seas generally	Ahead	Ahead of time	Synergy effects and benefits of regional scientific collaborations (*185*).

table S2. Valuation of benefits of environmental intervention or management measurements in the Baltic Sea area. Available estimates of monetary benefits or public willingness-to-pay for different management measures or improvements of the Baltic Sea environment.

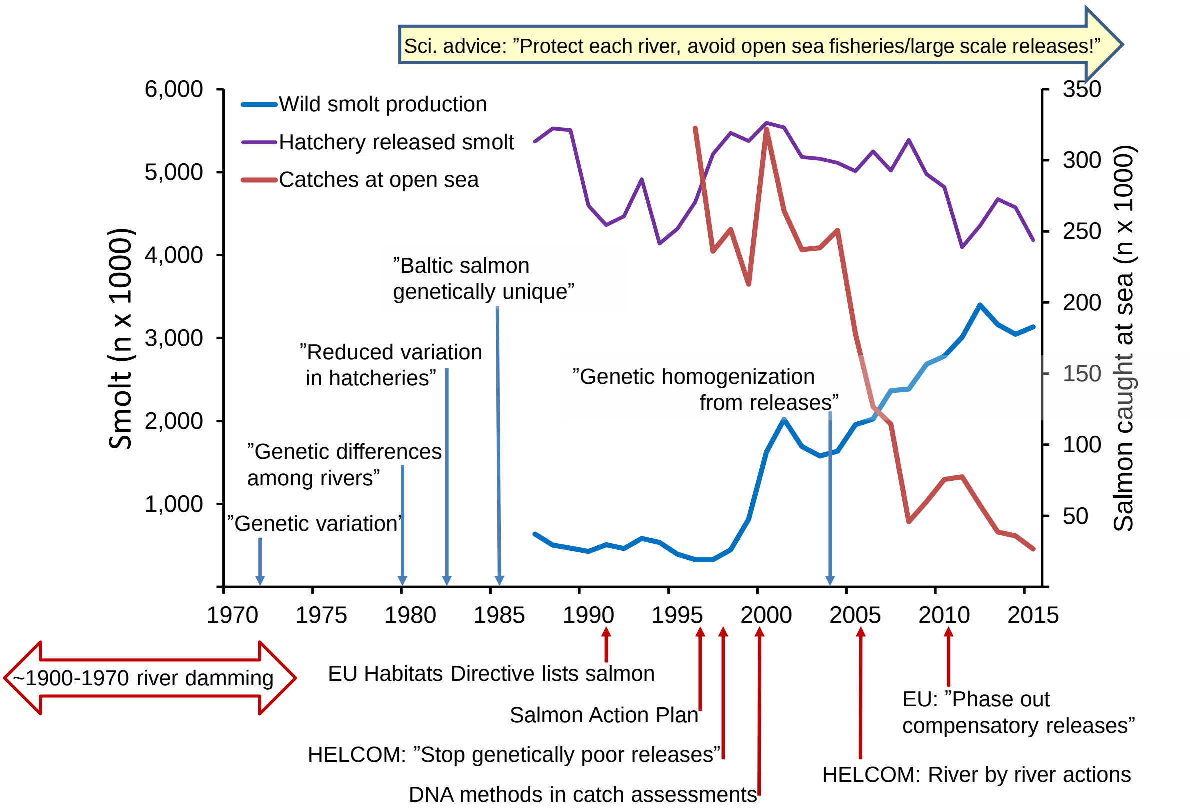
Study	Valuation of	Where	WTP of	Estimated annual benefits
(*186*)	reaching 'Good Environmental Status' (in relation to eutrophication abatement)	Open waters of the Baltic Sea	All Baltic Sea countries	EUR 3.6 billion, country-specific estimates available
(*187*)	reduced eutrophication of the Baltic Sea	Coastal waters of Lithuania, Poland and Sweden	Lithuania, Poland Sweden	EUR 1.9 billion (Sweden), EUR 1.7 billion (Poland), EUR 85 million (Lithuania)
(*188*)	reduced eutrophication of the Baltic Sea	Coastal waters of Poland and Sweden	Poland, Sweden	EUR 1.6 billion (Sweden), EUR 3 billion (Poland)
(*189*)	reduced probability of large oil spills and the probability of spills reaching the shore, improvements of water quality and the frequency of establishment of new non-indigenous species	Estonian sea waters	Estonia	EUR 38 million
(*190*)	preventing reduced number of native species, improved coastal water quality for recreation, and reducing the frequency of the establishment of new harmful alien species	Latvian waters	Latvia	EUR 11 million
(*191*)	improved coastal cod stock level, bathing water quality and a biodiversity indicator	Coastal waters of western Sweden	Counties of the southwestern part of Sweden	EUR 120 million
(*192*)	improved water clarity, the status of macro algae (e.g., bladder wrack), reduced occurrence of blue green algae blooms, the abundance of coarse fish	Gulf of Finland	Finland	EUR 278 million
(*193*)	Baltic Sea Action Plan actions aiming at healthy aquatic vegetation, conservation of currently pristine areas, and the protection of fish stocks	Finnish-Swedish archipelago and the Lithuanian coast	Finland, Lithuania, Sweden	EUR 884 million (Finland), EUR 181 million (Lithuania), EUR 3.9 billion (Sweden)
(*194*)	developing off-shore sites into wind farms or establishing marine protected areas	Estonian shoals	Estonia	EUR 17 million (marine protected areas), EUR -6 million (wind farms), EUR 15 million ('eco' wind farms)
(*86*)	Baltic Sea-based recreation	Baltic Sea coast	All Baltic Sea countries	EUR 14.8 billion, EUR 1.3 billion higher if water quality improvement; country-specific estimates available
(*195*)	Baltic Sea-based recreation	Inland and coastal waters of Finland	Finland	EUR 2.6 billion, EUR 150 million higher if water quality improvement; activity-specific estimates available

