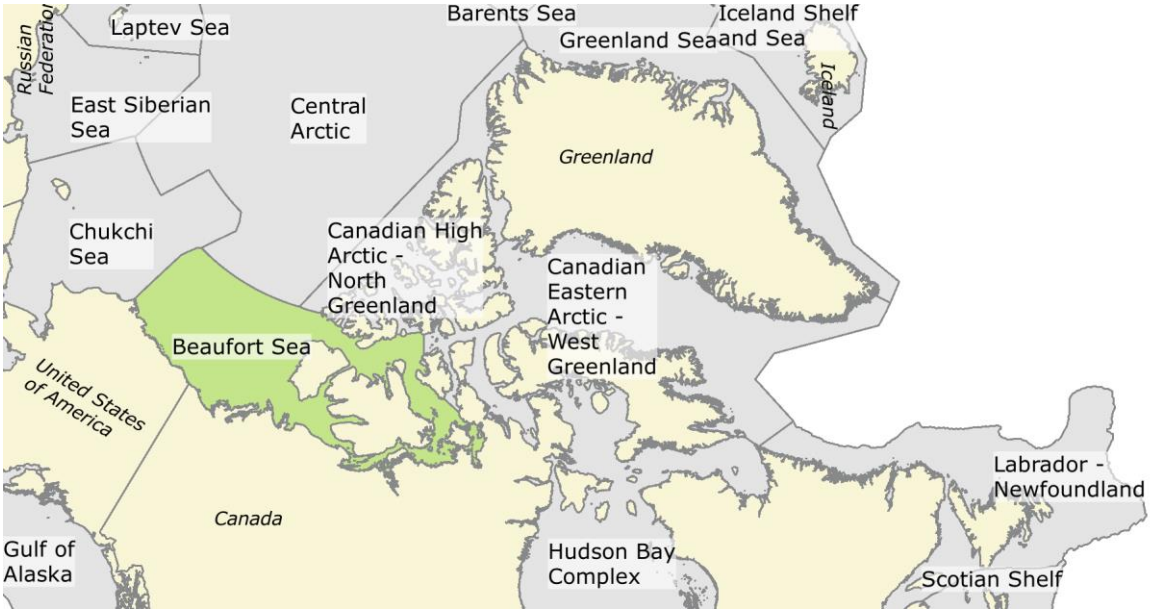
LME 54 – Beaufort Sea



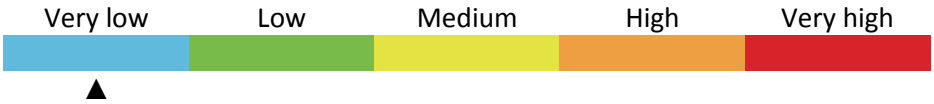
Bordering countries: Canada, United States of America.
LME Total area: 664,752 km^2

List of indicators

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.

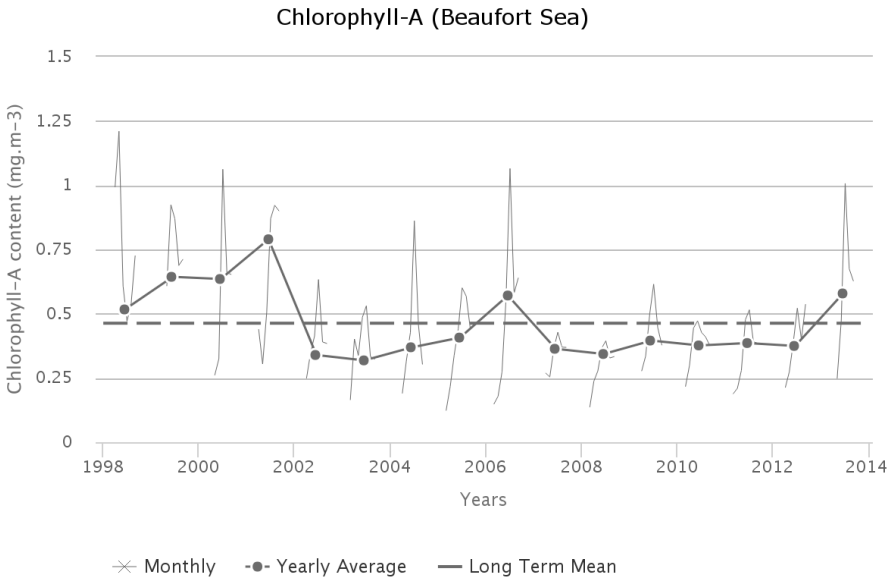
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is very low..

