LME 54 – Chukchi Sea

Bordering countries: United States of America, Russian Federation.
LME Total area: 783,245 km²

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LME overall risk
This LME falls in the cluster of LMEs that exhibit high percentages of rural coastal population, high numbers of collapsed and overexploited fish stocks, as well as high proportions of catch from bottom impacting gear.

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 low.

Productivity

Chlorophyll-A
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (2.63 mg.m$^{-3}$) in February and a minimum (0.480 mg.m$^{-3}$) during September. The average CHL is 0.664 mg.m$^{-3}$. Maximum primary productivity (314 g.C.m$^{-2}$.y$^{-1}$) occurred during 2001 and minimum primary productivity (186 g.C.m$^{-2}$.y$^{-1}$) during 2010. There is a statistically insignificant decreasing trend in Chlorophyll of -19.0 % from 2003 through 2013. The average primary productivity is 229 g.C.m$^{-2}$.y$^{-1}$, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).
**Primary productivity**

![Primary Productivity Chart](image)

**Sea Surface Temperature**

From 1957 to 2012, the Northern Bering-Chukchi Sea LME #54 has warmed by 0.65°C, thus belonging to Category 3 (moderate warming LME). The absolute minimum of <-0.4°C was reached in 1983. Such cold SSTs have not been approached after 1994. The SST warming rate between the coldest event of -0.4°C in 1983 and the warmest event of 0.8°C in 2007 was 1.2°C in 24 years. The recent years saw a reversal that began in 2008 after the all-time peak of >0.8°C in 2007. The recent cooling in the Chukchi Sea parallels a similar cooling in the Bering Sea. This synchronism can be expected given the connection between these two seas via the Bering Strait. As the Chukchi Sea was quickly losing its summer sea ice cover in a recent decade (apparently due to global warming, whose magnitude is amplified in the Arctic), the Chukchi Sea SST was expected to rise. Therefore, the recent cooling trend observed in LME #54 can only be explained by the concomitant cooling in the northern Bering Sea, exacerbated by the contemporaneous cooling in the East Bering Sea LME #1.
Fish and Fisheries

Key marine species in this LME are salmon (*Oncorhynchus* spp.), herring (*Clupea pallasii pallasii*), walrus (*Odobenus rosmarus*), seals, whales and various species of waterfowl. The key subsistence marine species are likely to undergo shifts in range and abundance due to climate change. The central and eastern Arctic Seas do not have a significant fishing industry, except near coastal areas. Very scarce data are available from the Russian part of the Chukchi Sea, which is only sparsely populated.

**Annual Catch**

The catch appears to consist overwhelmingly of salmonids. This is similar for the catch from the Alaskan part of the Chukchi Sea, i.e., taken north of Cape Prince of Wales on the Seward Peninsula, which are collected from commercial, subsistence and sport fisheries by Alaska’s Department of Fish and Game. These catches were assembled and added to the catch estimate from the Russian part of the Chukchi Sea. The overall annual catch from the Chukchi Sea range fluctuate between 36,000 t and 500,000 t and consist predominantly of salmonids.

![Annual Catch (Northern Bering Chukchi Seas)](image)

**Catch value**

![Catch Value (Northern Bering Chukchi Seas)](image)

**Marine Trophic Index and Fishing-in-Balance index**

Given the very low quality of the underlying catch data, the catch-based indicators for this LME (such as PPR, MTI or FiB) are likely to be very unreliable.
Stock status

Catch from bottom impacting gear
The percentage of catch from the bottom gear type to the total catch reached its first peak at 19% in 1964 and then fluctuated around 11% in recent decade.

Fishing effort
The total effective effort continuously increased from around 7 million kW in the 1950s to its peak around 30 million kW in 2005.
Primary Production Required
Given the very low quality of the underlying catch data, the catch-based indicators for this LME (such as PPR, MTI or FiB) are likely to be very unreliable.

Pollution and Ecosystem Health

Pollution

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 very low. (level 1 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 low (2). 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 very low (1). According to the Global Orchestration scenario, this remained the same in 2030 and 2050.
### POps

No pellet samples were obtained from this LME.