data S2. Box: Genetic knowledge in marine management—The recovery of Baltic salmon.

Many populations of anadromous fishes worldwide are in critical condition due to damming and overfishing (*196*). A case in point is Baltic Sea salmon (*Salmo salar*) that historically populated over 90 rivers draining into the Baltic Sea. Hydroelectric power plant constructions during 1880-1970 blocked salmon migratory routes to spawning grounds in many rivers. Early population genetics research showed that the Baltic salmon is strongly structured; historically each river harbored at least one genetically unique population (*197*). Lost reproduction of separate rivers thus results in the loss of such populations (*198*). Large-scale hatchery breeding and release of young salmon is carried out in the Baltic countries to compensate for the loss of natural reproduction. Initially, these releases were carried out in a genetically poor way. Too few breeders and fish from non-native rivers were used, resulting in elevated levels of inbreeding and loss of genetic variation (*199*). Subsequently, the genetic effects of the large-scale releases have been poorly monitored (*200*).

The case of the Baltic Sea salmon is a prime example where genetic considerations eventually have been recognized and reached an implementation phase (see Box figure). Scientists around the Baltic have long warned about the genetic losses and risks of genetically homogenizing remaining populations from large releases (*197*, *200-203*). These concerns gained recognition; the EU Habitats Directive (Council Directive 92/43/EEC) listed salmon as vulnerable in 1992 and in 1998 the Helsinki Commission (governing the Convention of the Protection of the Marine Environment of the Baltic Sea Area) adopted a recommendation on the protection and improvement of the wild Baltic salmon (HELCOM rec 19/2). In 2011 the EU Commission recommended phasing out of compensatory releases within seven years (COM(2011) 470), which remains to be put into practice (see Box figure).

Two multinational management modifications following scientific genetic advice (*201*) are facilitating the recovery of the Baltic salmon. First, fishing has moved from open sea fisheries, where multiple populations are harvested in a mixed fishery, to separate river fisheries, reducing the risk of overexploiting separate populations. Second, restoration efforts are performed in several rivers using original or genetically close populations (*52, 204*). Until now, 55 rivers in 6 countries have been subjected to such recovery programs resulting in successful return of wild reproduction in 23 rivers in 5 countries (*204*). Increasing numbers of wild smolt (Box-figure) indicate management success.