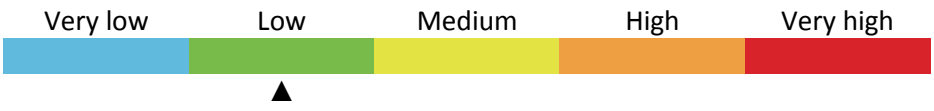


Productivity

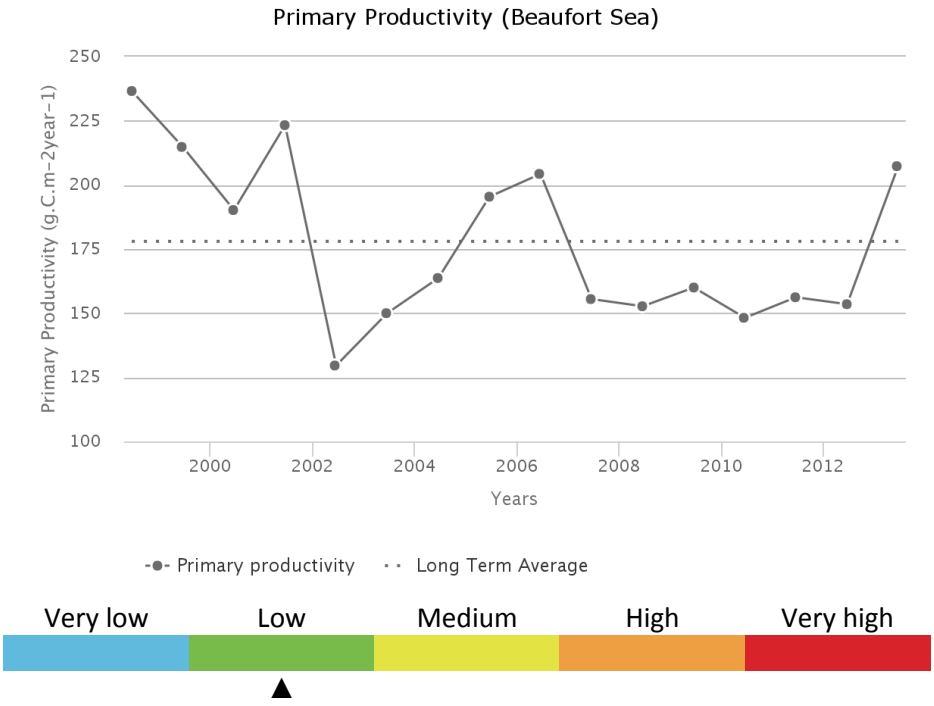
Chlorophyll-A

The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.404 $mg.m^{-3}$) in July and a minimum (0.137 $mg.m^{-3}$) during March. The average CHL is 0.463 $mg.m^{-3}$. Maximum primary productivity (237 $g.C.m^{-2}.y^{-1}$) occurred during 1998 and minimum primary productivity (130 $g.C.m^{-2}.y^{-1}$) during 2002. There is a statistically insignificant decreasing trend in Chlorophyll of -15.0 % from 2003 through 2013. The average primary productivity is 178 $g.C.m^{-2}.y^{-1}$, which places this LME in Group 2 of 5 categories (with 1 = lowest and 5= highest).