### 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 lowest 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 low values are due to the remoteness of this LME from significant sources of plastic. The abundance of floating plastic in this category is estimated to be over 400 times lower than those LMEs with the highest values. There is very limited 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 North Bering – Chukchi Seas LME experienced an increase in MPA coverage from 15,169 km$^2$ prior to 1983 to 15,672 km$^2$ by 2014. This represents an increase of 3%, within the lowest category of MPA change.
Cumulative Human Impact
The Northern Bering – Chukchi Seas LME experiences below average overall cumulative human impact (score 1.92; maximum LME score 5.22), but which is still above the LME with the least cumulative impact. It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, all four connected to climate change have the highest average impact on the LME: ocean acidification (0.46; maximum in other LMEs was 1.20), UV radiation (0.36; maximum in other LMEs was 0.76), sea level rise (0.17; maximum in other LMEs was 0.71), and sea surface temperature (0.71; maximum in other LMEs was 2.16). Other key stressors include ocean based pollution and demersal destructive commercial fishing.

Ocean Health Index
The Northern Bering – Chukchi Seas 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 increased 3 points compared to the previous year, due in large part to changes in the scores for clean waters and coastal livelihoods. This LME scores lowest on food provision, natural products, and tourism & recreation goals and highest on artisanal fishing opportunities, coastal economies, and lasting special places 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).
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 493,726 km². A current population of 56 thousand in 2010 is projected to decrease to 46 thousand in 2100, with a density of 11 persons per 100 km² in 2010 decreasing to 9 per 100 km² by 2100. About 100% of coastal population lives in rural areas, and is projected to be the same in share in 2100.

<table>
<thead>
<tr>
<th></th>
<th>Total population</th>
<th>Rural population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>56,490</td>
<td>56,490</td>
</tr>
<tr>
<td>2100</td>
<td>45,969</td>
<td>45,969</td>
</tr>
</tbody>
</table>

**Coastal poor**
The indigent population makes up 17% of the LME’s coastal dwellers. This LME places in the high-risk category based on percentage and in the very low-risk category using absolute number of coastal poor (present day estimate).

**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 $328 million for the period 2001-2010. Fish protein accounts for 10% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US $13 million.
LME 54 – Chukchi Sea
Transboundary Water Assessment Programme, 2015

$4,759 million places it in the low-revenue category. On average, LME-based tourism income contributes 8% 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 medium-risk category.

<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>327,890,066</td>
<td>10.4</td>
<td>4,759,031,758</td>
<td>8.4</td>
<td>0.7088</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 very high HDI and very low-risk category. Based on an HDI of 0.856, this LME has an HDI Gap of 0.144, 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 high-risk category (low HDI) because of reduced income levels and population values from those in a sustainable development pathway.

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 x 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 medium-risk (medium threat) category. The combined contemporaneous risk due to extreme climate events, degrading LME states and the level of vulnerability of the coastal population, is low. In a sustainable development scenario, the risk index from sea level rise in 2100 is very low, and increases to low under a fragmented world development pathway.

<table>
<thead>
<tr>
<th></th>
<th>Climate Threat</th>
<th>Contemporary Threat</th>
<th>SSP1</th>
<th>SSP3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>0.5766</td>
<td>0.2909</td>
<td>0.2813</td>
<td>0.4857</td>
</tr>
</tbody>
</table>

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

**Governance**

**Governance architecture**
While the halibut (IPHC) and polar bear (ACPB) arrangements do not appear to be connected, the arrangement for land-based and marine-based pollution, biodiversity in general and fisheries under the Arctic Council is well-integrated. However, since the Arctic Council is not constituted under a convention, it is limited in terms of its ability to create any binding agreements and is dependent on countries to implement its recommendations. However, this LME has been assigned an overall integration score of 1.0 due to the presence of the Arctic Council.

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><strong>88</strong></td>
<td><strong>69</strong></td>
<td><strong>1</strong></td>
</tr>
</tbody>
</table>

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