Bordering countries: Turkey, Bulgaria, Romania, Ukraine, Russian Federation, Georgia.
LME Total area: 461398 km²

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LME overall risk
This LME falls in the cluster of LMEs that exhibit low to medium levels of economic development (based on the night light development index) and medium levels of collapsed and overexploited fish stocks.

Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is high.

<table>
<thead>
<tr>
<th>Very low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>▲</td>
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</tbody>
</table>

Productivity

**Chlorophyll-A**
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (1.10 mg.m⁻³) in November and a minimum (0.757 mg.m⁻³) during July. The average CHL is 0.942 mg.m⁻³. Maximum primary productivity (610 g.C.m⁻².y⁻¹) occurred during 2001 and minimum primary productivity (433 g.C.m⁻².y⁻¹) during 2011. There is a statistically insignificant decreasing trend in Chlorophyll of -5.30 % from 2003 through 2013. The average primary productivity is 504 g.C.m⁻².y⁻¹, which places this LME in Group 5 of 5 categories (with 1 = lowest and 5= highest).
**Primary productivity**

![Primary Productivity Chart](chart)

**Sea Surface Temperature**

From 1957 to 2012, the Black Sea LME #62 has warmed by 0.31°C, thus belonging to Category 4 (slow warming LME). After peaking in 1966 at 16.1°C, SST dropped down to 14.0°C in 1987, an exceptionally cold year in this region. Thus, SST decreased by 2.1°C in 21 years between 1966 and 1987, after which SST rose to 15.8°C in 2001 and remained relatively high through 2012. Yet the long-term linear trend-based warming between 1957 and 2012 was just 0.31°C due to the pronounced cooling of the 1980s-1990s. These numbers compare favorably with those by Ginzburg et al. (2008) who studied seasonal and interannual variability from satellite SST in 1982-2002 and reported the same cold events of 1985, 1987, and 1992-1993 that are evident above; they also found out that winter SST has bottomed out in early 1993 and reported a 3°C increase in summer SST (from 23°C to 26°C) in 1982-2002, with the summertime SST trend being mostly decoupled from the wintertime SST trends except for the last few years. The extreme magnitude of the 1982-2002 trend reported by Ginzburg et al. (2008) is not corroborated by our data.
Fish and Fisheries
Marine fisheries are an important economic sector in the countries bordering the Black Sea LME, and virtually all its commercial fish stocks are shared among the bordering countries. In addition to capture fisheries, there is a long history of sturgeon aquaculture in the Azov Sea and more recently, the cultivation of mussels, oysters, shrimp and some finfish. Prior to the 1970s, there were abundant stocks of several valuable species in the LME.

Annual Catch
Total reported landings in this LME showed several peaks and troughs, driven primarily by the fluctuation in the landings of European anchovy, with a peak landing of 820,000 t recorded in 1984. The landings have increased following a precipitous decline from 1989 to 1991, however, they have not returned to the level achieved in the mid-1980s.

Catch value
The value of the reported landings reflected the trend in the landings, peaking in 1986 at about 1.1 billion US$ (in 2005 real US$).
Marine Trophic Index and Fishing-in-Balance index

The MTI has been on a decline since the 1950s, with very low values being observed in the 1990s. The increase in the FiB index from the 1970s to the mid-1980s is driven by the increased reported landings of anchovy during this period. The FiB index declined in the early 1990s, an indication of ‘fishing down’ of the food web in this LME.

Stock status

The Stock-Catch Status Plots indicate a high level of collapsed stocks (about 30%) which contribute less than 10% of the total catch, with close to 60% of the reported landings coming from overexploited stocks.
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch fluctuated between 2 and 30% from 1950 to 2010. This percentage fluctuated between 4 and 16% in the recent decade.

Fishing effort

The total effective effort continuously increased from around 50 million kW in 1950 to its peak around 270 million kW in 2006.
Primary Production Required

Pollution and Ecosystem Health

Nutrient ratio, Nitrogen load and Merged Indicator

Human activities in watersheds are affecting nutrients transported by rivers into LMEs. Large amounts of nutrients (in particular nitrogen load) entering coastal waters of LMEs can result in high biomass algal blooms, leading to hypoxic or anoxic conditions, increased turbidity and changes in community composition, among other effects. In addition, changes in the ratio of nutrients entering LMEs can result in dominance by algal species that have deleterious effects (toxic, clog gills of shellfish, etc.) on ecosystems and humans.

An overall nutrient indicator (Merged Nutrient Indicator) based on 2 sub-indicators: Nitrogen Load and Nutrient Ratio (ratio of dissolved Silica to Nitrogen or Phosphorus - the Index of Coastal Eutrophication Potential or ICEP) was calculated.