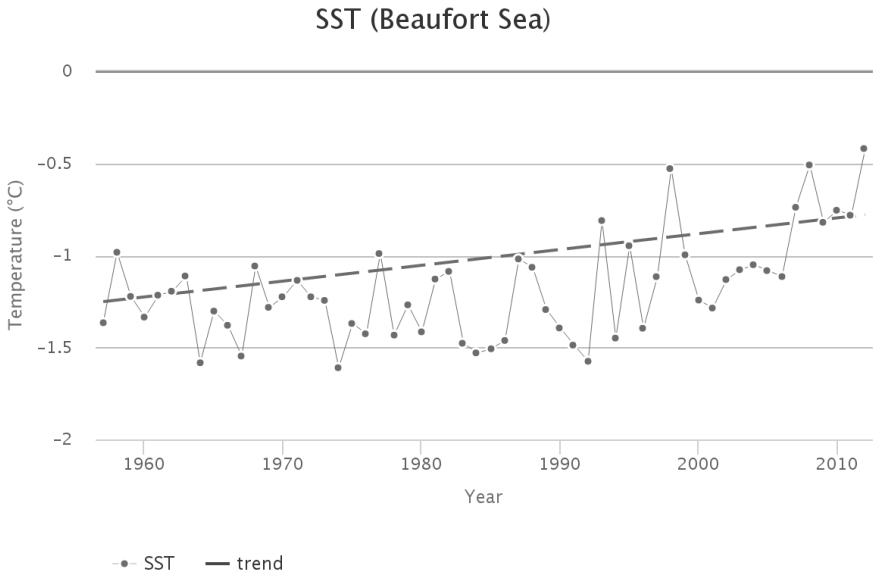


Primary productivity



Sea Surface Temperature

From 1957 to 2012, the Beaufort Sea LME #55 has warmed by 0.47°C, thus belonging to Category 3 (moderate warming LME). The Beaufort Sea's annual variability of SST was rather small, <0.5°C. The only significant event occurred in 1998, when SST exceeded -0.6°C. Comparison of SST time series with the Arctic Oscillation (AO) index suggests a strong correlation between SST and AO index, with negative SST anomalies corresponding to positive values of AO index. There are some similarities between thermal histories of the Beaufort and Chukchi Seas. In both cases, there was no warming until the end of the 20th century. In the Chukchi Sea, a transition to a warming regime occurred in 1983, whereas in the Beaufort Sea a similar transition to a warming regime commenced a decade later, resulting in an SST increase from nearly -1.6°C in 1992 to -0.5°C in 2012.

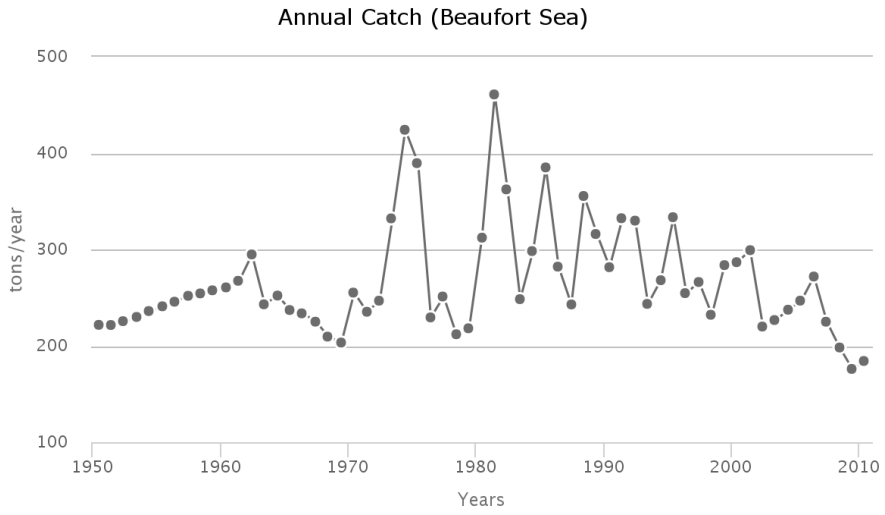


Fish and Fisheries

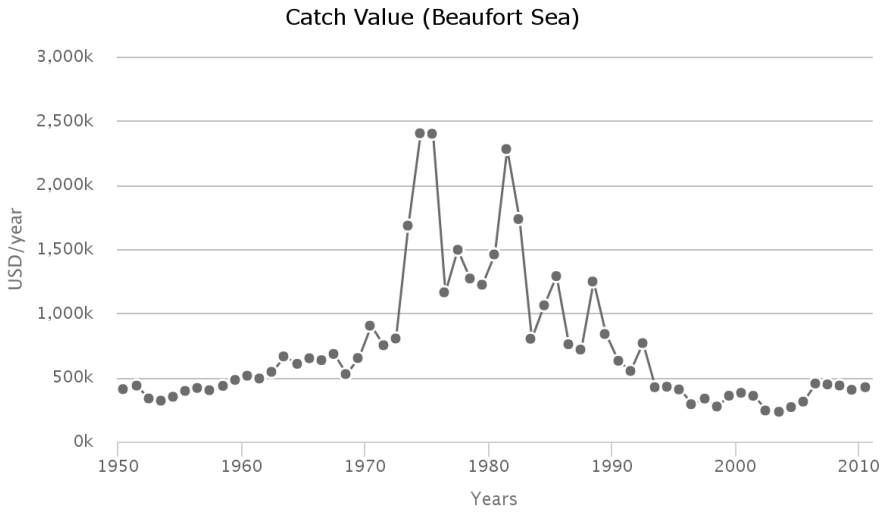
There are three coastal communities (Tuktoyaktuk, Sachs Harbour and Kaktovik) and two inland communities (Aklavik and Inuvik) that make use of the Beaufort Sea, largely for subsistence, but also some commercial fisheries occur in Canadian waters. The catch data from this LME are too crude for ecosystem indicators such as PPR, MTI or FiB index to be computed.