Box figure "Time course of Atlantic salmon management in the Baltic Sea". Major scientific breakthroughs, legislative agreements and management measures (x-axis, see text) during the history of salmon management in the Baltic Sea. The blue line depicts the increasing wild smolt production, a management success. Note that the catches at the open sea (red line) are declining because catches are now moving to the river mouths to be attributable to particular river systems.

data S3. Data sources for figures.

Fig. 1 A-D. The Baltic Sea time machine.

Fig. 1(B). Sea Surface temperature changes were computed based on the Extended Reconstructed Sea Surface Temperature (ERSST v5) observational data set (*121, 122*), online data source: https://www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst-v5.

(C) High - resolution surface seawater CO_2 variability (left panel) and mean values (+/- SD; right panel) for 2014 were computed based on the Kiel Fjord Time Series (KFTS), 54.2°N, 10.9°E (red symbols). Data for the 5 US American stations Twanoh, Kodiak, CCE2, Cheeca Rocks, Hawai'i, were obtained from the NOAA database accessible at https://www.pmel.noaa.gov/co2/.
Additional data sources:
station Kiel Fjord ref (*205*)
station WHOTS ref (*206*)
station Cheeca Rocks (Florida) - CHE: ref (*207*)
station CCE2 ref (*208*)
station Twanooh ref (*209*)
station Kodiak ref (*210*)

(D) Data for the expansion of hypoxic zones in the Baltic Sea during 115 years of monitoring were compiled in ref (*20*).

Fig. 2. Examples of long-term time series available for the Baltic Sea.

Fig 1(A) Temperature data (0-10 m) were compiled from data downloaded from the Baltic Environmental Database (BED), available at www.balticnest.org/bed. Compilation as in ref (*211*) for the entire year.
(B) pCO_2 -values in the bottom waters (>150 m) are from the Swedish Hydrological and Meteorological Institute (SMHI) data base at station BY15 (central Gotland Basin), available at www.smhi.se.
(C) Secchi depths were taken from the Baltic Sea Environmental Proceedings #133, available at www.helcom.fi (*212*).
(D) Benthic areas with anoxic conditions (<2 mg O_2 L^{-1}) are depicted based on ref. (*20*).
(E) The abundance of cyanobacteria in the Gulf of Finland was compiled based on ref (*213*).
(F) Zooplankton abundance (*Acartia* spp.) in Pärnu Bay, Estonia, was computed based on data in ref. (*214*).
(G) Eastern Baltic cod total spawning stock biomass data were obtained from ref (*215*).
(H) Herring total spawning stock biomass data were obtained from (*216*).
(I) The DDT concentration in sea eagles was obtained from ref (*217*).
(J) Counts of non-indigenous species over time were obtained from ref (*41*).

Fig. 3 A-C. Governance structure in the Baltic Sea region.

Fig. 3(A) Information on the bilateral agreements between Russia and EU were obtained from (*218*).

(B) The legal basis and enforcement of hazardous substances is described in (*219*), while the basis of HELCOM recommendations, the Baltic Sea Action Plan (BSAP), was published in 2007(*52*). The BSAP was initiated in 2007 following the EU Marine Strategy Framework Directive (MSFD) (*220*).

(C) How HELCOM targets the sources of eutrophication via several recommendations is outlined in the Baltic Sea Action Plan (*52*). How the relevant EU Common Agricultural Policy (CAP) influences nutrient management and is described in refs (*221*, *221*).

Fig. 4. Nutrient input into the Baltic Sea.

Data for five year moving average values of N- and P-loads (in 1000 metric $t*yr^{-1}$) to the Baltic Sea, as well as Baltic Sea Action Plan target values, were obtained from (updated from *18*).

Box 2 figure "The return of top predators"

Cormorant counts were obtained from Baltic wide censuses and HELCOM approximations of breeding pairs as reported in (*107*).

Counts of white-tailed sea eagle breeding pairs in Baltic Sea riparian countries were obtained from (*108, and references therein*), complemented with data from Eionet European Topic Centre on Biological Diversity for Latvia, Lithuania, Estonia, and Poland for 1980 and 2010.

Seal abundance is based on the HELCOM seal database (http://www.helcom.fi/baltic-sea-trends/data-maps/biodiversity/seals), complemented with data and estimations from (*106*, *222-224*). The harbour seal counts include populations to the South - East of the Kattegat, excluding counts from Skagerrak.