Nitrogen load

The Nitrogen Load risk level for contemporary (2000) conditions was moderate (level 3 of the five risk categories, where 1 = lowest risk; 5 = highest risk). Based on a “current trends” scenario (Global Orchestration), this remained the same in 2030 and 2050.

Nutrient ratio

The Nutrient Ratio (ICEP) risk level for contemporary (2000) conditions was high (4). According to the Global Orchestration scenario, this remained the same in 2030 and 2050.

Merged nutrient indicator

The risk level for the Merged Nutrient Indicator for contemporary (2000) conditions was high (4). According to the Global Orchestration scenario, this remained the same in 2030 and 2050.

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen load</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Nutrient ratio</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Merged nutrient indicator</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Legend: Very low, Low, Medium, High, Very high
POPs
Data are available for only one sample from one location. This shows minimal concentration (ng.g\(^{-1}\) of pellets) of 5 for PCBs, low concentration of 15 for DDTs, and moderate concentration of 9.6 for HCHs, corresponding to categories 1, 2, and 3, respectively, of the five risk categories (1 = lowest risk; 5 = highest risk). Dominance of DDT over the degradation products was observed, suggesting current inputs of DDTs. Agricultural application and/or antifouling agent may explain the DDTs, although the level was low. The sample was collected in 2009, after the onset of regulation by the Stockholm Convention. Illegal usage is suspected. Extensive monitoring is necessary in this LME.

<table>
<thead>
<tr>
<th>Locations</th>
<th>PCBs</th>
<th>DDTs</th>
<th>HCHs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>15</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Legend:
- Very low
- Low
- Medium
- High
- Very high

Plastic debris
Modelled estimates of floating plastic abundance (items km\(^{-2}\)), for both micro-plastic (<4.75 mm) and macro-plastic (>4.75 mm), indicate that this LME is in the group with the highest plastic concentration. Estimates are based on three proxy sources of litter: shipping density, coastal population density and the level of urbanisation within major watersheds, with enhanced run-off. The high values are due to relative importance of these sources in this LME. The abundance of floating plastic in this category is estimated to be on average over 400 times higher than those LMEs with lowest values. There is moderate evidence from sea-based direct observations and towed nets to support this conclusion.

Ecosystem Health

Mangrove and coral cover
Not applicable.

Reefs at risk
Not applicable.
Marine Protected Area change
The Black Sea LME experienced an increase in MPA coverage from 1,905 km² prior to 1983 to 4,750 km² by 2014. This represents an increase of 149%, within the low category of MPA change.

Cumulative Human Impact
The Black Sea LME experiences well above average overall cumulative human impact (score 4.48; maximum LME score 5.22). It falls in risk category 5 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.96; maximum in other LMEs was 1.20), UV radiation (0.53; maximum in other LMEs was 0.76), and sea surface temperature (1.82; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, sea level rise, ocean based pollution, invasive species, and demersal non-destructive low-bycatch commercial fishing.

Ocean Health Index
The Black Sea LME scores below average on the Ocean Health Index compared to other LMEs (score 70 out of 100; range for other LMEs was 57 to 82). This score indicates that the LME is well below its optimal level of ocean health, although [there are some aspects that are doing well. Its score in 2013 decreased 2 points compared to the previous year, due in large part to changes in the scores for natural products and clean waters. This LME scores lowest on mariculture, natural products, tourism & recreation and iconic species goals and highest on artisanal fishing opportunities, coastal
economies, and habitat biodiversity goals. It falls in risk category 3 of the five risk categories, which is an average level of risk (1 = lowest risk; 5 = highest risk).

Ocean Health Index (Black Sea)

Socio-economics

Indicators of demographic trends, economic dependence on ecosystem services, human wellbeing and vulnerability to present-day extreme climate events and projected sea level rise, are assessed for this LME. To compare and rank LMEs, they were classified into five categories of risk (from 1 to 5, corresponding to lowest, low, medium, high and highest risk, respectively) based on the values of the individual indicators. In the case of economic revenues, the LMEs were grouped to 5 classes of revenues from lowest, low, medium, high and highest, as revenues did not translate to risk.

Population

The coastal area stretches over 385 846 km². A current population of 29 487 thousand in 2010 is projected to decrease to 18 123 thousand in 2100, with a density of 76 persons per km² in 2010 decreasing to 47 per km² by 2100. About 43% of coastal population lives in rural areas, and is projected to decrease in share to 40% in 2100.