Annual Catch

Catches peaked in 1981 at approximately 453 t and were estimated at approximately 224 t in the recent decade. Important species include Dolly varden (*Salvelinus malma*), whitefish (*Coregonidae*) and two other species, inconnu (*Stenodus leucichthys*) and Pacific herring (*Clupea pallasii*), which are of lesser importance.



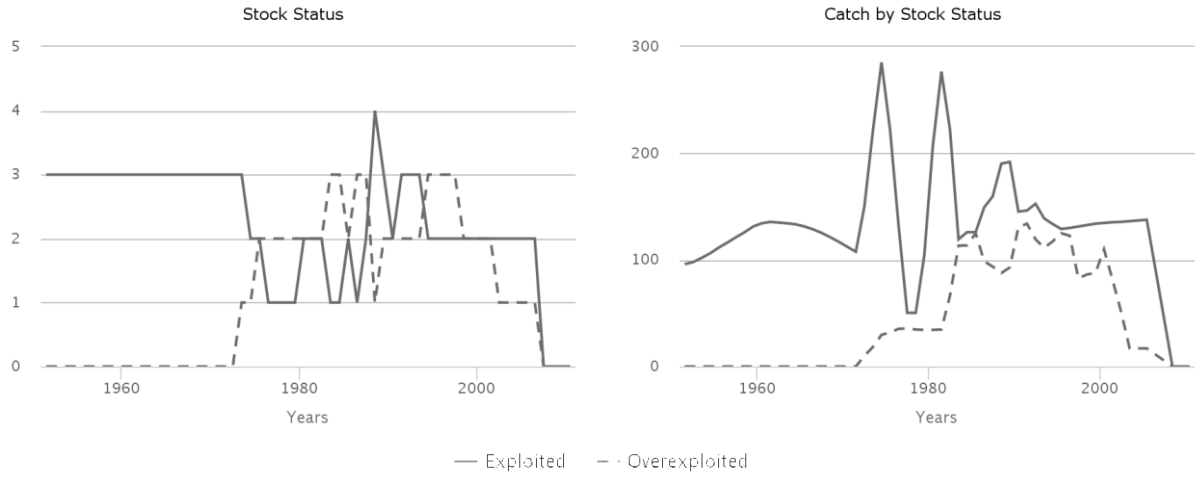
Catch value



Marine Trophic Index and Fishing-in-Balance index

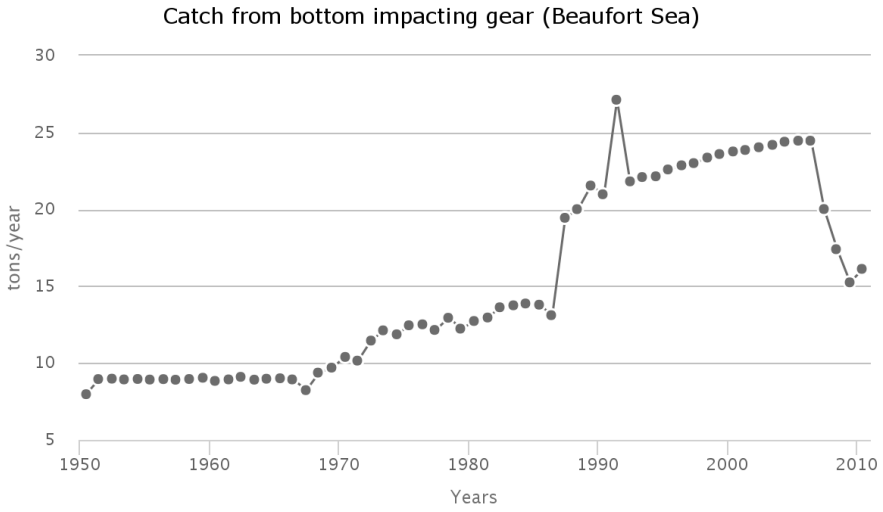
Given the very low quality of the underlying catch data, the catch-based indicators for this LME (such as PPR, MTI or FiB) are likely to be very unreliable.

Stock status



Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch increased from 3% in the early 1950s to the peak at around 11% in 2001. Then, this percentage fluctuated around 9% in recent decade.



Fishing effort

No effort data is available in this LME.

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 moderate (3). 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.

2000			2030			2050		
Nitrogen load	Nutrient ratio	Merged nutrient indicator	Nitrogen load	Nutrient ratio	Merged nutrient indicator	Nitrogen load	Nutrient ratio	Merged nutrient indicator
1	3	1	1	3	1	1	3	1

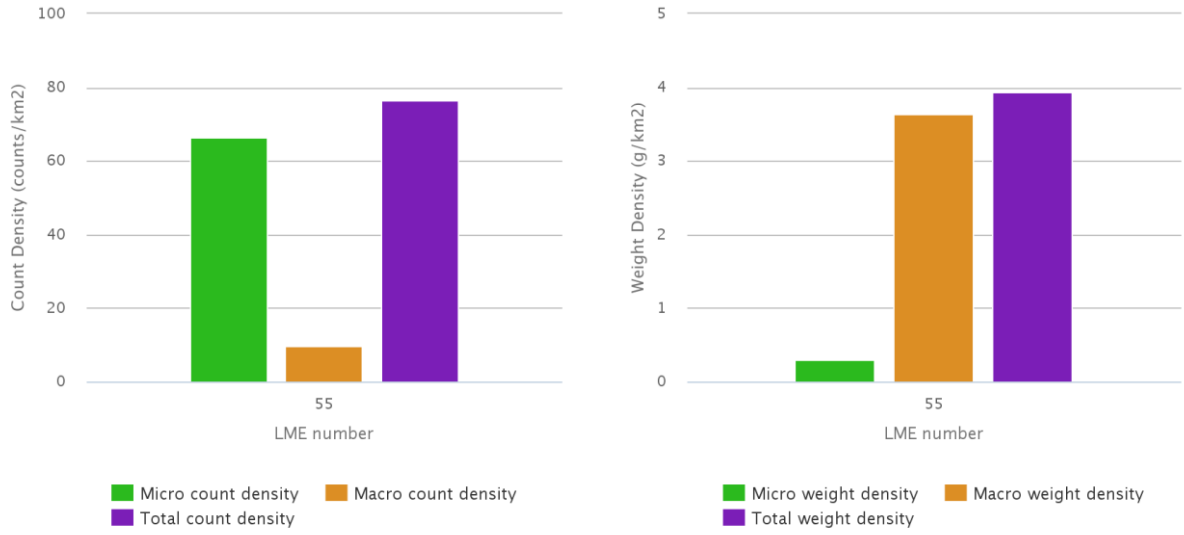
Legend: Very low | Low | Medium | High | Very high

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 limited evidence from sea-based direct observations and towed nets to support this conclusion.