<table>
<thead>
<tr>
<th>Total population 2010</th>
<th>2010</th>
<th>2010</th>
<th>2010</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>29,486,553</td>
<td>18,123,039</td>
<td>12,588,784</td>
<td>7,314,617</td>
<td></td>
</tr>
</tbody>
</table>

Legend:

<table>
<thead>
<tr>
<th></th>
<th>Very low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal poor</td>
<td>3,062,470</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. This LME ranks in the medium-revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $601
milllion for the period 2001-2010. Fish protein accounts for 9% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US $43 086 million places it in the high-revenue category. On average, LME-based tourism income contributes 11% to the national GDPs of the LME coastal states. Spatial distribution of economic activity (e.g. spatial wealth distribution) measured by night-light and population distribution as coarse proxies can range from 0.0000 (totally equal distribution and lowest risk) to 1.0000 (concentrated in 1 place and most inequitable and highest risk). The Night Light Development Index (NLDI) thus indicates the level of spatial economic development, and that for this LME falls in the category with medium risk.

<table>
<thead>
<tr>
<th>Fisheries Annual Landed Value</th>
<th>% Fish Protein Contribution</th>
<th>Tourism Annual Revenues</th>
<th>% Tourism Contribution to GDP</th>
<th>NLDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>600,629,668</td>
<td>8.9</td>
<td>43,085,614,652</td>
<td>10.8</td>
<td>0.7929</td>
</tr>
</tbody>
</table>

Legend:
- Very low
- Low
- Medium
- High
- Very high

Human Development Index

Using the Human Development Index (HDI) that integrates measures of health, education and income, the present-day LME HDI belongs to the high HDI and low-risk category. Based on an HDI of 0.760, this LME has an HDI Gap of 0.240, the difference between present and highest possible HDI (1.000). The HDI Gap measures an overall vulnerability to external events such as disease or extreme climate related events, due to less than perfect health, education, and income levels, and is independent of the harshness of and exposure to specific external shocks. HDI values are projected to the year 2100 in the contexts of shared socioeconomic development pathways (SSPs). This LME is projected to assume a place in the very low risk category (very high HDI) in 2100 under a sustainable development pathway. Under a fragmented world scenario, the LME is estimated to place in a very high-risk category (very low HDI) because of reduced income levels and population values from those in a sustainable development pathway.

<table>
<thead>
<tr>
<th>HDI 2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDI</td>
</tr>
<tr>
<td>0.7605</td>
</tr>
</tbody>
</table>

Legend:
- Very low
- Low
- Medium
- High
- Very high

Climate-Related Threat Indices

The Climate-Related Threat Indices utilize the HDI Gaps for present-day and projected 2100 scenarios. The contemporary climate index accounts for deaths and property losses due to storms, flooding and extreme temperatures incurred by coastal states during a 20-year period from 1994 to 2013 as hazard measures, the 2010 coastal population as proxy for exposure, and the present day HDI Gap as vulnerability measure. The Contemporary Threat Index incorporates a Dependence Factor based on the fish protein contribution to dietary animal protein, and on the mean contribution of LME tourism to the national GDPs of LME coastal states. The HDI Gap and the degree of dependence on LME ecosystem services define the vulnerability of a coastal population. It also includes the average of risk related to extreme climate events, and the risk based on the degrading system states of an LME (e.g. overexploited fisheries, pollution levels, decrease in coastal ecosystem areas). The 2100 sea level rise threat indices, each computed for the sustainable world and fragmented world development pathways, use the maximum projected sea level rise at the highest level of warming of 8.5 W/m² in 2100 as hazard measure, development pathway-specific 2100 populations in
the 10 m × 10 km coast as exposure metrics, and development pathway-specific 2100 HDI Gaps as vulnerability estimates.

Present day climate threat index of this LME is within the high-risk (high threat) category. The combined contemporaneous risk due to extreme climate events, degrading LME states and the level of vulnerability of the coastal population, is medium. There is no projected data for sea level rise in the Black Sea for year 2100.

<table>
<thead>
<tr>
<th></th>
<th>2010 Climate Threat</th>
<th>2010 Contemporary Threat</th>
<th>2100 SSP1</th>
<th>2100 SSP3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.7576</td>
<td>0.3100</td>
<td>No data</td>
<td>No data</td>
</tr>
</tbody>
</table>

Legend:
- Very low
- Low
- Medium
- High
- Very high

Governance

**Governance architecture**

In this LME, neither of the two transboundary arrangements for fisheries (GFCM and EU-CFP) nor the biodiversity arrangement for cetaceans (ACCOBAMS) appear to be linked formally. However, the two arrangements for land-based and marine based pollution and biodiversity (landscape/ habitat modification) are well connected under the Bucharest Convention. No integrating mechanisms, such as an overall policy coordinating organisation for the LME, could be found. There may be interaction amongst the arrangements through participation in each other’s meetings, but this appears to be informal.

The overall scores for ranking of risk were:

<table>
<thead>
<tr>
<th></th>
<th>Engagement</th>
<th>Completeness</th>
<th>Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>74</td>
<td>77</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Legend:
- Very low
- Low
- Medium
- High
- Very high