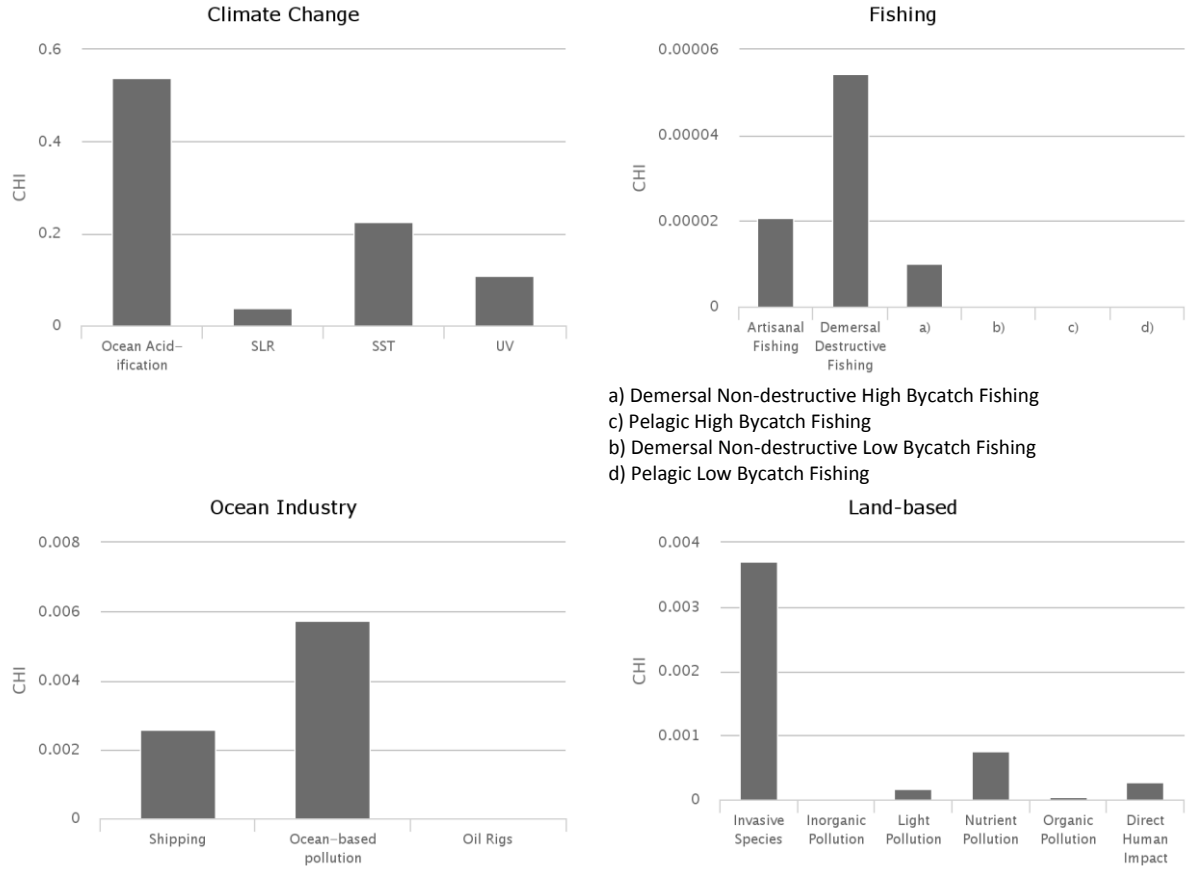
Ecosystem Health

Mangrove and coral cover
Not applicable.

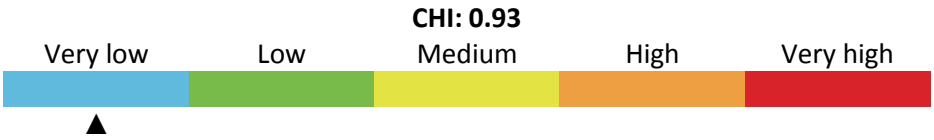
Reefs at risk
Not applicable.

Marine Protected Area change
The Beaufort Sea LME experienced an increase in MPA coverage from 10,030 km^2 prior to 1983 to 11,844 km^2 by 2014. This represents an increase of 18%, within the lowest category of MPA change.

Cumulative Human Impact
The Beaufort Sea LME experiences one of the lowest overall cumulative human impact (score 0.93; maximum LME score 5.22). 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, three connected to climate change have the highest average impact on the LME: ocean acidification (0.54; maximum in other LMEs was 1.20), UV radiation (0.11; maximum in other LMEs was 0.76), and sea surface temperature (0.23; maximum in other LMEs was 2.16). The only other key stressor is sea level rise.



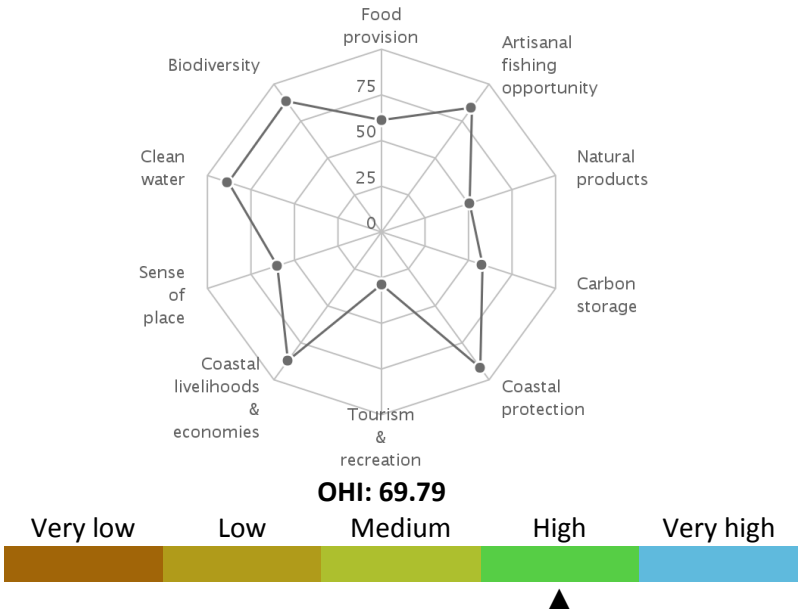
a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing



Ocean Health Index

The Beaufort Sea LME scores above average on the Ocean Health Index compared to other LMEs (score 71 out of 100; range for other LMEs was 57 to 82), but still relatively low. This score indicates that the LME is below its optimal level of ocean health, although there are some aspects that are doing well. Its score in 2013 increased 4 points compared to the previous year, due in large part to changes in the score for clean waters. This LME scores lowest on fisheries, natural products, carbon storage, tourism & recreation, and lasting special places goals and highest on artisanal fishing opportunities, coastal protection and coastal economies 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 (Beaufort Sea)



OHI: 69.79

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 974 278 km^2. A current population of 18 thousand in 2010 is projected to decrease to 8 thousand in 2100, with a density of 2 persons per 100 km^2 in 2010 decreasing to 1 per 100 km^2 by 2100. About 100% of coastal population lives in rural areas, and is projected to be the same in share in 2100.

Total population		Rural population	
2010	**2100**	**2010**	**2100**
18,042	7,938	17,987	7,919

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

Coastal poor

The indigent population makes up 14% of the LME's coastal dwellers. This LME places in the low-risk category based on percentage and in the very low-risk category using absolute number of coastal poor (present day estimate).

Coastal poor
2,473

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. This LME ranks in the very low-revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $0.42 million 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 2013

$16 299 million places it in the medium-revenue category. On average, LME-based tourism income contributes 6% 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 low risk.

Fisheries Annual Landed Value	% Fish Protein Contribution	Tourism Annual Revenues	% Tourism Contribution to GDP	NLDI
417,730	8.9	16,298,971,350	6.1	0.6842

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 0.903, this LME has an HDI Gap of 0.097, 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 medium-risk category (medium HDI) because of reduced income levels and population values from those in a sustainable development pathway.

	HDI 2100	
HDI	SSP1	SSP3
0.9027	0.9709	0.7391

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

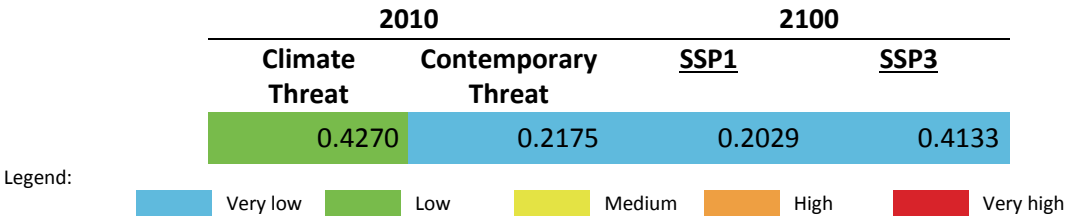
Climate-Related Threat Indices

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/m^2 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 low-risk (low threat) category. The combined contemporaneous risk due to extreme climate events, degrading LME states and the level of vulnerability of the coastal population, is very low. In a sustainable development scenario, the risk index from sea level rise in 2100 is very low, and maintains this even under a fragmented world development pathway.



Governance

Governance architecture

For this LME, the only transboundary agreement addressing the issues is the Arctic Council (AC). It appears that the AC has the potential to develop into an informal overall policy coordinating organization, its policy coordination role with respect to fisheries is weak. Nevertheless, this LME has been assigned an overall integration score of 1.0 due to the presence of the Arctic Council.
The overall scores for the ranking of risk were: